SCIENTIFIC AMERICAN

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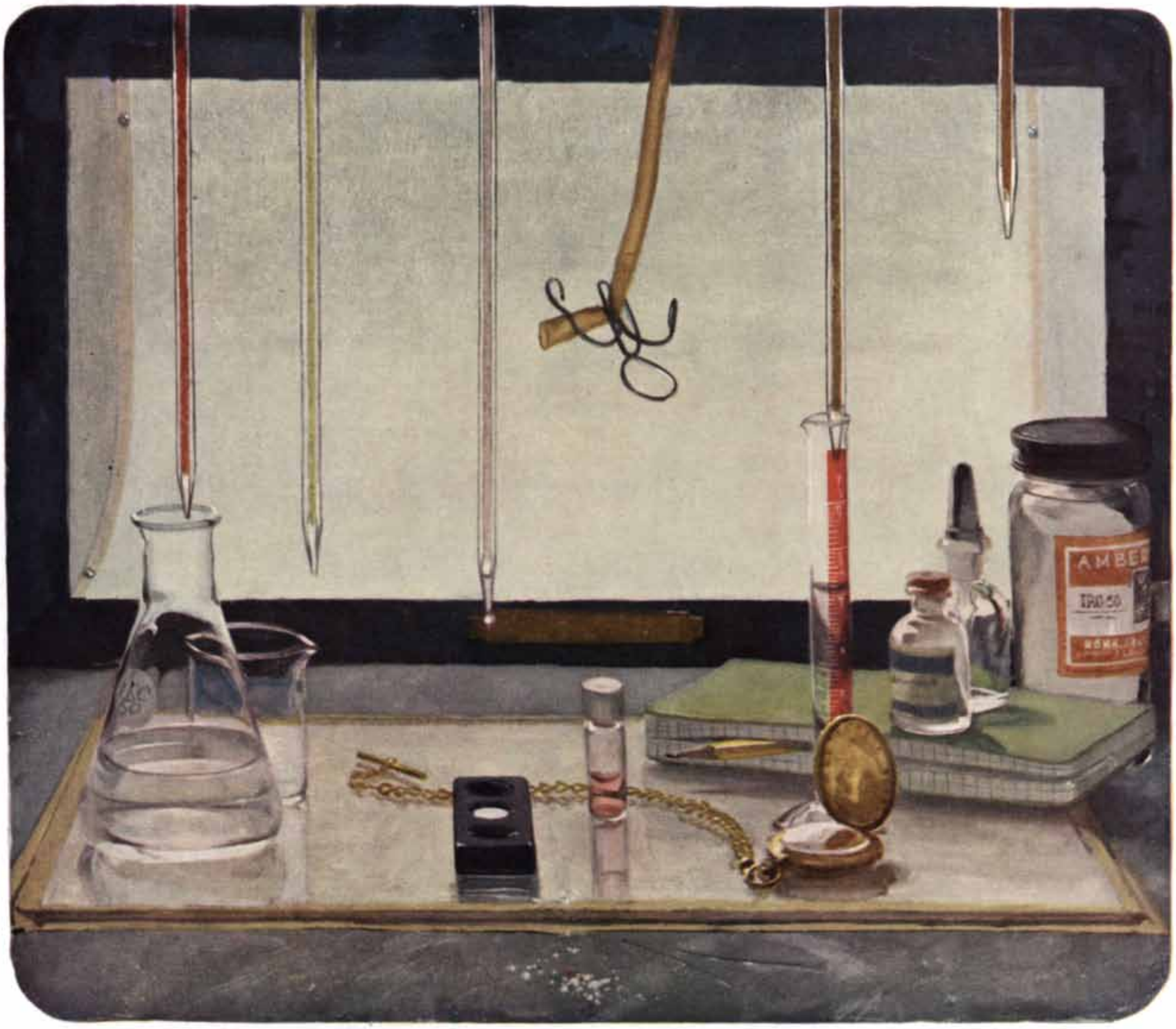
April 1953

METHOD FOR OBTAINING HEALTHY YIELDS



Discovery alone will not bring the benefits of a wonder drug to the waiting world. Ways must be found to manufacture it in quantity at low cost. In the case of streptomycin, the method was provided by AMBERLITE® IRC-50, a Rohm & Haas cation exchange resin.

When standard techniques for extracting antibiotics from fermentation broths proved inefficient, the producers turned to Rohm & Haas Company. Working with the columns shown here, Rohm & Haas chemists learned that a standard, strongly acidic AMBERLITE exchanger adsorbed streptomycin, but with an affinity too great for satisfactory elution. So they synthesized a new, weakly acidic exchanger—and the method became practical. Today this resin, AMBERLITE IRC-50, is used in producing most of the world's streptomycin, by a greatly simplified, lower cost process.

This type of cooperation can be applied to your problem. It may well lead you to a new process, or a better process, through AMBERLITE ion exchange.

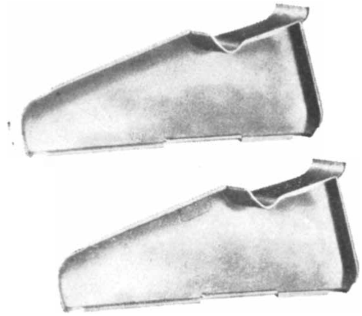
AMBER-HI-LITES, *a bi-monthly report on ion exchange, is available on request.*

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION PHILADELPHIA 5, PENNSYLVANIA

Where would the price of pork be if hog cholera continued to destroy millions of pigs? It has done that since its discovery 120 years ago. One infected pig could destroy a herd of 1000. Hog cholera serum, developed during the last decade, and largely made on Stokes Freeze-drying equipment, is eliminating the scourge of hog cholera from the world's stock farms. The same type of Stokes equipment is used in the preparation of "wonder drugs" which daily save the lives of thousands of humans.

What converts the dull two-cent slush-metal casting to the brilliant piece of costume jewelry? Just three millionths of an inch of aluminum! It vaporizes under vacuum, deposits itself on the dull surface, and the ugly duckling becomes a sparkling decoration. Low-cost molded plastic is also used as a base. Over the aluminum is applied a lacquer coating. With this alone, the aluminum looks like brilliant silver; the top-coat can also be dyed in colors which simulate silver, gold, copper, selenium or other metals.



What is the difference between these two seemingly identical castings? One will leak; one will not. Both have tiny pores which often occur in casting but are quite invisible to the eye. But one of these castings has been impregnated with a sealing compound in Stokes Vacuum Impregnating equipment. When the compound has hardened, the casting is proof against heat and pressure. Many manufacturers are eliminating the cost of rejected castings by vacuum-impregnating *all* castings without test.

Many watch-springs are now annealed in vacuum to modify surface characteristics of the metal, and improve mechanical properties. The process also offers great economies over treatment in controlled, or inert, atmosphere. Similarly titanium and zirconium sheet and bar stock must be annealed in vacuum. Indeed, these metals, after ores are reduced to oxides, must be handled almost entirely under vacuum until they reach finished shape. In the presence of air, they tend to combine with the material of the vessels in which they are processed.

Is Your Business Headed for a Vacuum?

Many businesses are in vacuum processing now, and many more will be.

From the earliest commercial processing of blood plasma — a Stokes milestone in vacuum processing — Stokes has led in the application of practical vacuum techniques for industry.

Antibiotics, atomic energy, electronics, radio, diesel locomotives . . . all these and many other modern developments depend on vacuum processing techniques and vacuum processing equipment.

Now comes the application of vacuum processing to the making and treatment of titanium and other metals destined to make new industrial history.

Stokes Vacuum Engineering and Stokes equipment are a part of that history, as they are of every industrial advance which has utilized vacuum processing techniques. Stokes has designed, built, and installed more working high-vacuum equipment than any other manufacturer.

Stokes is FIRST in Vacuum, and Stokes engineers are available for consultation on problems of vacuum processing.

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LETTERS

Sirs:

The February issue of *Scientific American* contains an article entitled "Incriminating Stains," by Charles E. O'Hara and James W. Osterburg. Beautiful spectrograms illustrate an application of atomic emission spectroscopy to the identification of paints connected with housebreaking. "Spectra were employed to identify paint stains on a jimmy, the tool used by burglars to open doors or windows. At the top is the spectrum of the paint on the jimmy. At the bottom is the spectrum of paint from a door that had been opened with a jimmy. The similarity of the top and bottom spectra indicates that the door had been opened with the jimmy in question." The last statement is false. . . .

A trained spectroscopist can see at a glance that the paint spectra were made with a quartz-prism spectrograph and that the ultraviolet portions reproduced extend from 3187 to 2773 angstroms. Although this limited spectral region will not permit a complete analysis of the paint samples, it is rich in diagnostic lines for many chemical elements; it reveals the presence of lead, silicon, magnesium, aluminum, bismuth, iron, titanium and zinc in both samples, the first as a major constituent and the rest as minor components or impurities.

If the paint on the jimmy had the same source as the paint on the door, these spectra would not only be similar, they would be essentially identical. Obviously this is not the case. Silicon is about the same strength in both, but the jimmy paint is relatively richer in lead by a factor of three or more. As regards impurities the door paint is definitely

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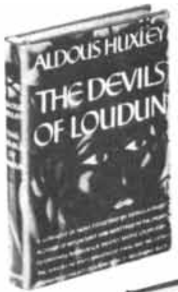

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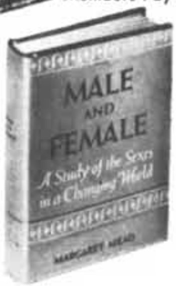

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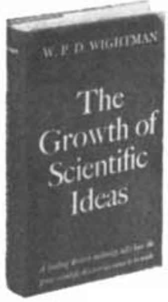

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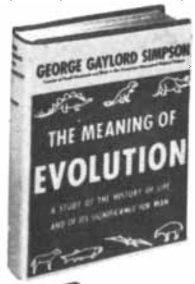

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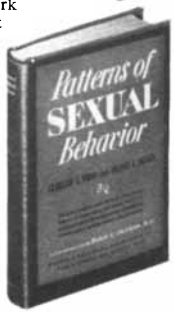

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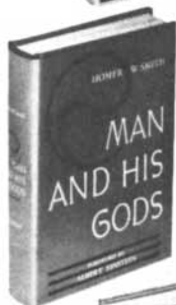

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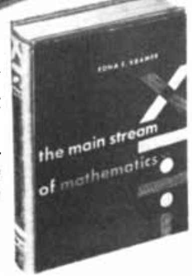

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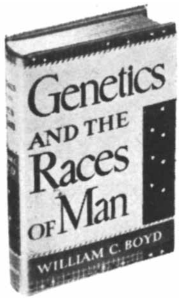

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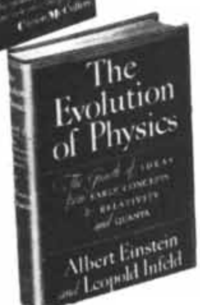

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richer in magnesium, iron, titanium and zinc. Two critical impurities are aluminum and bismuth; the former is at least 10 times more abundant in the door paint, whereas the latter is about five times more plentiful in the jimmy paint. The similarities identify both samples as paint, but the dissimilarities prove conclusively that they are not the same paint, that is, the door was not opened with the jimmy in question! If this evidence was used to convict a "burglar," I sincerely hope that the innocent prisoner will be promptly freed with apologies for injustice done.

WILLIAM F. MEGGERS

Washington, D. C.

Sirs:

I hasten to say that no one is in jail as a result of the spectrogram mentioned by Dr. Meggers. As a matter of fact, the illustration was intended to depict the physical appearance of a spectrogram for the general reader, and not to be the basis for a critical discussion of an important problem in criminalistics. The spectrogram was an experimental one comparing two paints that were similar but not identical. This is not to say that spectrograms cannot be used to show that two samples of paint are identical; such spectrograms have been made and introduced as evidence in court. Unhappily the perfect example was not available to us. It would have been a pity, however, not to show how the technique is applied.

JAMES W. OSTERBURG

Queens, N. Y.

Sirs:

A few weeks ago John Cameron Swayze's NBC-TV news broadcast, reporting the typhoid fever epidemic in Stuttgart, commented that the disease had been eliminated among Americans by inoculation! Now comes the February issue of *Scientific American* with an article on the geography of disease, saying in a caption to an illustration that cholera has been eliminated from the U. S. by quarantine!

Of all the afflictions of mankind, one might say that typhoid fever and cholera are the classic examples of disease transmitted on the fecal-oral route by water. And they stand, with yellow fever, malaria, plague, typhus, infant diarrhea and hookworm, as notable diseases that have been suppressed primarily by water treatment and sanitary disposal of sewage. Few scientific advances have contributed so much to the security of the urban home and to the longevity of the urban family. Yet few triumphs in public health are so poorly publicized.

What peculiarity of the subconscious mind do you suppose permits so little popular acknowledgement of these basic services in the field of preventive medicine?

MARCUS ROSENBLUM

Bureau of State Services
Public Health Service
Washington, D. C.

Sirs:

There have been four major outbreaks of cholera in the U. S., all of which have been introduced from the outside. The first official step taken against this was an act of Congress, approved July 13, 1832, which empowered the Secretary of the Treasury to use revenue cutters to enforce quarantine laws made by the states.

On May 26, 1866, Congress intervened again to restate that the Secretary of the Treasury was empowered to make and to "carry to effect such orders and regulations of quarantine as in his opinion may be deemed necessary and proper."

The Chicago exposition of 1892 attracted many visitors from Europe. The fear that this might be the starting point of a cholera epidemic (cholera was then prevalent in Europe) expedited the passage of the quarantine act of 1893.

The acts of April 12, 1900 and April 30, 1900 extended the quarantine services to Puerto Rico and the Hawaiian Islands.

This list could be extended, but the point is that the geographical environment of the U. S. is not one that allows for prolonged existence of cholera endemicity—as do certain districts of India, whence came every single one of the cholera epidemics which have devastated the world during the 19th century. So cholera in the U. S. must be introduced from the outside, and quarantine is the main factor in stopping its introduction. This does not mean that Mr. Rosenblum is not right in stressing the importance of water treatment as a contribution to the security of the urban home and to the longevity of the urban family. It is also true that the considerable improvements which have been brought about in the domestic water supply would help in circumscribing and limiting the disastrous effects of the introduction of the cholera vibrio in this country.

But I repeat that if we do not have cholera in the U. S. any longer, or for that matter anywhere in the world except Asia and Egypt (last epidemic in 1947), it is because of the effective quarantine measures.

JACQUES M. MAY, M.D.

American Geographical Society
New York, N. Y.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

APRIL, 1903: "Prof. Curie has announced to the French Academy of Sciences that radium possesses the extraordinary property of continuously emitting heat without combustion, without chemical change of any kind, and without any change in its molecular structure. Radium, he states, maintains its own temperature at a point 1.5 deg. Centigrade above the surrounding atmosphere. Despite this constant activity, the salt apparently remains just as potent as it was at the beginning."

"Several interesting experiments have been carried out by the Austrian army to obtain reliable data relative to the possibility of disabling a balloon when floating in the air, by either rifle or gun fire. For the purpose of the experiments a balloon was anchored at the height of about 7,000 feet, and the gunners, kept in ignorance of the range, were then commanded to disable the balloon. The difficulty of hitting the balloon when in mid-air can be realized from the fact that the gunners fired twenty-two shots before the approximate range was found, and that it was not till the sixty-fourth round that the balloon was hit, and then only slightly. The small tear in the gas bag, however, was sufficient to cause the balloon to descend slowly."

"R. Blondlot points out that there are now only two possible theories on the nature of X-rays, one of them regarding the rays as light of very small wave-length, and the other regarding them as consisting of instantaneous impulses produced by the impact of electrons upon the anti-cathode. The latter is the true explanation, which agrees with all the facts. It has been worked out by Stokes, Wiechert, and Thomson. According to Stokes, the X-rays are produced by a rain of electrons upon the anti-cathode. Carrying the parallel further, the X-rays might be likened to the sound waves produced by raindrops on impact; and the patter of raindrops on a roof, which does not produce a note of definite pitch (wave-length) is their acoustic equivalent."

"It has been said that transatlantic telephony will not pay. Michael Pupin is himself of that opinion, not because of

any inherent fault in his system for long-distance transmission, but because of the customs of the business world. A transatlantic telephone system would be used chiefly during the business day of six or seven hours. Since the day begins in London and Paris five hours earlier than it does in New York, it follows that only during a period of one or two hours would the line be in use. Prof. Pupin's system, however, is equally adapted to the improvement of the submarine telegraph cable, so that its practical utility is by no means as curtailed as it might seem."

"Last July, the British wooden steamer *Morning* sailed from England to relieve the *Discovery*, which left England in 1901 for the Antarctic zone. The *Morning* arrived at Auckland, New Zealand, March 25, and reports that the *Discovery* has been in winter quarters at Victoria Land since February last year. On March 24 the ship was frozen in; but the expedition passed a comfortable winter near Mounts Erebus and Terror. The lowest temperature recorded was 62 deg. below zero. Capt. Scott, Dr. Wilson, and Lieut. Shackelton traveled 94 miles to the south from the base, reaching land in latitude 80 deg. 7 min., longitude 136 deg. This is the most southerly point yet attained."

SCIENTIFIC AMERICAN

APRIL, 1853: "It is stated that the various expeditions that have been fitted out within the last five years for the discovery of Sir John Franklin have cost an aggregate of £728,466. Nearly eight years have elapsed without tidings from the missing voyagers. No less than 15 expeditions in all, consisting of thirty vessels besides boats, have been engaged in the pursuit, and the effort is still being continued."

"Experiments have been lately made at Berlin with cannon having rifle bores and loaded at the breech with a conical missile which is hollow and contains powder. These experiments are said to be very successful. With 1½ pounds of powder a missile was thrown more than 6,000 feet."

"The new Bible House which has been erected by the American Bible Society is the largest edifice that New York contains. Its area is about three-fourths of an acre, and the shape of the building is irregular, with irregular sides, having been planned of a corresponding figure to that of the ground on which it is situated. The height of the building

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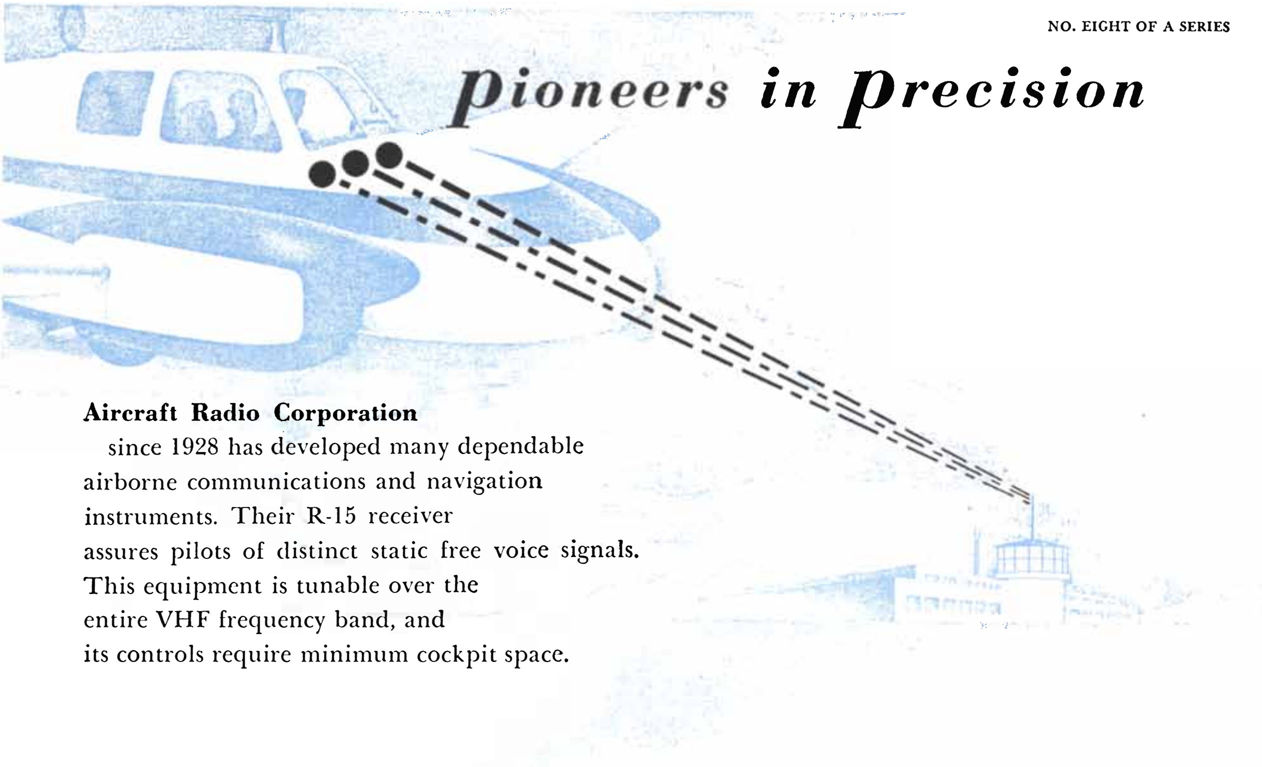

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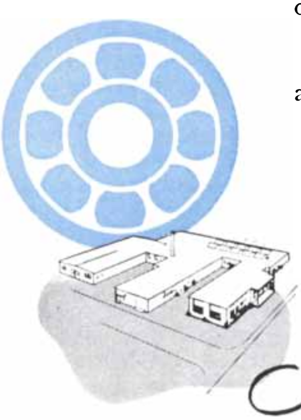

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from the sidewalk is over seventy feet, and it is divided into six stories."

"In a few weeks we expect to be able to present engravings of a pneumatic telegraph, invented by J. S. Richardson of Boston. This kind of telegraph is composed of a tube, which, by exhausting the air from it by a steam engine working a huge air pump, is intended to send packages from one place to another with great velocity. Mr. Richardson's atmospheric tube telegraph and railway is very ingenious, and in a tube one mile long it has operated successfully for some time. A joint stock company is about to be formed for a line of this telegraph, between New York and Boston."

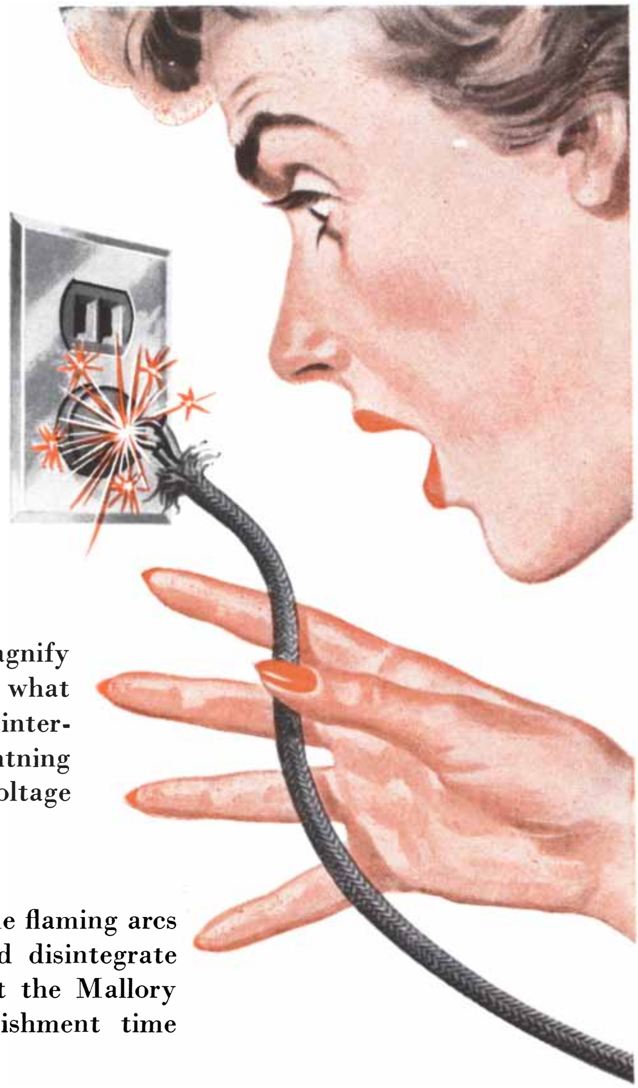
"Theodore Poesche has presented a plan for navigating the atmosphere with a car propelled by a steam engine without employing a balloon. He trusts to the propeller to drive his long boat through the air, but he will find himself greatly mistaken. The screw was proposed long ago to drive aerial ships with balloons, but could not do it."

"The aurora borealis seems to be composed of a vast mass of electric matter, resembling in every respect that generated by the electro-galvanic battery; the currents from it change, coming on telegraph wires, and then disappearing as the mass of the aurora rolls from the horizon to the zenith—sometimes so faintly as to be scarcely perceptible, and then so strongly as to emit one continuous blaze of fire."

"Six years ago there were only two mercantile steamships in the whole United States; these belonged to New York and were but insignificant in size. Then we had no mail steamships, and the Star-Spangled Banner had never floated but in a solitary instance in a foreign port above the quarter-deck of an American steamer. But what a change has taken place in that short period! The four largest and as yet the fleetest ocean steamships in the world belong to our country, and the rivers Mersey in England, the Seine and Weser in France and Germany, are now visited regularly by eight American steamships of large tonnage and powerful engines. Our total Atlantic fleet of steamships now amounts to 19,800 tons burden."

"Mr. Charles Goodyear has recently taken out a patent in England for a new compound composed of india rubber and coal tar vulcanized with sulphur. Coal tar is heated in an open boiler until it acquires the consistency of melted rosin, when it is mixed with india rubber in proportions which may vary according to the character of the material to be produced for a specific purpose. It is mixed with sulphur and then heated to vulcanize it."

Magnify These Sparks a Million Times



Sparks fly when a worn electric cord shorts out. Magnify them a million times and you'll have an idea of what goes on in a big power plant circuit breaker as it interrupts the surging overloads of power when lightning strikes . . . or when wind and ice bring down high voltage lines carrying power enough for a city.

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Elkonite is just one example of how Mallory has helped industry solve a problem. Mallory metallurgists have also been active in the development of high temperature titanium alloys for jet engines, superchargers and gas turbines. Another alloy . . . Mallory 1000 . . . is a high density metal that saves critical space in the designing of rotors, flywheels and counterweights.

The research and development of new materials for tomorrow's equipment is but one of the many ways Mallory has pioneered in the fields of electronics, electrochemistry and metallurgy. If you are designing for tomorrow's markets, investigate our specialized production facilities and engineering services today. We have helped many manufacturers turn out better, more saleable products . . . at lower costs.

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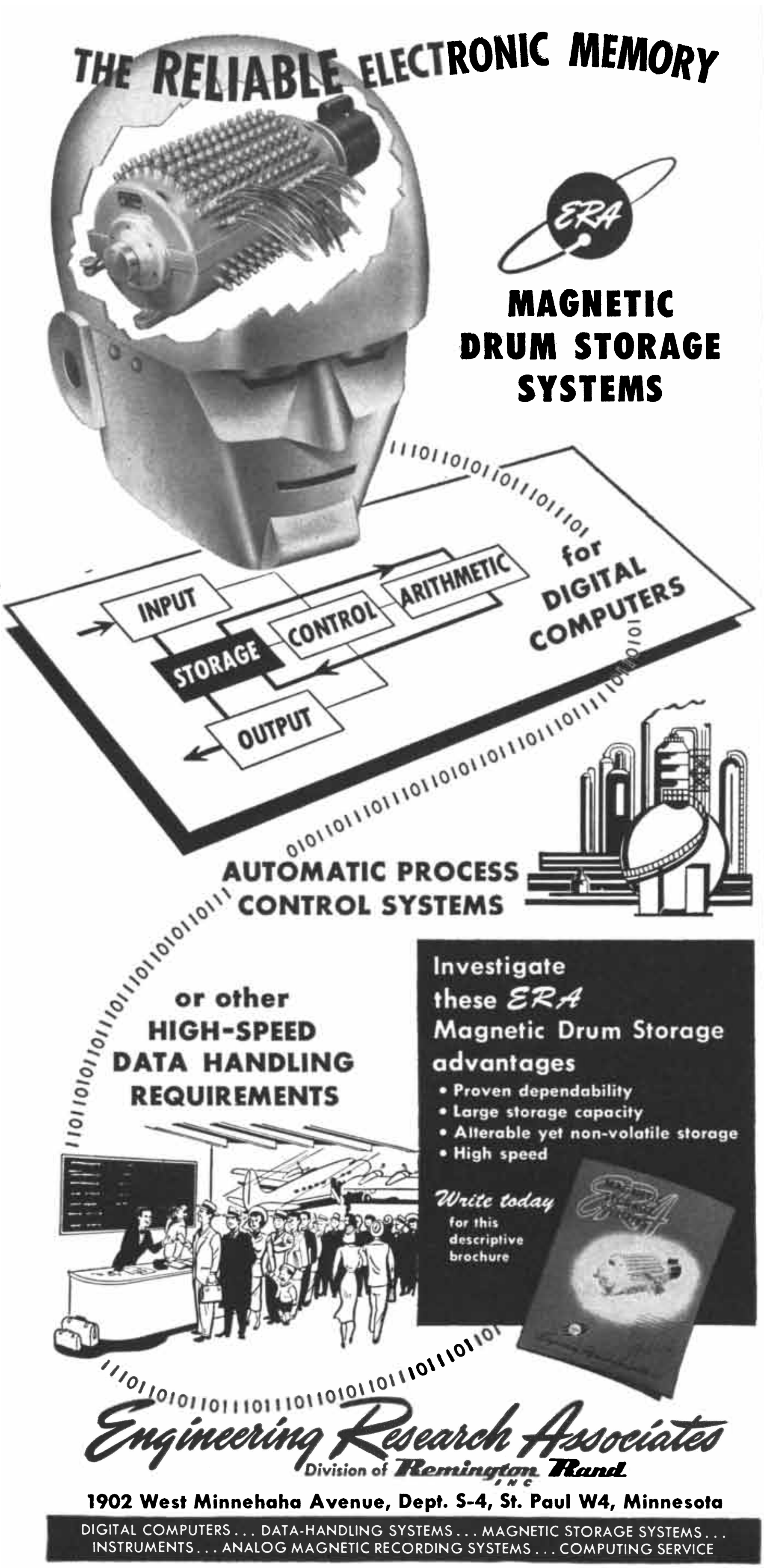

THE AUTHORS

SIR MACFARLANE BURNET ("The Influenza Virus") is an Australian physician, director of the Walter and Eliza Hall Institute of Medical Research at the Royal Melbourne Hospital, and one of the world's leading virologists. He has worked chiefly on bacterial viruses and on influenza. One of his important contributions is the technique for using chick embryos in viral research, now a basic tool in this field. Burnet was born in Traralgon, Australia, in 1899. An early interest in "birds, butterflies and beetles" led him, he says, to medicine and biology. He took an M.D. at Melbourne University in 1923 and has spent his entire career at the Melbourne Hospital, except for study and lecture visits to England and the U. S. Knighted in 1951, he has also received a U. S. honor, one of the 1952 Lasker Awards of the American Public Health Association "for fundamentally modifying our knowledge of virus disease and the inheritance of characteristics by viruses." He is a fellow of the Royal Society and the winner of its Royal Medal in 1947. A skillful amateur painter, he now finds little time for art. "The Influenza Virus" is his second contribution to SCIENTIFIC AMERICAN; his first, a general article on viruses, appeared in May, 1951. His book *Virus as Organism*, published in 1945, is considered a classic on the subject. He has written several books and hundreds of scientific papers. A slightly built, somewhat shy man, he is a fascinating speaker on the lecture platform.

JAMES E. McDONALD ("The Earth's Electricity") is a busy man. Assistant professor of physics at Iowa State College at 32, he has six children, teaches meteorology, climatology and astronomy, does research in cloud physics, and tries to keep abreast of developments in paleoclimatology, atmospheric electricity, ionospherics and astrophysics. He studied chemistry at the University of Omaha, meteorology at M.I.T. while in the Navy, and received his Ph.D. in physics from Iowa State in 1951. He has just completed a study for the Navy of the aerodynamics of large, highly deformed raindrops. Another of his recent research projects was the problem of supercooled cloud droplets, trying to explain why these drops are liquid at temperatures 40 degrees below freezing. His present article grew out of a study of thunderstorm electricity and is the second he has done for SCIENTIFIC AMERICAN. His first, on the Coriolis effect, appeared in May, 1952. At the moment McDonald is off to the University of Chicago on a year's leave to do theoretical cloud-physics research. When last heard from, he was looking

for a Chicagoan willing to rent a house to a family with six children.

ALBERT I. LANSING ("Experiments in Aging") decided while still in high school to make his career research in the problem of aging. Thinking that he would need medical training for this work, he enrolled at New York University as a premedical student. He soon decided, however, that biology was more to the point than medicine, and went on to study at the University of Pennsylvania, George Washington University, Johns Hopkins and finally Indiana University, where in 1941 he took his doctorate in zoology. After the war, during which he served as an aviation physiologist with the Air Force, Lansing went to Washington University in St. Louis, where he is now associate professor of anatomy. The experiments described in his article are the combined result of his interest in the aging problem and his training in cell genetics at Indiana. Lansing is married and the father of five children. His principal hobbies are hard physical labor and fishing.

FREEMAN J. DYSON ("Field Theory") is one of the chief architects of the theory of the quantum electromagnetic field. He concisely outlines his own career thus: "Born in England in 1923. Son of Sir George Dyson, professional musician. Started off with an appetite for mathematics and astronomy from the age of six. Studied mainly mathematics at Cambridge University. Spent the last two years of the war at headquarters of R.A.F. Bomber Command doing operations research. Investigated causes of bomber losses in night operations. Found this a frustrating experience, scientific honesty only rarely being allowed to prevail over political expediency. Decided to make a fresh start after reading the Smyth Report in the fall of 1945, thinking that physics would be the major stream of scientific progress during the next 25 years. Also encouraged to become a physicist by the discovery that physics was in more of a mess than mathematics or astronomy. Came to America with a Commonwealth Fund Fellowship in 1947 and learnt most of the physics I know from Professors Bethe and Feynman at Cornell University. Was lucky to arrive and start research in the exciting days of 1947 when the Lamb-Retherford experiment was new and Bethe and Feynman were busy understanding it. This determined the direction of all my subsequent work. Studied for a time at the Institute for Advanced Study, Princeton, and married one of the mathematicians there. Am now back at Cornell as professor of physics."

DAVID LACK ("Darwin's Finches") is director of the Edward Grey Institute of Field Ornithology at Oxford Universi-

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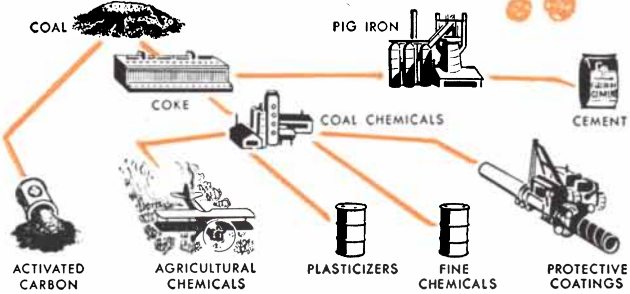

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ty in England and a fellow of the Royal Society. Interested in birds since boyhood, he took a Sc.D. in zoology at Cambridge University, and has since devoted his time to teaching and research in ornithology. In 1938, at the instigation of Julian Huxley, he and four other biologists made the trip to the Galapagos Islands to study the birds about which he writes in this issue. Lack brought back 30 live finches from the expedition, intending to put them in the London zoo. The birds were such poor travelers, however, that he had to leave them in California, where some of them nested successfully. Lack has written a more extensive account of his Galapagos researches in a book also entitled *Darwin's Finches.* This work won the Brewster Gold Medal, an award given periodically by the American Ornithologists Union for the most important publication in the preceding six years on birds of the American continent.

ALPHONSE CHAPANIS ("Psychology and the Instrument Panel") was educated at the University of Connecticut and at Yale University, where he received a Ph.D. in 1943. As an officer in the Aero Medical Laboratory at Wright Field during the war, he found himself continually expostulating with aircraft designers: "But you can't do that! People aren't built that way." It was this experience that led him into research on designing machines to fit their operators, a problem on which he continued to work after the war in the Psychological Laboratory of the Institute for Cooperative Research at the Johns Hopkins University, where he helped design radar and other naval information systems. Chapanis is an experimental psychologist whose interests have also embraced mental testing, psychological statistics and color vision. He wrote an article on color blindness for SCIENTIFIC AMERICAN in March, 1951. He is co-author of a book, *Applied Experimental Psychology: Human Factors in Engineering Design.* In recent years Chapanis has been consultant to the National Research Council's Committee on Highway Safety Research, to the Civil Aeronautics Administration's Air Navigation Development Board and to the Air Force's Air Research and Development Command. This month he is leaving Johns Hopkins to join Bell Telephone Laboratories.

PAUL K. STUMPF ("ATP") dates his interest in enzyme systems from his study, as a Harvard undergraduate, of how potatoes manufacture starch. Graduating in 1941, Stumpf went to Columbia University to work in its Department of War Research and study for his doctorate in biochemistry. He took his degree in 1945, spent two years as an instructor in the University of Michigan's School of Public Health and in 1948 was

invited to the University of California, where he is now associate professor of plant biochemistry, "to develop the enzyme approach to problems of plant metabolism." He has done research on carbohydrate, nitrogen and fat metabolism in plants. In his spare time he is kept busy by three young daughters and by building furniture in the local high school woodworking shop.

EVERETT F. COX ("Atomic Bomb Blast Waves") was a member of the test manager's advisory panel for the recent atomic weapons tests in Nevada. As manager of the Weapons Effects Department of the Sandia Corporation (subsidiary of American Telephone and Telegraph for developing atomic weapons) he also participated in the 1951 and 1952 tests on Eniwetok. A physicist, he studied at Miami University in Ohio and at California Institute of Technology, where he took his doctor's degree in 1933. Until 1940, when he got into war work, Cox taught at Colgate University. December 7, 1941, found him at Pearl Harbor as Chief Physicist of the Degaussing Unit. He spent "anxious hours that day and later searching for magnetic mines that, fortunately, the Japs had failed to sow." Cox later did research on torpedoes and acoustic devices for the Naval Ordnance Laboratory. As background for his work on atomic blasts, he made acoustic measurements when the Army-Navy Explosives Safety Board set off 250-ton stacks of TNT in Idaho in 1946, and when the British demolished Helgoland with a single 5,000-ton blast in 1947.

ABRAHAM STONE, who reviews Simone de Beauvoir's book, *The Second Sex*, in this issue, is a physician who has devoted himself to helping both sexes in their relations with each other. He is director of the Marriage Consultation Center of Community Church of New York, and his lectures, writing and counseling have steered many toward a better marriage. He is co-author with his late wife, Hannah Stone, of the well-known *Marriage Manual*, and, with Norman Himes, of *Planned Parenthood*. A pioneer in the fields of human fertility and birth control, Stone is director of the Margaret Sanger Research Bureau and vice-president of the Planned Parenthood Federation of America. In 1951 he went to India to advise the government on family planning. Last fall he toured the world with Margaret Sanger, and in Bombay gave a talk as a delegate to the Third International Conference on Planned Parenthood. He is a member of the editorial boards of the journals *Fertility and Sterility* and *Marriage and Family Living*, and is associate professor of preventive medicine at New York University-Bellevue College of Medicine.

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THE COVER

The painting on the cover is a symbol of the earth's electric charge with respect to the atmosphere (*see page* 32). The puzzling thing about this phenomenon is that, while the atmosphere is sufficiently ionized to conduct electricity, the earth is able to maintain its charge. Early investigators studied the problem with the electroscope, the instrument which appears at the right side of the painting. When the air around the electroscope is charged, the two gold leaves within it stand apart. In the background is a thunderstorm, in which the answer to the question is now thought to have been found.

THE ILLUSTRATIONS

Cover painting by Stanley Meltzoff

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30	David E. Scherman
31	James Egleson
32	Standard Oil Co. (N. J.)
33-35	U. S. Weather Bureau (*top*) Rudolph Freund (*bottom*)
36	Sara Love
37	Daniel T. O'Connell
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112-118	Roger Hayward

WORLD'S FASTEST In a trial run, "Slo-Mo-Shun IV" streaks over Lake Washington, Seattle, at better than 180 miles an hour.

What keeps her from flying to pieces?

Death crowds right into the cockpit beside you when you drive a boat like that.

Strange things happen. Every little wave jars the hull like a rutted road. Your foot burns at the touch of the jiggling accelerator. Your eyeballs jounce around in their sockets like glazed marbles as you keep watch for a sight you never hope to see:

Screw heads popping off like bullets as the beaten hull breaks up around you from the incessant pounding.

But that is one threat you no longer need to fear—not when your boat is held together with Anchorfast. Stan Sayres (he owns and drives the world's fastest boat) can tell you: Not even the varnish has cracked where her joints are nailed with Anchorfast.

What is "Anchorfast?" Just about the most revolutionary fastener you ever did see (at right). Once you drive it in, it can split the handle of a claw hammer before it budges a thread.

Anyone could see what a wonderful idea it was when the manufacturer came to INCO with his question: "What metal?"

It had to be strong and tough for holding power, of course. And hard and stiff so you could drive it into hard wood without bending. Yet so rust-free and durable that it would outlast wood. Not too expensive either, mind you, for Anchorfast would sell in competition with ordinary brass screws.

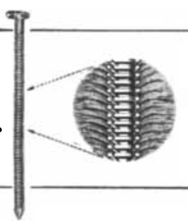
Monel fulfilled every requirement as if it had been an INCO Nickel Alloy especially made for Anchorfast.

Then came INCO's Customer Cooperation to help Independent Nail & Packing Co. find markets and spread the news of their Monel Anchorfast. (Come to think of it, this advertisement itself is an example of that cooperation.)

Today you find Anchorfast in boats from "Slo-Mo-Shun IV" down to slow plodding work boats, in cooling towers, catwalks, mushroom trays—for any NPA-approved use where joints must stay tight as long as the wood lasts.

Does Anchorfast remind you of a metal problem in some product of your own? Let's talk it over. The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

Drives like a NAIL...



***HOLDS** like a screw!*

The holding power of Monel Anchorfast comes from its unique "biting tooth" design. The wedged wood fibers lock into the grooves like dozens of tiny vises. Like to try it yourself? Write for "Anchorfast Test Sample."

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SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR APRIL, 1953 VOL. 188, NO. 4

ARTICLES

DEPARTMENTS

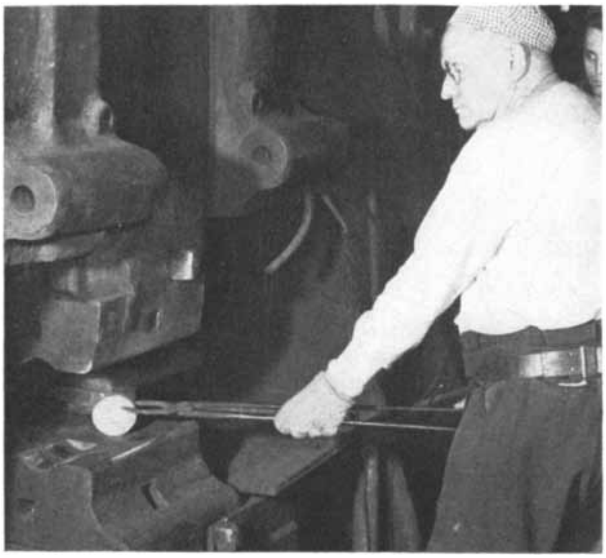
What's Happening at CRUCIBLE

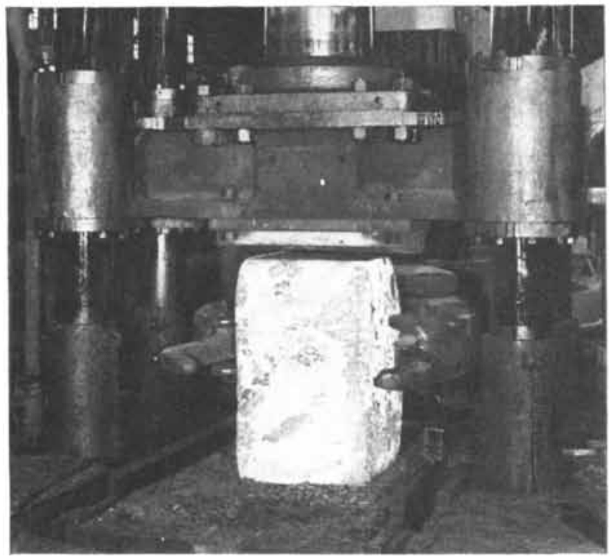
about tool steel forgings

Whether 1½ pounds or 7 tons . . . forgings get the same sensitive handling

Crucible's reputation as the specialty steel leader is built on a devotion to the smallest detail . . . regardless of the size of the order.

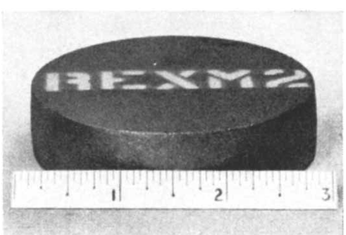
These forgings are good examples of Crucible specialists at work:

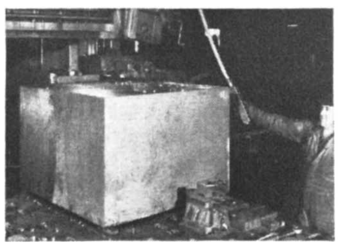




Rex M-2 High Speed Steel Disc Forging (1½ pounds)

Pancake forgings such as these are used extensively by small tool makers. Extreme care is taken in the preparation of the slug stock. The upsetting insures proper flow lines. Milling cutters, gear shavers and similar cutting tools that require maximum toughness, coupled with the best cutting ability, are made from these forgings.





CSM-2 Plastic Mold Forging (14,000 pounds)

This CSM-2 plastic mold steel forging was made from a 25,000-pound ingot. This block will be heat-treated and worked to produce a mold for the manufacture of large plastic parts. The finished weight of the forging is 14,000 pounds. And it is the largest mold forging yet produced by Crucible.

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Crucible's engineering service is geared to meet your research and development problems. If you use special forgings, or any special purpose steel, check with Crucible. Crucible Steel Company of America, General Sales and Operating Offices, Oliver Building, Pittsburgh, Pa.

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SCIENTIFIC AMERICAN

APRIL, 1953 VOL. 188, NO. 4

The Influenza Virus

The organism which causes the disease that sweeps nations is curiously changeable. This makes it difficult to anticipate epidemics with vaccines, and suggests a future hazard to man

by Sir Macfarlane Burnet

IN A WORLD from which medical science and social progress have almost eliminated serious infectious disease, influenza holds a unique position. It is the only acute infectious illness that still attacks most adults in advanced Western countries. And it is the only disease which in the 20th century has shown a capacity to increase in virulence and sweep unchecked around the world, killing millions in the process. That happened in 1918-19. Could such an outbreak occur again, and if it did, could our present-day vaccines and drugs control it? No one can yet say.

The main objective of work on influenza is to be prepared to deal with a lethal pandemic of that type, should one appear again. The periodic epidemics of influenza that we have had in recent years, one of which is now running its course in North America and Europe, have been of a milder form. As long as influenza retains the character it has shown since 1933, our practical objectives are limited. Immunization with vaccines has been applied mainly to military personnel for the purpose of avoiding loss of time, particularly during training. Theoretically it might be desirable to protect the whole population by similar methods; what is good for the soldier surely is good for the civilian. Actually not many people regard influenza as a serious enough danger to want to have one or two immunizing "shots" each fall, and without a better knowledge than we have of what strains of influenza viruses are likely to produce epidemics, it is difficult to become enthusiastic about large-scale immunization.

Yet there is one group in the civilian population that needs close study, with a view to deciding whether we should try to immunize all its members each year. These are the elderly people. Whenever an epidemic of influenza passes through a community, there is a sharp peak of deaths from various causes among the aged. Any elderly person rendered frail by physical disability is likely to succumb to an attack of influenza. This was heavily underlined during the 1951 influenza outbreak in Great Britain. In Liverpool the epidemic passed like an angel of death amongst the old. During the peak week there were more deaths than in the worst week of the 1918-19 pandemic. An investigation of the saving of life that might be effected by appropriate immunization of the aged against influenza would seem to be a very worthwhile project.

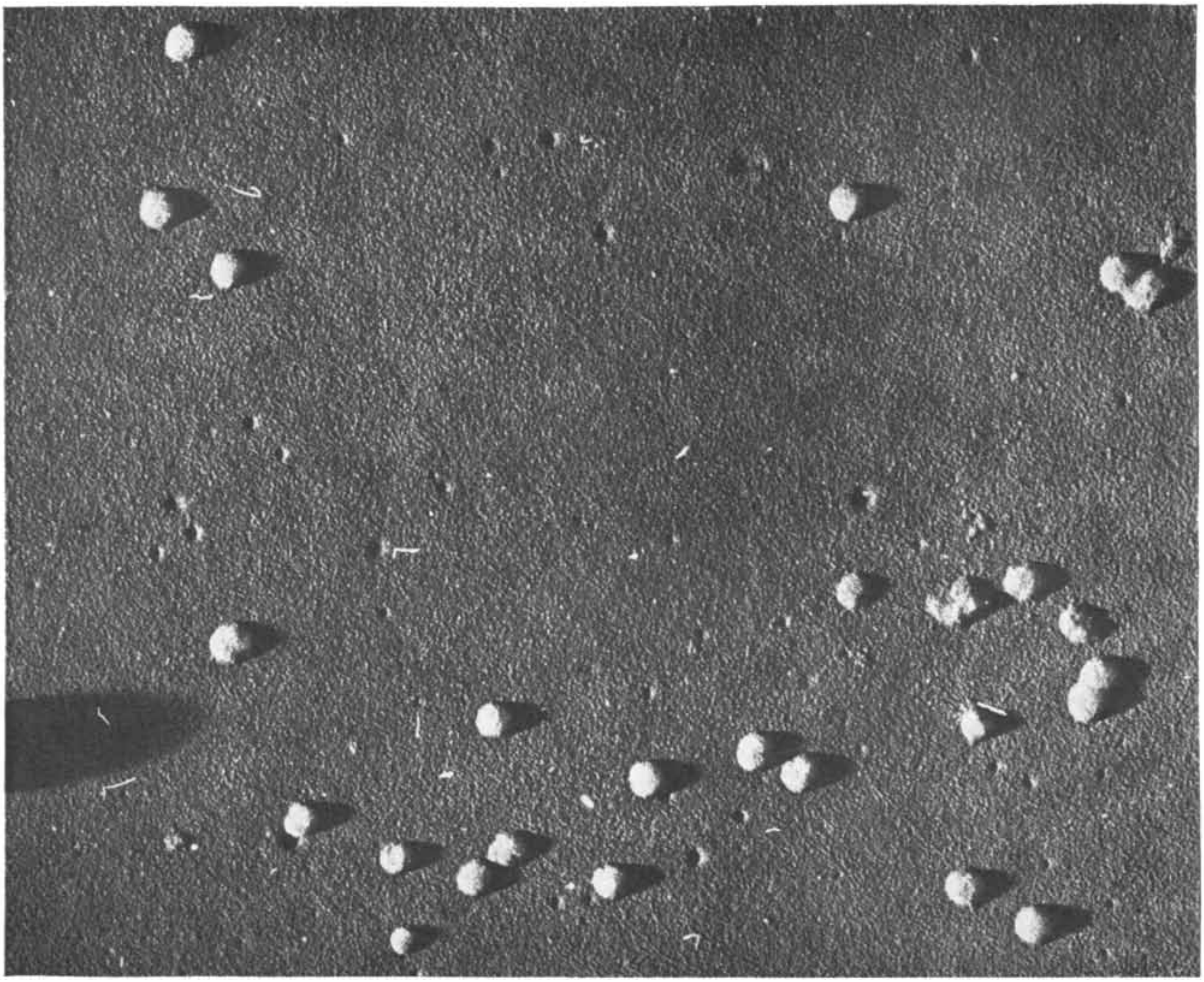
WE NOW HAVE a substantial fund of knowledge about the virus of human influenza, which was first isolated in 1933. For this knowledge we are largely indebted to two major technical discoveries made about 1941: (1) a convenient way of growing the virus (in chick embryos), and (2) a test to determine the presence of the virus (the clumping of red blood cells suspended in a test tube). Thanks to these laboratory aids, it is hardly too much to say that the influenza virus today is as well understood as the diphtheria bacillus or the pneumococcus. They have given a tremendous stimulus to the investigation of all aspects of influenza.

The first requirement in the study of any disease is to be able to define it in terms of the responsible microorganism. This is especially important in the case of influenza because its symptoms are just like those of at least a dozen other known infections, notably certain common feverish colds which are quite indistinguishable clinically from mild influenza.

One way to identify influenza is to isolate the virus. This is normally done by inoculating into chick embryos throat washings taken from persons in the acute febrile phase of the illness. After four or five days' incubation, the embryo fluid will contain enough virus to agglutinate red cells. Thereafter the virus can be transferred to fresh embryos for further study.

A more convenient way is to take two samples of blood from the patient, one at the earliest stage of the illness, the other two weeks later, and test the serum for the presence or absence of antibody against standard types of virus. If in the second blood specimen five out of six patients of the sampled population have antibody against a specific influenza virus, we can be certain that the outbreak was due to that type of virus. If, on the other hand, none shows an increase in antibody against any type of influenza virus, we must look for another cause of the epidemic.

This use of immune reactions for diagnosis introduces us to the important question of the different species and types of influenza virus. There are three species, called influenza A, B and C. Immunologically the three are completely distinct. Infection with one produces no antibodies or immunity against either of the others. Influenza C is a rare type which apparently produces only trivial illness; it need not be further considered. Of the other two, influenza A



ELEMENTARY PARTICLES of the influenza A virus appear as small spheres in this electron micrograph by Robley C. Williams of the University of California. The micrograph enlarges the particles 70,000 diameters.

occurs more frequently and in larger and more severe epidemics than influenza B. Most of the research has been done on influenza A.

An influenza A virus is defined as a virus which reacts with antibody produced by infection with a standard A-type virus. But A viruses differ among themselves in various ways. For instance, on the basis of immunity tests in animals we can identify three distinct strains, called A1, A2 and A3. All three cross-react in the test tube, but in experimental infections they induce very little immunity against one another. There is good evidence from large-scale tests in the U. S. Army that a vaccine prepared from A2 virus was effective against an A2 epidemic in November, 1943, but was quite useless against an A3 epidemic which reached North America in February, 1947.

The difference is one of degree, and the most convenient way of studying it is by what we call hemagglutinin inhibition tests. Given a set of the three A-type strains and a set of the three immune blood sera obtained from animals infected with the same three strains, we perform a series of cross-reactions to determine the least amount of each serum that will prevent a standard dose of each virus strain from agglutinating chicken red cells. It turns out that while the A1 antiserum, for example, can inhibit the effects of all three viruses, far less of it is required to counteract the A1 virus than either of the others. A1 antiserum from a rabbit can be diluted to one part in 2,000 and it will still neutralize the A1 virus, but to inhibit the A2 virus the serum must have a concentration of one part in 200, and to counteract the A3 virus, one part in 100. Similarly, A2 virus is effectively counteracted by A2 antiserum in a dilution of one part in 3,000, but the same serum must be concentrated to one part in 400 to inhibit the A1 virus, and one part in 300 to inhibit A3. In practice this means that A1 antibody is ineffective against the A2 virus, say, because it is not usually present in high enough concentration to neutralize the latter.

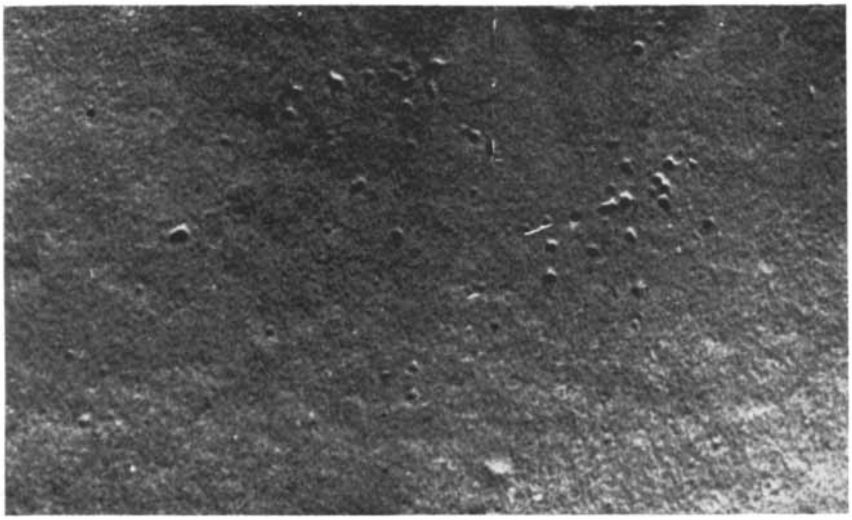
With this background we can turn to the history of influenza from the time when it became possible to study the virus in the laboratory. Influenza A has recurred in the Northern Hemisphere every second or third year. Some outbreaks have been more widespread and severe than others. In England, for instance, 1933, 1937, 1947 and 1951 were years of severe epidemics. The activity of influenza B is less clearly defined: the U. S. suffered outbreaks of the B type in 1940 and 1946.

One simple generalization emerges from the work of the last 10 years: the virus changes type frequently. When it does so, the new type rapidly supersedes its predecessor. The serological character of the A virus has changed seven or eight times since 1933, and each change in character has within a year been evident all over the earth. Soon after influenza A2 was found in the U. S., it appeared in Australia and England as well. After it had taken hold, no A1 strains were found anywhere. And so for each successive change. Occasionally an anomalous virus that seems out of step with the current type does appear, but by and large the rule of world-wide dominance by one type holds. This is a phenomenon of great interest to epidemiologists: it may well provide the key to the understanding of influenza.

There are diseases that maintain their character unchanged for centuries. The mumps virus, for instance, apparently caused much the same symptoms in Hippocrates' time, 2,500 years ago, as it does today, and we can find only trivial immunological differences among present strains of the virus. One attack of mumps will give practically lifelong immunity to the disease. Influenza, on the other hand, gives rise to an immunity which becomes ineffective as soon as a new strain of the virus appears. It also possesses another peculiar feature. In every influenza epidemic many people who never "report sick" are infected mildly with the virus and develop immunity. After a widespread epidemic has passed through a city, few of its people will lack antibody against that particular type of virus.

Here we have a key to the behavior of the influenza A virus. It is a parasite whose only natural host is man. To survive, it must pass continually from one human being to another, but from the very effectiveness of its means of transfer—it is inhaled and lodges in the respiratory tract—it soon finds itself in the position epidemiologists call "exhaustion of susceptible hosts." In other words, almost the entire population becomes immune. In such circumstances there are two ways by which a highly transmissible virus can survive. It may, like mumps or measles, live at the expense of the newborn and become a children's disease. Or it may meet the situation, as the influenza virus does, by a transformation of character—a mutation that enables it to overcome its host's immunity. The importance of such mutations is emphasized by their swift race over the world. In 1946 a new type of A virus was isolated in Melbourne. Australia is a long way from the great centers of population in the Northern Hemisphere. But within a year the new virus was causing widespread influenza in those distant places. Influenza vaccines from previous types of virus were powerless against that sudden epidemic of February, 1947. (Their failure, incidentally, was largely responsible for our first serious recognition of the importance of the influenza viruses' continual change in type.) From 1947 to 1950 the Melbourne virus was the only type found world-wide.

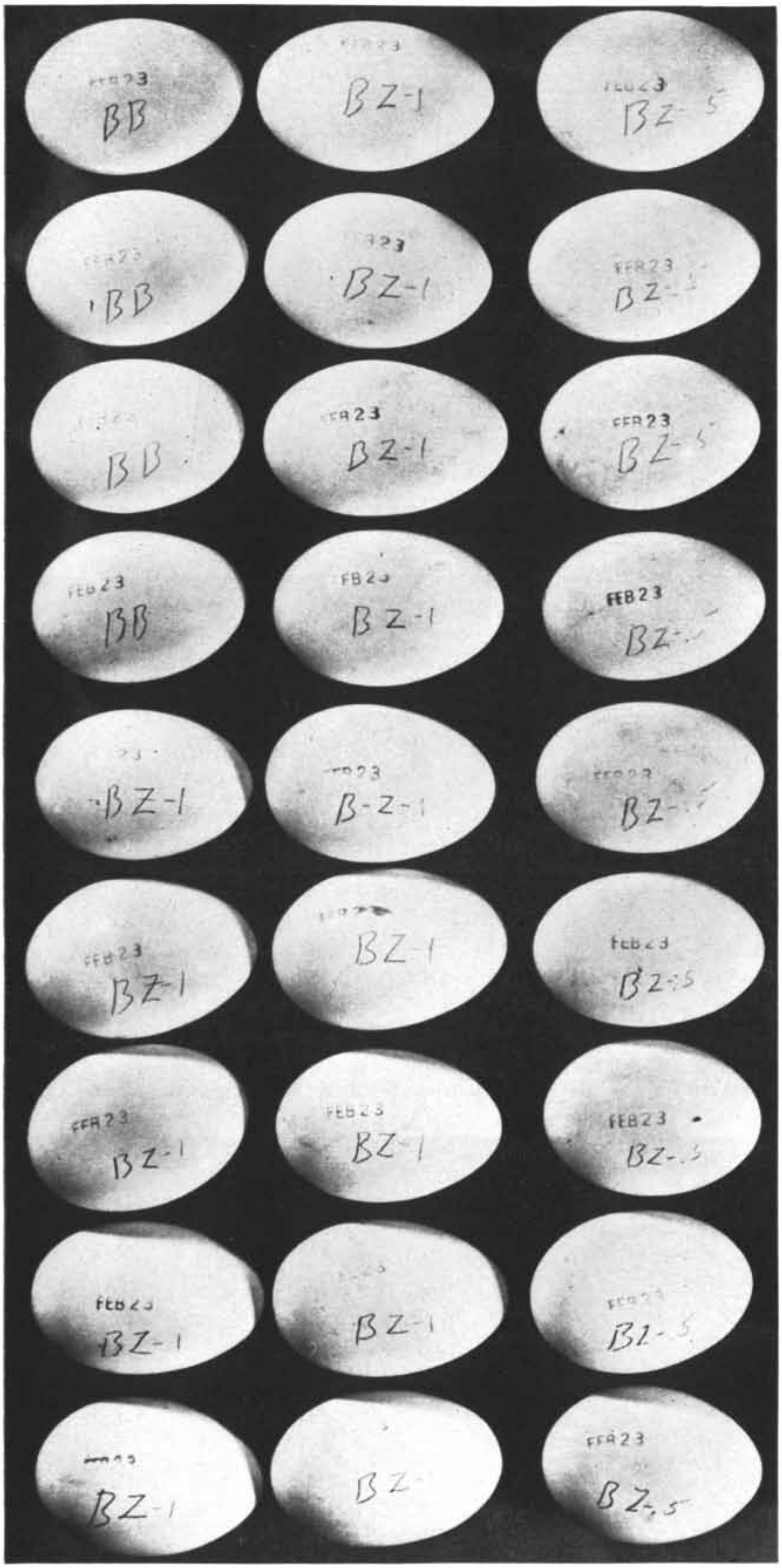
IMMUNITY is not the only quality that changes. The virus probably maintains a continuous series of mutations, each producing inheritable changes in this or that quality. Each



SURFACE of a human red blood cell is shown in this electron micrograph by Morris Rhian, Alfred S. Evans and Joseph L. Melnick of Yale University.

VIRUSES of influenza adhere to the surface of another red cell in a micrograph by Rhian, Evans and Melnick. Some of the viruses are lodged in pits.

PITS remain in the surface of a third red cell after the viruses have been removed by salt solution. The micrograph was made by the same workers.



EGGS containing chick embryos are used to cultivate the influenza virus in the Groton, Conn., Virology Laboratory of Chas. Pfizer & Co., Inc. The virus is inserted into the embryo through a hole in the end of the egg.

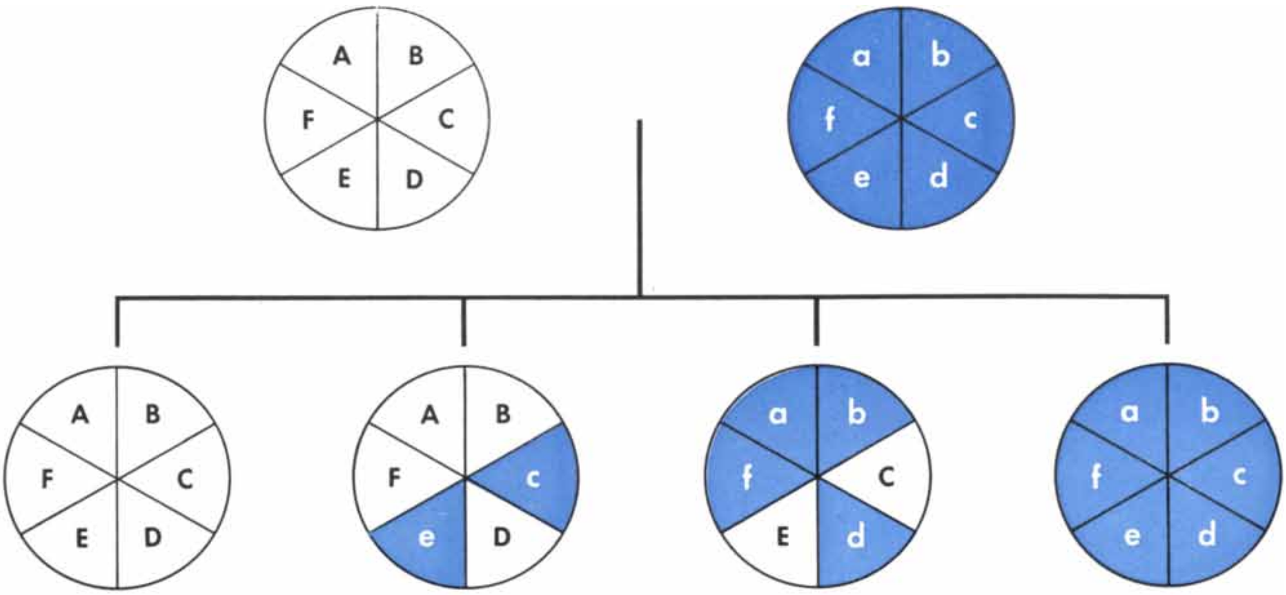
new form must, as it were, go through the test of survival in competition with the old form. It may take a variable time before a really successful competitor emerges. But when it does appear, its success is apt to be so overwhelming that a wave of influenza ripples over the whole of the world. The epidemics may not be severe, but in one form or another each wave represents a new pandemic. It is reasonable to believe that the great pandemic of 1918-19 was the result of the emergence of a series of influenza virus-A mutations which eventually developed a virulence and invasiveness beyond any former precedent.

From what has been said about the changing immunological character of influenza viruses, it will be realized that to provide effective immunization we must make a vaccine from virus types as close as possible to the one that will be dominant during the coming winter. The main hope of doing this is to have in existence an organization for watching the immunological changes of the virus in all parts of the world. If, for instance, a winter epidemic in Australia is found to be due to a new type, that particular type should certainly be incorporated in any North American vaccine for use during the following winter. If we should have a repetition of 1918-19, there would be a special need for swift recognition of new types and streamlined progress from the laboratory to mass production of the vaccines. The World Health Organization's Influenza Center in London is the laboratory primarily concerned with keeping in touch with the changing pattern of influenza viruses. There is a second center in the U. S. and a large number of collaborating laboratories around the world.

IN ONE SENSE everything we have discussed so far is at a rather superficial level. To go a little deeper into the problem of the changes in viruses we must enter the newest of the biological subsciences, virus genetics.

Everyone who has handled influenza viruses in the laboratory has experienced their capacity to undergo inheritable changes in character—to mutate. In fact, every time we isolate virus from a human throat we automatically sort out those mutants that multiply readily in the chick embryo. The cells of the chick embryo favor certain mutant types different from the forms favored by the cells of human air passages. By now there is a great deal on record about the types of variants that can be selected out in the laboratory, and it is becoming clear that an influenza virus is far from being as simple as its small size and undistinguished appearance under the electron microscope might suggest.

Within the last three years a new approach has been made in my laboratory



RECOMBINATION of characteristics occurs in the genealogy of influenza viruses. Here two strains of the virus are indicated by the circles at the top. The circles are divided into six segments to symbolize six characteristics that differentiate the strains. When both strains are injected into the same chick embryo, their descendants are found to include forms that have combined the characteristics of their ancestors (*circles at bottom*).

toward a further analysis of variation in influenza viruses. The technique is basically similar to hybridization in higher organisms. It is well known that when two bacterial viruses infect a single bacterium, they may give rise to progeny with qualities derived from both viruses: we might almost call them parents. We have now found that influenza viruses, like the bacteriophages, also interact genetically. When two different influenza virus particles not too distantly related to each other can be induced to infect a single cell at the same time, more than two types of descendent virus eventually emerge. The genetic characters of the parents are reshuffled and recombined in them. It is hard to believe that anything really comparable to sexual fusion takes place, but there is only a rather vague and speculative hypothesis to offer as an alternative.

If we try to combine the results from virus work with what is known to date of influenza virus multiplication within the cell, the picture that emerges is something like this. A virus can be regarded as composed of two systems. One provides the means of entry into the host cell and incidentally carries the immunological qualities that are so important for medicine. These are essentially surface qualities and can be regarded as equivalent to the body tissues of a higher organism. The second system is probably made up of genes and is responsible for the inheritable character of the virus. Apparently the only function of the first system—the somatic portion of the virus surface—is to make possible the virus entry into the cell. Once the virus particle has gained entry, its soma seems to play no further part. Only the genetic material is concerned in the next stage. In one way or another the genes manage to draw from the host cell what they need to duplicate and reduplicate themselves, until there are about a hundred copies of each gene in the infected cell. It is not yet clear whether the whole group of genes duplicates as a unit—one might picture it in the cell as a thread of genes splitting into two threads—or whether each gene goes about its duplication in partial or complete independence of the others. If the first is the case, the genetic interaction between two types must be analogous to "crossing over" in classical genetics. In either case the process must eventually reach a stage where many complete new gene groupings are available. Each of these must then in some way control the construction of a new soma around itself. Until this is done, no detectable virus particle can emerge from or be artificially extracted from the infected cell. Clearly the mystery of biological replication is no less a mystery in the smallest of living organisms than in the largest.

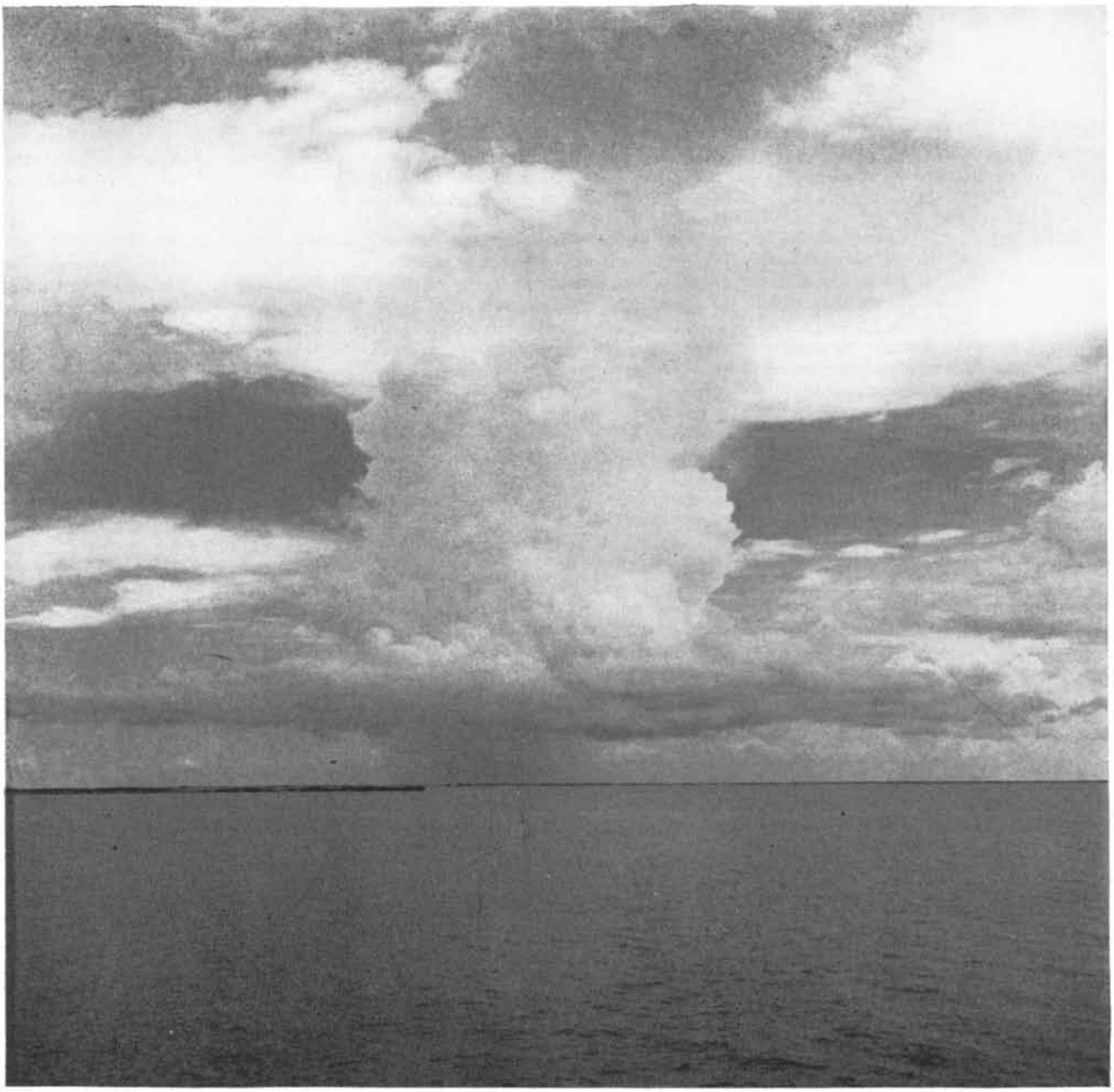
WHATEVER the mechanism, this process of recombining qualities from two different strains provides us with a powerful method of analyzing virus activities. The genetic approach is of extreme importance for every type of biological problem. Biochemistry and bacteriology in recent years have been completely rejuvenated by its application, and it can hardly fail to yield similar help to virus research. There seems to be no theoretical reason why we should not eventually obtain a detailed understanding at the genetic level of the nature of virulence, and of the nature and limitations of immunological changes in influenza viruses. That might still leave us a long way from understanding these qualities in physical-chemical terms, but probably it would provide all that would be needed at the important clinical level. We could look forward to being able to predict the changes in influenza epidemics from year to year and to preparing appropriate vaccines. The same approach might also prove applicable to other viruses and cut short the work needed to find the best types of immunizing agents for various virus diseases, such as poliomyelitis, for example.

There is, however, one thing which we dare not forget. In dealing with viruses responsible for human disease, we are dealing with matters of life and death. Full knowledge of the influenza virus would enable us to save life, but it would also make it possible to let loose, maliciously or by accident, another plague like that of 1918-19, which spread unchecked through civilized and uncivilized countries alike, and in the process killed 25 million people. Microbiology is bound to advance just as nuclear physics has advanced, but perhaps even more manifestly the impact of that advance on human affairs will depend upon the way in which it is applied. Medical microbiology in the past has produced the most directly beneficial of all social revolutions by removing most of the dangers of infectious disease. It would be a bitter irony if its further development should bring man-made plagues even more lethal than the natural epidemics of the past.

THE EARTH'S ELECTRICITY

The earth is charged with respect to the atmosphere, and the atmosphere is sufficiently ionized to be a conductor. How, then, is the earth capable of maintaining its charge?

by James E. McDonald



THUNDERSTORM over the Louisiana bayous pours rain and negative electric charge upon the earth. Towering above it is the cumulo-nimbus cloud. Later the cloud forms an "anvil" top (*see pages 34 and 35*).

IN 1887 a little-known German physicist named F. Linss raised a question which has plagued scientists for two generations. The French physicist C. A. de Coulomb had observed a century earlier that air conducts electricity away from charged objects. Linss made careful measurements of the rate of this leakage and found that it was much more rapid than had been supposed. The question then raised was: How does the earth—a charged object quite obviously exposed to the atmosphere—maintain its charge? The fact that it did so was well known.

By measurements of the natural electric field in the lowest few feet of the atmosphere, physicists had shown that the earth has a negative charge which in modern units amounts to some 400,000 coulombs. We walk about with our heads in air that is some 200 volts positive with respect to the ground under our feet. If the air conducts electricity, Linss reasoned, the earth's charge must constantly leak into the atmosphere. He calculated that the earth as a whole must be leaking charge at the prodigious rate of 1,800 amperes, and at this rate it should lose 90 per cent of its charge to the atmosphere within an hour! Yet the earth's charge persisted, and there was every reason to believe that it had not decreased appreciably since at least early geologic time.

Linss's paradox captured the interest of many physicists, and as often happens with such puzzles, a whole new branch of science was built up around efforts to resolve it. The investigations led to the discovery of cosmic rays, among other things. The story is one more instance of the way in which important developments in science often grow out of efforts to account for small discrepancies between theory and observation.

In 1899 J. Elster and H. Geitel in Germany and C. T. R. Wilson in England independently discovered ions in the atmosphere. J. J. Thomson had shown earlier that ions were responsible for gaseous conduction in the laboratory. Atmospheric ions differ slightly from those of the chemist's test tube. They consist of clusters of molecules held together by the electric field of a central charged molecule. (Such ions should not be confused with the much larger ones that form on particles of dust or other matter in the air.) Because of their high mobility, the molecular ions carry most of the atmosphere's currents.

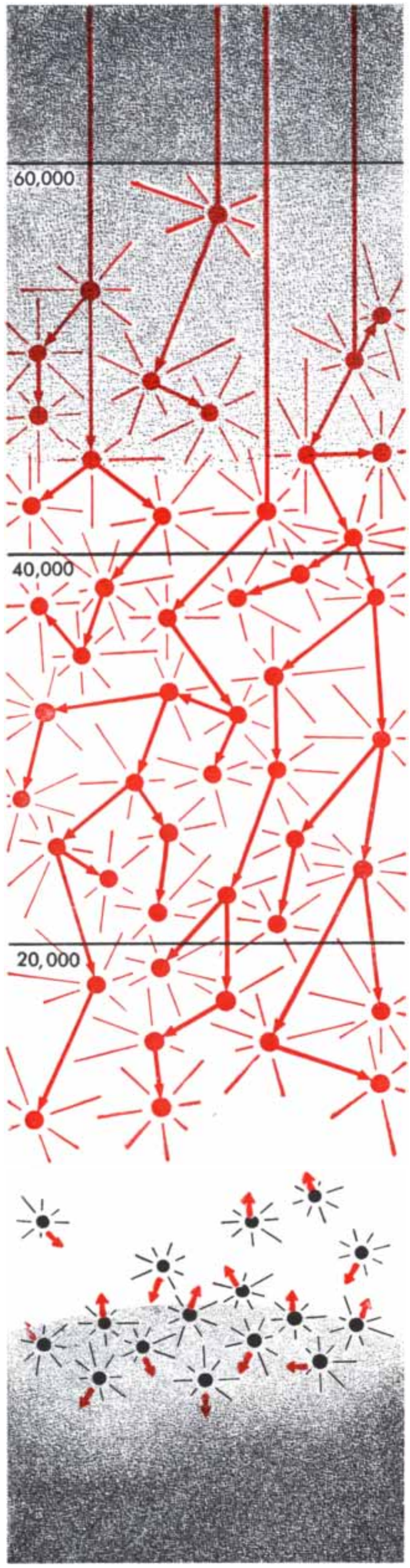
ONCE the existence of atmospheric ions had been established, the next task was to explain how the central molecules acquired their charges. Elster and Geitel at once found an answer in the then new and exciting discovery of radioactivity. Radiations from the radioactive minerals in the earth and from radioactive gases (mainly radon) in the air, they said, ionized the air molecules. Their first measurements of the average ionization rates produced by these radioactive substances seemed to bear out their suggestion.

When they went on to check the hypothesis further in the laboratory, however, they discovered something puzzling. They hoped to be able to prove that air shielded from radioactivity would show a lack of ionization. They enclosed samples of purified air in vessels so heavily shielded with lead that no known radiation, not even the very penetrating gamma rays, could enter. The conductivity of this air should have been zero. But Elster and Geitel found that the shielded air was still able to carry a current. They decided that it must have been ionized by some extraordinarily penetrating "ultragamma" radiation from an unknown mineral in the earth.

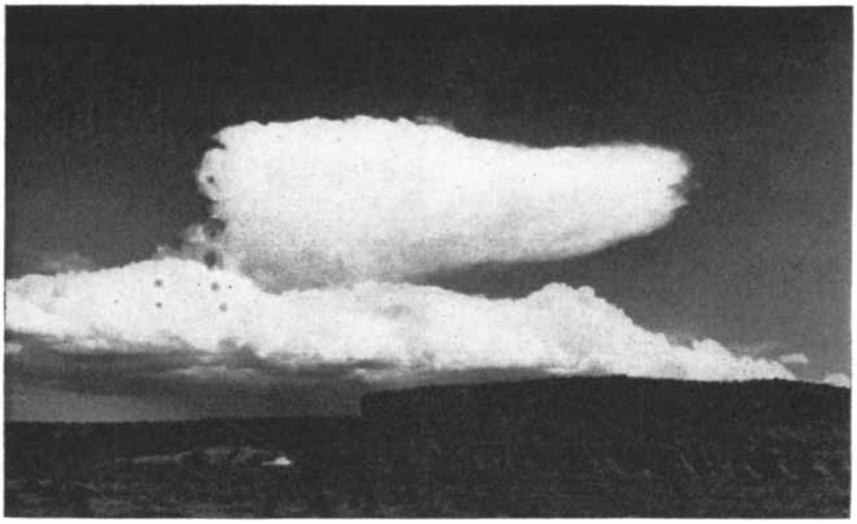
If this was true, atmospheric ionization should decrease as one went farther away from the earth. In 1911 the Viennese physicist Victor Hess went up 16,000 feet in a balloon to test the theory. He discovered that instead of decreasing, the ionization actually increased as he went to high altitudes. At the top of his flight the ionization rate was several times greater than at sea level! In short, the "ultragamma" rays that penetrated lead chambers were coming from above, not from below. They were soon named "cosmic rays" [see "Cosmic Rays," by George W. Gray; SCIENTIFIC AMERICAN, March, 1949].

Exactly where the cosmic rays were coming from was not clear then, and it is still not entirely clear today, 42 years later. But from the point of view of atmospheric electricity, Hess's discovery of cosmic rays (for which he was awarded a Nobel prize in 1936) was most stimulating. Cosmic rays were found to account for some 15 to 20 per cent of the ground-level ionization of the air over land and for almost all the ionization over the oceans, which contain little radioactive matter. Moreover, later ascents to higher altitudes showed that the atmosphere's conductivity steadily increased with height. At 60,000 feet, which was reached by a National Geographic Society balloon in 1935, the conductivity was about 100 times greater than the average at sea level.

The high ionization of the upper atmosphere might well play an important part in maintaining the earth-atmosphere electrical balance. But how? In 1920 Wilson suggested an answer which now seems almost certainly the correct one. Wilson, whose name is associated with the cloud chamber he devised to study the paths of ions, had been making careful measurements of vertical electric field intensity near the earth's surface. During fair weather, he found, the earth's negative charge was con-



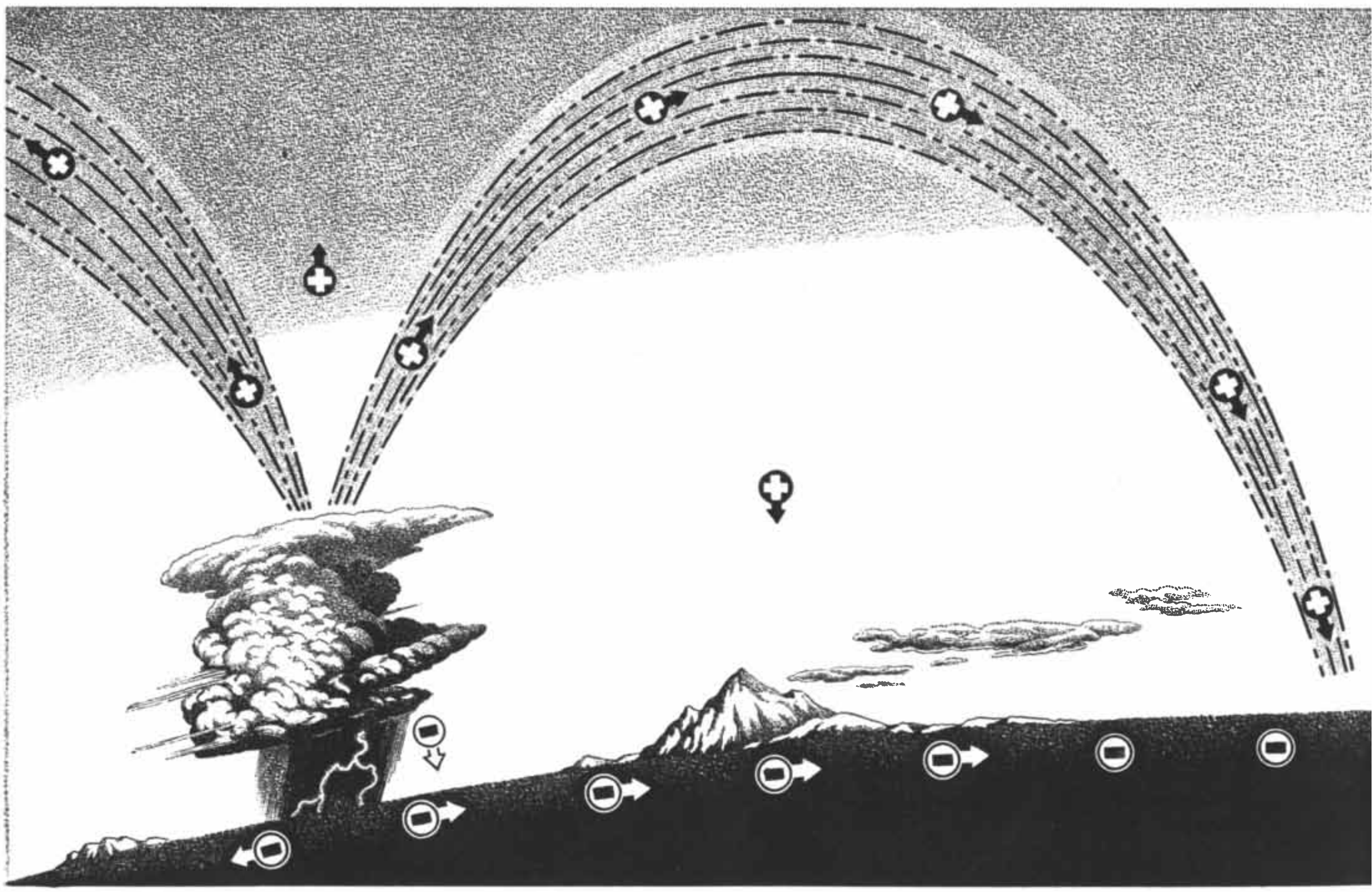
IONIZATION of the atmosphere is due to cosmic rays (*red symbols in the upper part of drawing*) and the disintegration of radioactive atoms (*red symbols at bottom*). The approximate altitudes at which these phenomena produce ions is in feet.



GROWTH OF THE ANVIL TOP of a cumulo-nimbus cloud is depicted in these three photographs from the collection of the U. S. Weather Bureau. This is the final stage in the development of the cloud. The anvil some-

stantly and rapidly being neutralized by a steady downward flow of positive ions —which is electrically equivalent to the upward leakage of negative charge. But Wilson noticed that during thunderstorms the field intensity fluctuated wildly and rose to very high values. More important, he showed that beneath thunderstorms the electric field was often positive instead of negative, and that large negative currents must be flowing to the earth. He suggested that lightning strokes from thunderstorms, which occur in many parts of the world every day, might supply enough negative charge to the earth to balance its loss of charge to the atmosphere in storm-free areas.

Stripped of its details (and in 1920 Wilson was unable to fill in many of these anyway) his hypothesis visualized the thunderstorms that are scattered over the globe at any one instant as a battery of many cells in parallel. Their lower poles fed negative charge downward to the earth *via* lightning and point discharge currents from trees,

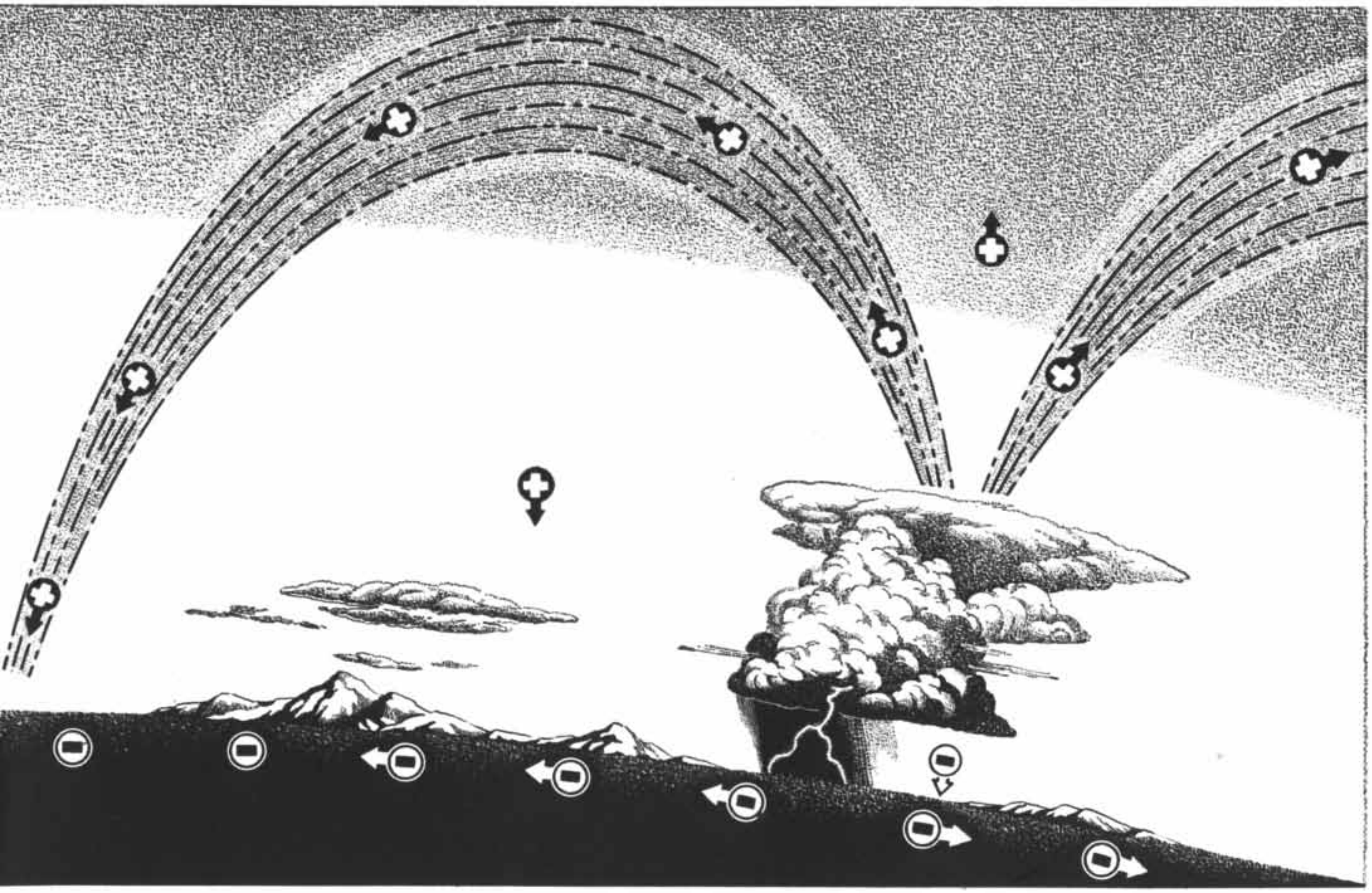


FLOW OF CURRENT maintaining the earth's charge is shown in this diagram suggested by the hypothesis of C. T. R. Wilson. At the left and right are two thunderstorms, which add negative charge to the earth and pos-

times reaches phenomenal heights. The average height of summer thunderstorms observed in Ohio was 37,000 feet, with some attaining 50,000 feet. The shape of anvil indicates that its movement is from left to right.

towers and other pointed and grounded objects. Their upper poles, embedded in the highly conducting region of the high atmosphere, leaked an equivalent positive charge to that region. This upward flow was then dispersed through the region and supplied the charge for the descending currents in fair-weather areas. Pursuing the analogy further, one may say that Wilson regarded thunderstorms as cells lying in the gap between the two electrodes of a gigantic spherical condenser. The inner, negative sphere of this condenser was the earth; the somewhat leaky "nonconductor" was the atmosphere; the outer, positive sphere was assumed to be a highly conducting shell of the upper atmosphere. The existence of such a shell had already been suspected from its effects on radio transmission, and a few years after Wilson published his theory it was confirmed by experiments and named the "ionosphere."

Wilson's thunderstorm hypothesis has so far survived all attacks upon it and has become more firmly established with



itive charge to the ionosphere. If measurements were made in the storm-free region near the center of the diagram, they would show a descending current of positive charge tending to neutralize the negative charge.

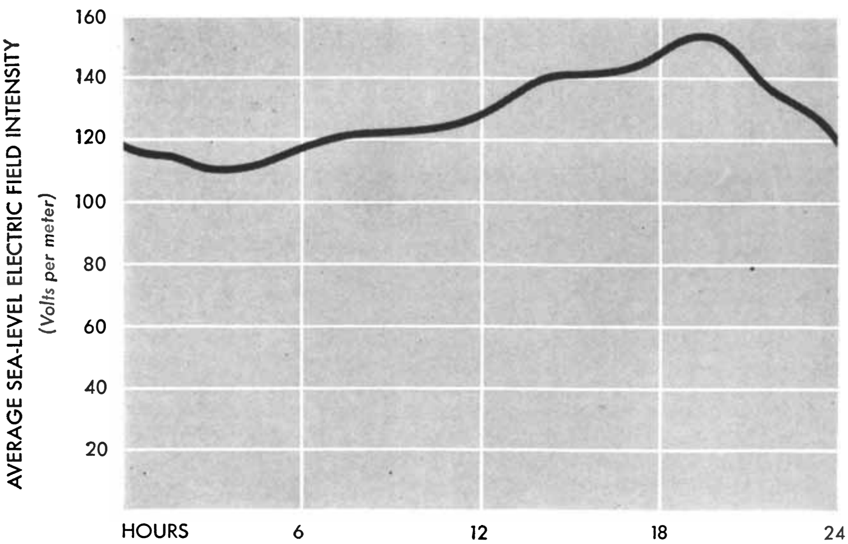
the passage of time. The British meteorologist Sir George Simpson found what he thought was evidence against the theory: in balloon flights he discovered that the air at the base of many ordinary clouds had a positive rather than a negative charge. But it is now believed that these positive charges are negligible compared to the large negative charges in the lower parts of most thunderstorms. Simpson also objected that the conductivity of the upper atmosphere was inadequate to sustain the large positive flow needed to supply the fair-weather currents. The 60,000-foot ascent of the National Geographic Society balloon proved, however, that the conductivity was sufficient at the altitudes it reached.

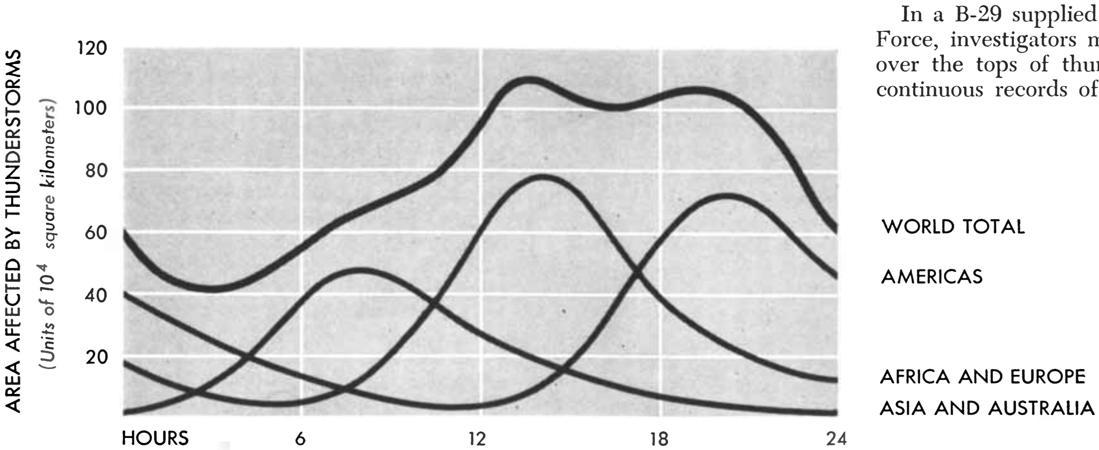
The same flight established that, although the electric field decreases rapidly with height, the ionosphere is still some 400,000 volts positive with respect to the earth! It is this voltage difference that drives positive charge downward through all parts of the atmosphere free from thunderstorms, and which thus tends continuously to neutralize the earth's negative charge. Thunderstorms succeed in driving current in opposition to this high voltage only because they separate charge at so titanic a rate as to create voltage differences of the order of hundreds of millions of volts between their upper and lower charge centers. For this reason it is quite possible for the top of a thundercloud to be at a very large positive voltage above the ionosphere while its base is negative with respect to the earth. The separation of charge is what enables clouds to pump negative charge at a tremendous rate to the earth and thereby replenish its losses.

ONE of the first important tests of the Wilson hypothesis came within a year after he had suggested it. S. J. Mauchly, chief of the terrestrial electricity section of the Carnegie Institution of Washington, analyzed measurements of the electric field intensity that had been made in many parts of the world by the research yacht *Carnegie*. From his analysis he reached the conclusion that the positive voltage of the ionosphere with respect to the earth was at a maximum at a certain time each day: namely 7 p.m. Greenwich Mean Time. This was a curious fact; if Wilson's theory was correct, it should mean that the total thunderstorm activity over the whole earth hit a peak at about that hour each day. The British meteorologist F. J. W. Whipple proceeded to examine world weather records and found that this was indeed the case: as a world average, thunderstorms were most active between 3 and 8 p.m. G. M. T. The explanation has to do with the earth's pattern of land and water distribution. When it is seven in the evening at Greenwich, many noon heat thunderstorms are occurring in the central part of the Western Hemisphere, and it is not long after the afternoon peak of storms in Europe and Africa. All this activity, plus smaller contributions by Asia and Australia, make this one period of the universal day the most stormy on the average over the world. The storms spew out positive charge to the ionosphere and negative charge to the earth at such a rate as to build up the voltage difference to about 15 per cent above the day-long mean.

The crucial question remains: Does the total transfer of negative charge to the earth by thunderstorms balance the leakage of charge from the earth? This question has been difficult to answer. The closest approach was made in 1947 by O. H. Gish and G. R. Wait of the Carnegie Institution. Recognizing the difficulties involved in measuring charge transfer under thunderclouds, they turned to the other poles of Wilson's cells—the top of a thundercloud and the ionosphere. The net current exchange there, they argued, should on the average equal that between the cloud base and the earth. And it should be much easier to measure.

In a B-29 supplied by the U. S. Air Force, investigators made many flights over the tops of thunderstorms. From continuous records of the vertical field





DAILY VARIATION in the intensity of the electric field at sea level is shown in the upper chart. The variation in the number of thunderstorms is given in the bottom chart. The rough agreement between the upper curve and the world total thunderstorm curve indicates that thunderstorms replenish the earth's charge.

LIGHTNING STRIKES from the bottom of a cumulonimbus cloud in this photograph made by Daniel T. O'Connell from the edge of Grand Canyon. Some strokes are photographically reversed by overexposure.

strength and the conductivity, they calculated that the average current was of the order of half an ampere above each active region of a thunderstorm. The total leakage of current from the earth, it will be remembered, is 1,800 amperes. To return that amount of current to the earth there would have to be 3,600 active thunderstorm regions at all times over the whole earth. Gish and Wait have given fairly good reasons for believing that this number of storms is in fact present at all times.

Since the measurements were made at only 40,000 feet, far below the base of the ionosphere, it might be objected that a substantial portion of the ascending positive charge which they measured may not reach the ionosphere to replenish that region's charge. Recently R. E. Holzer of the University of California at Los Angeles and D. S. Saxon of the National Bureau of Standards have examined this question theoretically. On the basis of reasonable assumptions as to the conductivity at great heights, they estimate that 85 per cent of the current measured during a typical flight above a storm does reach the ionosphere and only 15 per cent fountains out and down to the ground. This analysis by Holzer and Saxon considerably strengthens the Gish-Wait experiment.

To CONFIRM Wilson's thunderstorm hypothesis conclusively the Gish-Wait experiment must be repeated in many parts of the world, and a more thorough count of the world's thunderstorms must be compiled. But it now appears that Wilson's penetrating insight hit upon the correct explanation when he suggested 33 years ago that the earth constantly replenishes its huge charge from thunderstorms, which at any one time cover less than 1 per cent of the earth's surface.

Experiments in Aging

The exotic little rotifer, a microscopic animal that lives in ponds, yields some significant information about a factor that may shorten or lengthen the natural life span of an organism

by Albert I. Lansing

IT IS a common error to confuse aging with the span of life. How long an individual lives may be determined by any of a number of other things—accident, violence, a congenital defect, disease. Aging very likely has something to do with some of the ailments that kill, such as cancer and cardiovascular disease, but few people die of old age itself. Curiously, of all the causes of death, aging is the one we understand least. I propose to sketch briefly some biological aspects of aging and to describe certain experiments on a simple animal which give some clues about the process.

We are hobbled at the start by the difficulty of defining what aging is. Does it mean failing powers? Undoubtedly most of the changes that take place as we age are unfavorable, but some have human value: men are said to grow, for example, in wisdom—though this may be debatable. Is aging measured by years? We all know men of 70 who enjoy the vigor of middle age, and of other people who are constitutionally old though young in years. Indeed, there is a children's disease, known as progeria, which may give the child a mature mentality, the physical characteristics of an old man and susceptibility to diseases of old age.

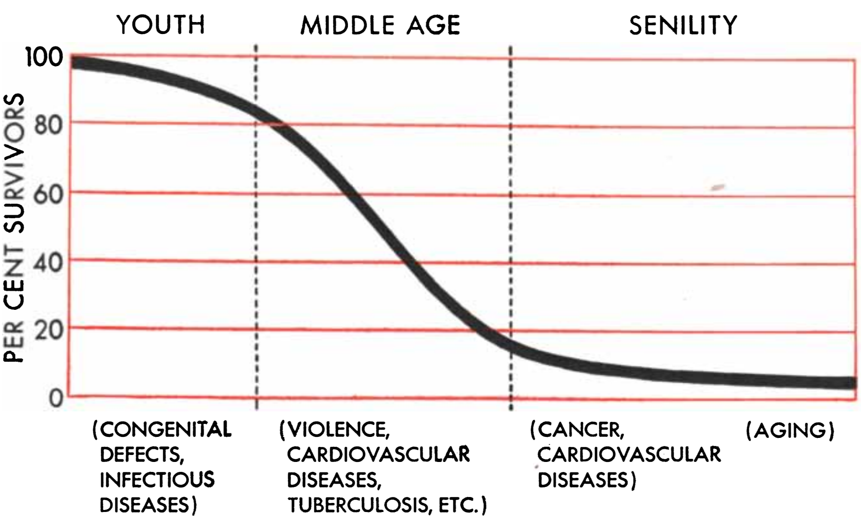
In general, aging is an anomaly of the biological world. Some theories attribute it to a breakdown of blood vessels or connective tissue; yet many organisms have neither blood vessels nor connective tissue. Some argue that organisms age because their cells wear out, as automobiles or shoes do. But the body continues to rebuild its cells as long as it lives (indeed, this is a cardinal distinction between living and non-living matter), and as long as protoplasm has this ability it should not wear out. In all probability the main reason that organisms age is not a wearing out of cells but a decline in the body's cell-building efficiency.

There is no reason to doubt that all species of animals and plants age. Their life span, of course, varies enormously. Some trees live as long as thousands of years; tortoises are reputed to live 300 years; man has a span of about 70 years; mice live two to three years; certain insects live only one day. Even protozoa, those simple organisms that endlessly renew themselves from their own substance, will go into a decline if the nucleus is not invigorated by self-fertilization or by fertilization through mating.

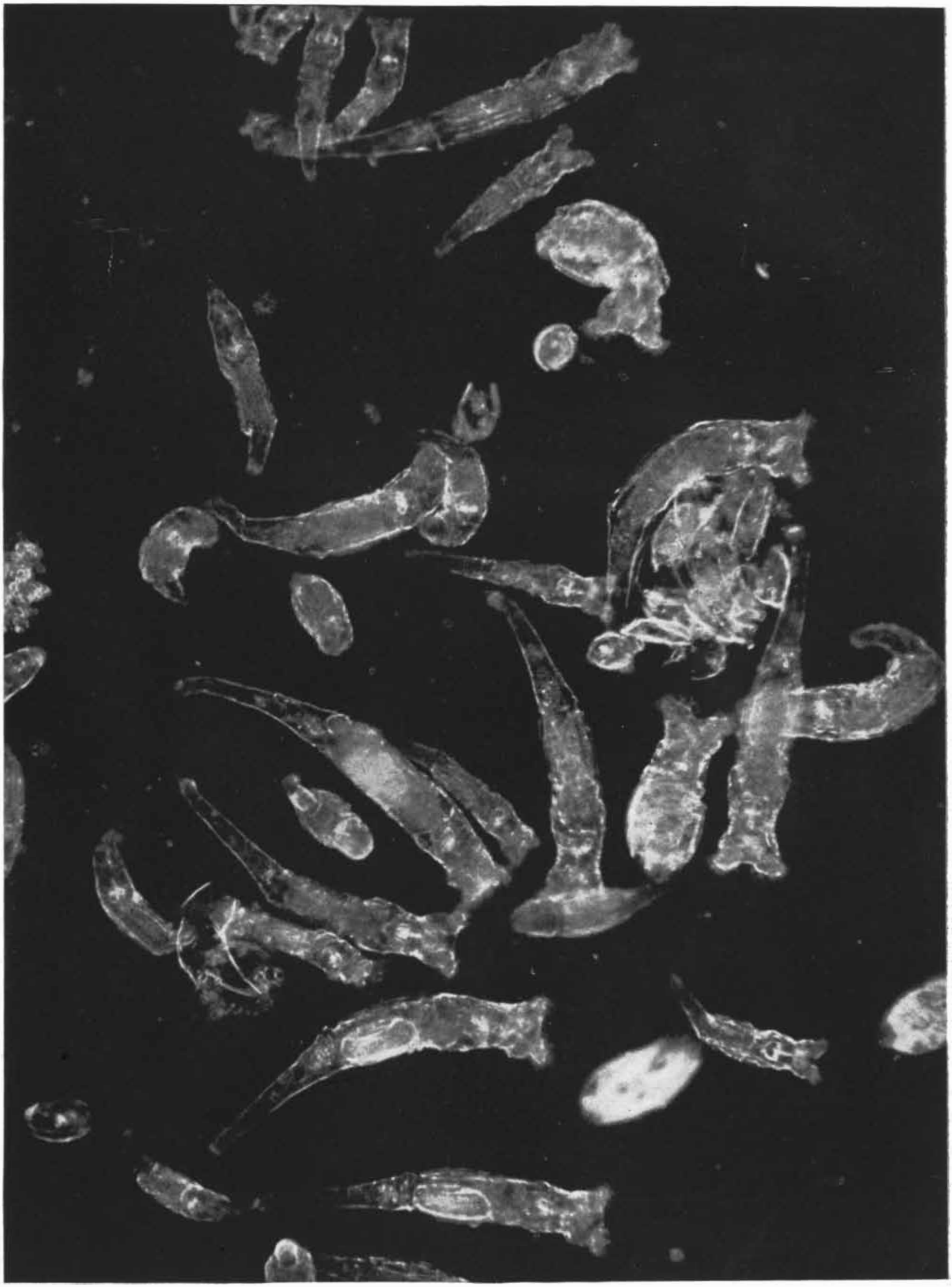
ONE POINT seems reasonably clear: as long as protoplasm keeps on growing, it does not age. Apparently aging begins only after growth stops. The long-lived trees go on adding growth year after year; tortoises grow slowly but steadily larger. Even in mammals cells that keep on dividing (such as epidermal cells) do not age. The cells that show age are those which have differentiated and matured.

From all this it follows that slowing down growth should increase longevity. That just this is true was neatly shown by the Cornell University nutritionist Clive McCay. He divided litter-mate rats into two groups, one of which he fed a normal diet and the other a diet limited in calories so that growth was held back. The growth-retarded rats lived much longer than the normal ones. Similar studies with the water flea *Daphnia* and other invertebrates show essentially the same effect. Animals subjected to semi-starvation during adolescence live much longer than well-fed animals. Once growth is completed, however, semi-starvation seems to have no significant effect on the life span.

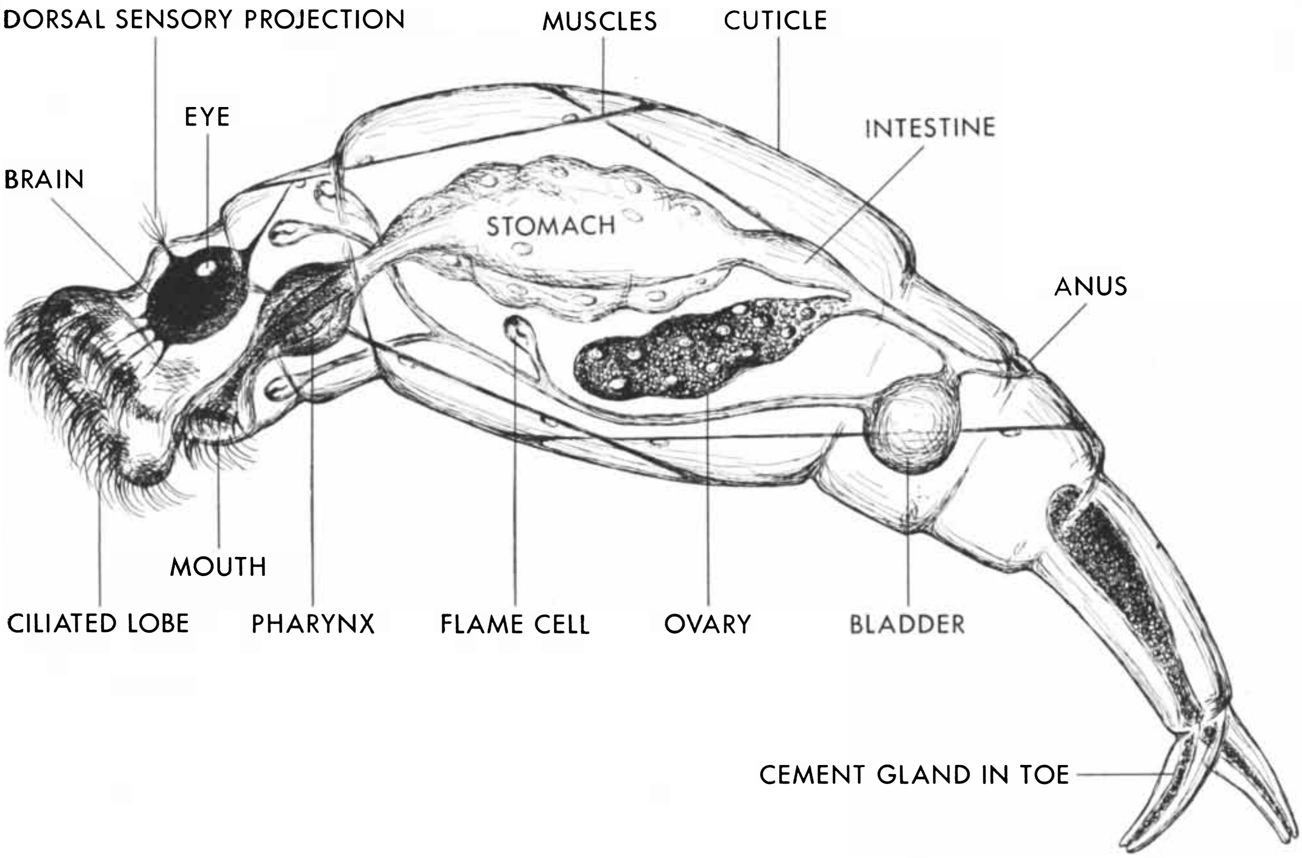
The geneticist T. M. Sonneborn, of Indiana University, carried out an even more remarkable experiment with a certain flatworm which multiplies asexually by splitting in two. The split section that consists of the forepart of the animal contains most of the original body, including the nervous system and most of the alimentary tract; the other section receives only a small bit of the tail. As a result the forepart needs to grow very little, while the posterior fragment must grow almost an entirely new



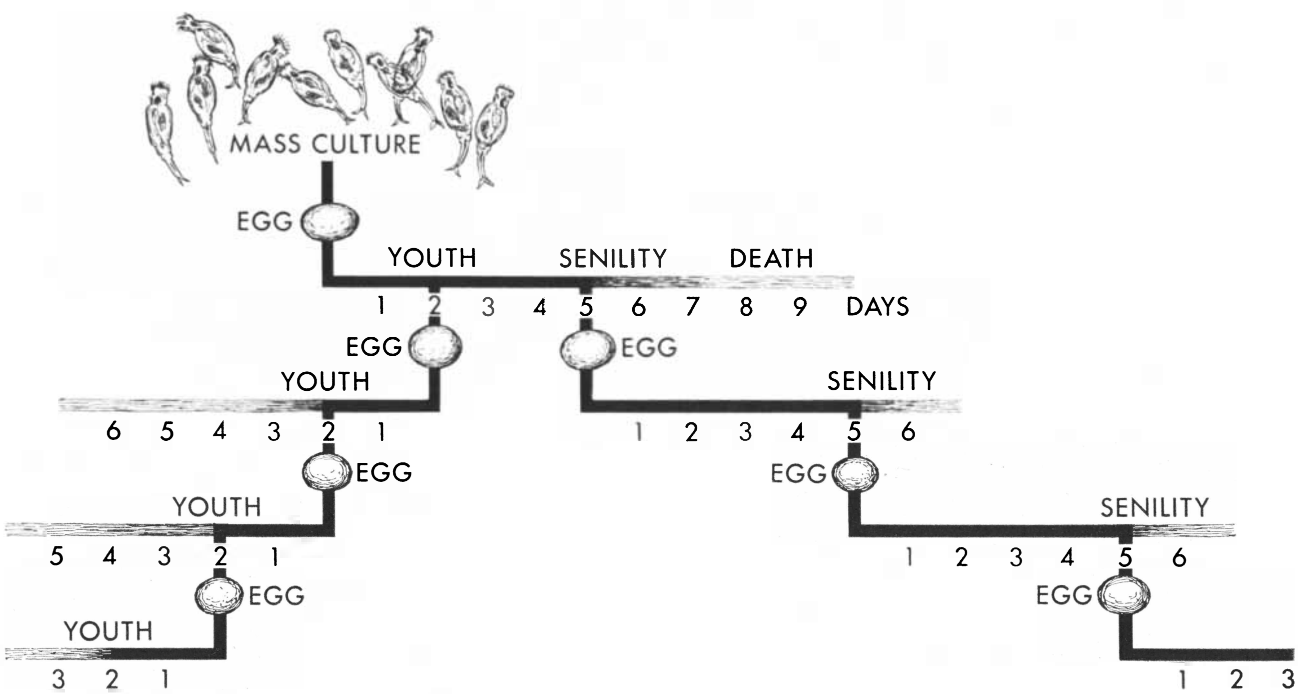
LONGEVITY depends on many factors. This chart indicates the main causes of death at various ages. Few people die of old age itself.



ROTIFERS are a phylum of water animals that abound in stagnant ponds. They are only a millimeter or less long, barely visible to the naked eye. The life span of the various species ranges from one to four weeks.



ANATOMY OF A ROTIFER shows that it is a fairly complex animal. It has two sexes, but the female's eggs can develop without fertilization by the male, and the males of the species seem unimportant.



REPRODUCTION CHART shows how lines from young and old mothers were bred. Species here was short-lived (8 days). In one line, young were hatched from eggs laid at two days; in the other, at five days.

body. Sonneborn selected and traced successive generations of flatworms derived from foreparts only and from posterior ends only. The amazing conclusion was that, without genetic or environmental variation entering in, the actively growing animals from the posterior fragments flourished vigorously, while those from the front ends soon went into decline and died out.

SEVERAL years ago I set out to make a related study of multicellular organisms that reproduce sexually. Essentially the problem was to determine whether the life span of offspring from a young growing mother differed from that of progeny from a full-grown mother. To put this to test I needed an organism which reproduced sexually, had a reasonably short life span, was genetically uniform and could be raised in large numbers under carefully standardized environmental conditions. I found what I was looking for in the rotifer, a tiny water animal which had been little studied in the laboratory.

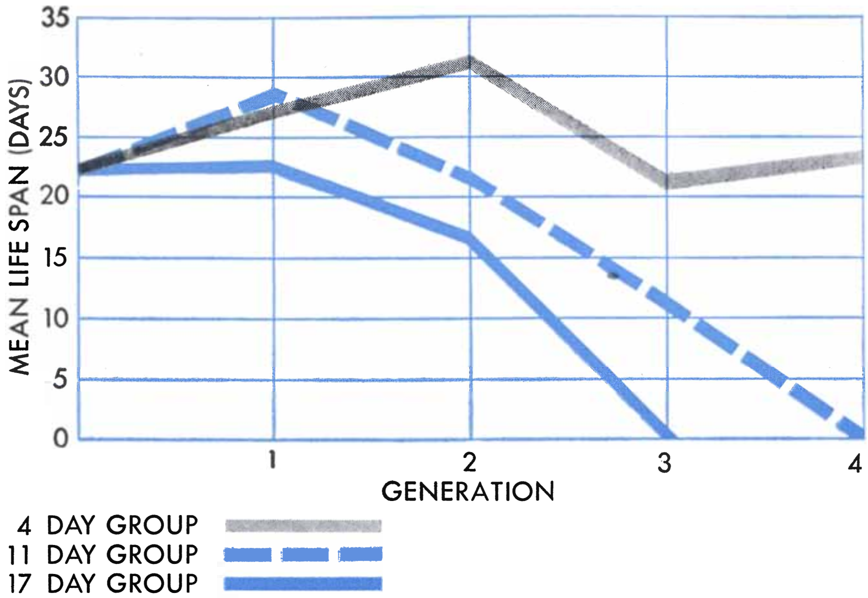
The rotifer is a common animal, found in almost any stagnant pond. It is less than a millimeter long, just barely visible to the naked eye. Although it reproduces sexually, the female's eggs do not have to be fertilized by a male; they are stimulated to divide merely by contact with pond water. Indeed, the males of most species of rotifers have never been seen, and those that have been observed have generally lacked an alimentary tract and died when about 24 hours old. Rotifers therefore can produce homogeneous populations free of genetic variations.

A relatively complex animal, the rotifer possesses a primitive brain, a light-sensitive structure comparable to an eye, a well-developed digestive tract, urinary and reproductive systems and muscle cells. Altogether it has several hundred to 1,000 cells.

The life span of most species of rotifers varies between one and four weeks. This short life is particularly attractive to a biologist who doesn't wish to grow old while waiting for his experimental animals to age. The eggs of *Philodina*, one of a group of creeping rotifers, hatch after one day at room temperature. The young grow very rapidly, begin to lay eggs on the fifth day and reach full size on the sixth day. Their vigorous adulthood generally lasts until they are 15 days old. Then senility begins to set in, and on the average they die at the age of 24 days.

To follow the complete life history of individual rotifers, we grow them separately, each in a numbered small glass depression containing artificial pond water and an abundance of food, generally algae. Here the animals have a constant environment. First, eggs from a stock of rotifers of identical genetic composition are hatched in the individual glass dishes. Then, from this starting population, we select and follow several separate lines. One line comes entirely from young mothers. As soon as the adolescent mothers have laid their first eggs, these are collected and hatched. From the new generation in turn we take the early eggs laid in adolescence and allow them to hatch. So the procedure is continued through several generations, each time selecting the eggs laid by the mothers in youth. Another line are the selected offspring of older mothers. Starting from the same original population, we hatch the eggs laid by senile mothers, select the eggs of their offspring when they in turn have become senile, and so on. In this way we grow a number of lines from mothers at various ages.

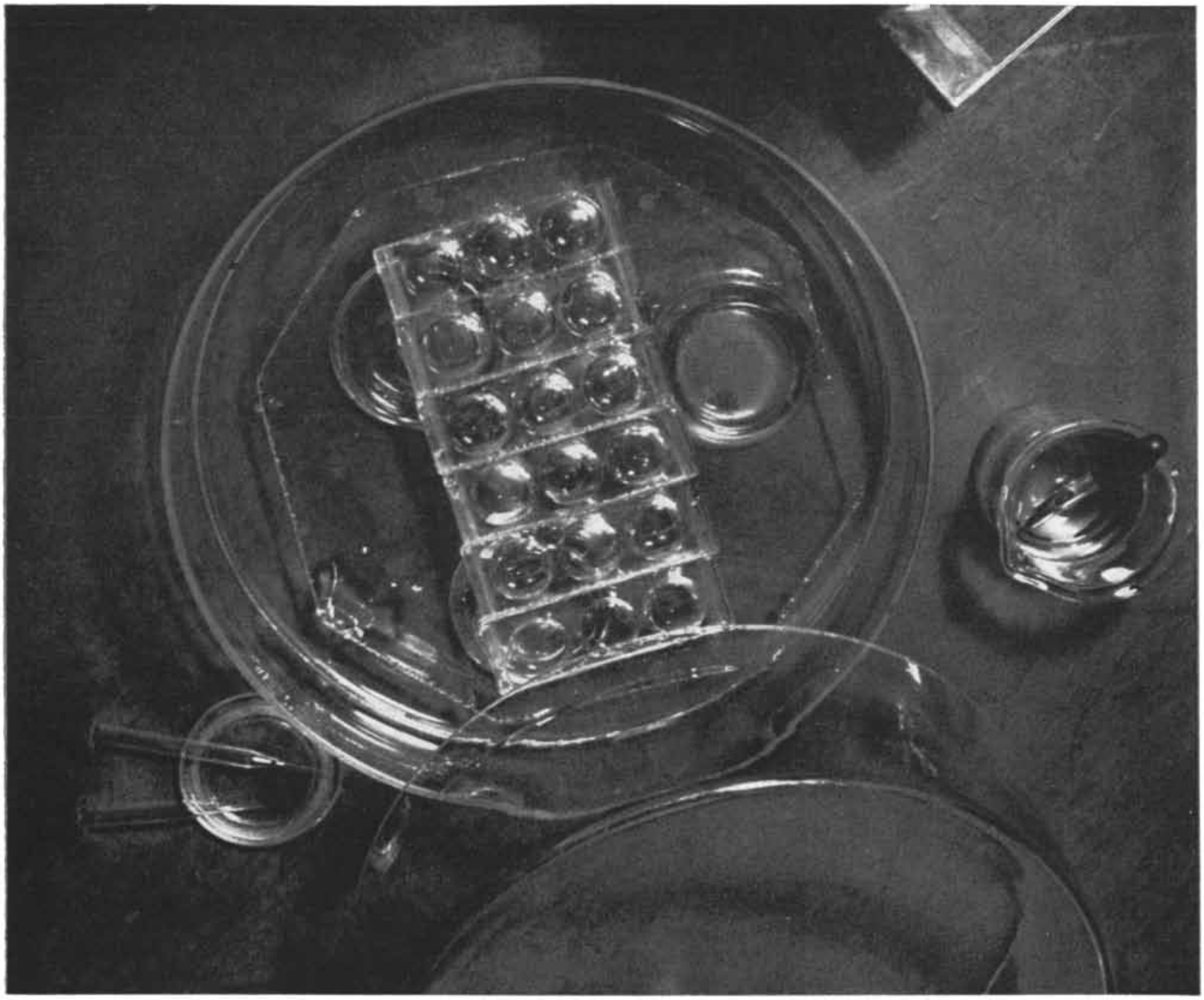
Now since all the rotifers are genetically identical and live in a constant environment, there is no reason to expect any significant difference in longevity between the various groups. Yet each successive generation of the rotifers born of old mothers showed a progressive decrease in life span, culminating in extinction of the line. For example, the mean life span of a line of rotifers from senile mothers 17 days old declined from 24 days for the original mothers to approximately 18 days in the first generation and 14 days in the second. In the third generation the eggs were nonviable. A line from less senile mothers (11 days old) declined in longevity more slowly; it took four generations to produce nonviable eggs. Even vigorous adult mothers in the eighth day of life produced lines which declined steadily and died out in eight generations. Lines derived from six-day-old mothers, just reaching full growth, showed a slow but steady decline through 17 generations.



LONGEVITY CURVES summarize respective life spans of progeny from young, middle-aged and senile mothers. Latter two lines soon became extinct.

THESE results would seem to indicate that all full-grown rotifers transmit to their eggs the capacity for accelerating aging. The capacity is cumulative, in that each successive generation ages more rapidly than the preceding. It can be reversed by the simple expedient of selecting the eggs laid when the mothers are young rather than old. Finally, it seems clear that the capacity for accelerating aging increases with age: the older the mother, the shorter the lives of the offspring. This can be shown in graphic form by plotting a curve based on the number of generations required to produce extinction of the line at various maternal ages. At six days, when the mothers are just fully grown, the curve is rising sharply. By extrapolation to five days (adolescence), the curve rises vertically to infinity. One might predict that the adolescent five-day maternal line would not contain the aging factor and thus could be maintained indefinitely.

This prediction was confirmed by experiment. A line of rotifers derived from adolescent mothers was maintained through 54 generations, at which time the experiment was discontinued. In sharp contrast to the lines from adult and old mothers, this adolescent line showed a slow but steady increase in span of life, until it reached 104 days at the end of the experiment. It appears therefore, that, as in Sonneborn's experiment with flatworms, the progeny of actively growing individuals resist aging, while the progeny of nongrowing individuals age rapidly. The experiments confirm what has been suspected for a long time: that there is some significant



ROTIFERS WERE RAISED in glass dishes with a separate niche for each animal, so that the life span of individual rotifers could be followed. Temperature and feeding were kept constant for all the subjects.

relation between the growth processes and aging.

It is, of course, much easier to speculate on this than to offer experimental data. One might suggest that growth cessation itself may set off the aging process. Such an idea was implied in McCay's experiments on rats. The rotifer experiments, indeed, go a step further in bringing up evidence on this score. In following a number of generations derived from old mothers, a curious fact was noted. Their progeny showed a small but significant speeding up of the time required to reach full size, followed in later generations by a decrease in maximal size. This suggests that the progeny of old mothers not only contain an aging factor but also increasing amounts of a growth factor, which finally reaches a level where it actually inhibits growth. Conversely, the progeny of adolescent rotifers show a progressive lengthening of the time required for full growth, and ultimately reach a point where their size is strikingly increased. Here the lack of an aging factor is correlated with the presence of less growth factor and, finally, less growth regulator.

All this suggests that aging may be connected with some specific substance. In rotifers aging mothers may accumulate a toxic material, or, on the other hand, they may progressively have less and less of some essential substance. Possibly the growth factor, growth regulator and aging factor are one and the same material, producing different physiological effects in different concentrations. Much of the results of the rotifer experiments may be explained by assuming that a single material in a low concentration behaves as a growth factor, in a higher concentration as a growth regulator or inhibitor, and in still higher concentrations as an aging factor. Some of the experiments suggest that calcium may be involved, for rotifers live much longer after calcium has been removed from their cells.

Do the findings about rotifers have any bearing on higher animals? There is some ground for believing that maternal age influences the longevity of mammals and even of human beings. Louis I. Dublin, biometrician for the Metropolitan Life Insurance Company, has noted a tendency of early-born children to live longer than late-born. A Finnish investigator, E. O. Jalavisto, analyzed the vital statistics in her homeland and reached the same conclusion. At a recent conference on aging at the New York Academy of Sciences, various workers reported that, in mammals, maternal age influences intelligence, behavior, congenital malformations, the time of opening of eyelids and several other traits.

The rotifer experiments by no means suggest a key to immortality. But they do challenge the defeatist doctrine of the inevitability of aging and encourage a quest for the biological characteristics of the aging process.

Kodak reports to laboratories on:

our cautious approach to malononitrile . . . a new approach to an old printing process . . . stripped lard and vitamin E . . . an improved technique for microradiography

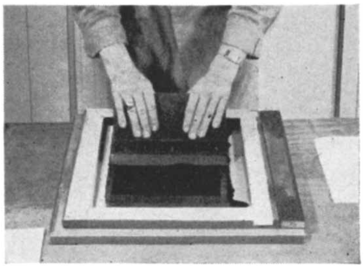
Stay off the alkaline side

We make *Malononitrile* by treating cyanoacetamide with phosphorus oxychloride to split out the water. This is a simple operation, but the chemist assigned to the job tried to make it harder by removing the last traces of acids formed in the reaction. The resulting explosions (no casualties) led to a trip to the library where we found the explanation: "Malononitrile trimerizes rapidly in the presence of alkali." This is an understatement. The heat of polymerization is given off so rapidly, the temperature goes up so fast and so far, that violent decomposition ensues and one can get soot on one's snoot if one is not careful. Our *Malononitrile* continues to come just a trace on the acidic side, and we advise utmost caution about altering this situation.

We supply more than 3500 other organic chemicals for science and industry. They're listed in Eastman Organic Chemicals List No. 38. For your copy write to Eastman Organic Chemicals Department, Distillation Products Industries, Rochester 3, N. Y.

Silk screen

Should you want to reproduce just about any kind of pattern in just about any kind of medium on just about any kind or shape of surface, you ought to look into the new Kodak Ektagraph Process. You start with an image on film or plate and some 20 minutes later Copy No. 1 is ready to dry. Your total outlay for all the equipment and supplies for a uniquely versatile printing plant that you can store in a desk drawer needn't exceed the cost of a decent pair of shoes. This represents our contribution to silk screen printing, one of the oldest forms of the art of printing, wherein the material which serves as the ink is squeezed through permeable areas in a silk screen. Specifically, our contribution is a film that can be handled by incandescent room light and incorporates its own tanning developer. After exposure and immersion in the processing solutions, the unexposed gelatin washes away in warm water, the film is placed face down and dried on the silk screen, the film base is peeled off, and the gelatin pattern dries down to block off the desired interstices in the screen. Then you're ready to print a complex circuit in silver



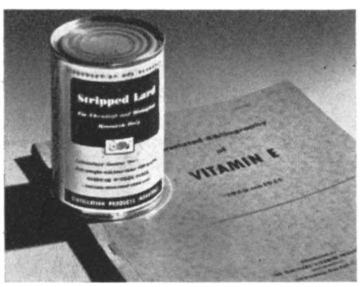
paste, an instrument dial, an illustration for a monograph, or a portrait of an ancestor on a shaving mug. Preserves fine detail, too.

Kodak Ektagraph Film is sold by Kodak Graphic Arts dealers, and full information about it is available from Eastman Kodak Company, Graphic Arts Division, Rochester 4, N. Y.

Vitamin E

The missing ingredient in the strange lard we put up in the can below is vitamin E, and its removal to less than 5 micrograms per gram of fat (accomplished by molecular distillation, a specialty of the house) is a service we perform for those who want to see what happens to creatures kept alive without vitamin E.

It so happens that we are major producers of vitamin E (obtained not from lard but from vegetable oils) for the pharmaceutical and feed industries, and thus find ourselves in the unusual position of



trafficking both in a commodity and in the absence of that same commodity. The latter, of course, is small business, but there *is* a good deal of research going on about vitamin E. Over 600 scientific papers on work in this field during 1950 and 1951 are summarized in a bibliography recently compiled in our laboratories.

Volume II, Annotated Bibliography of Vitamin E, 1950 and 1951, *is available from The National Vitamin Foundation, Inc., 150 Broadway, New York 7, N. Y. A hermetically sealed tin containing 400 grams of stripped lard is available at $2 from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Microradiography

Of the total film acreage that we produce for the finding of voids, fractures, porosities, inclusions, and other defects in man, metal, and beast, an infinitesimal fraction is used in the sub-technique of microradiography. This is in effect two-stage x-ray photomicrography: a film or plate of high resolution is exposed to x-rays through a thin specimen section and then an optical enlargement is made of the resultant radiographic image. Thus by differential x-ray absorption is revealed the distribution of various elements in the microstructure of the specimen. For accurate identification, it is helpful to employ the line-emission from the tube target, but it is not convenient to keep changing targets in order to find the sets of line-emissions desired. Furthermore the continuous spectrum plays a distracting *obbligato* to the nice, clear-cut relations of *K*-emissions and absorptions.

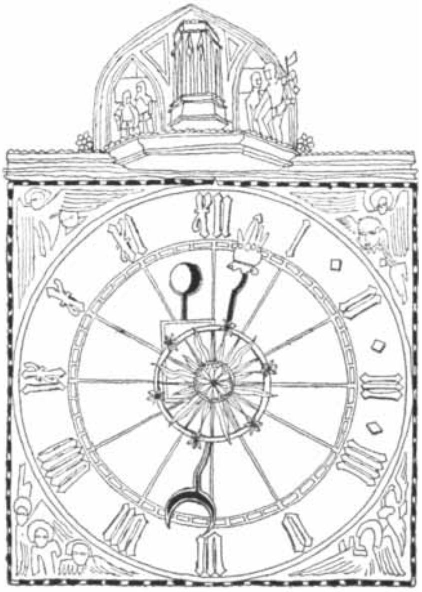
Unworried by the knowledge of how little the consumption of materials for microradiography contributes to their salaries, a few of our research people have been attacking this problem and have just put out a paper that tells how to use a variety of dependably homogeneous *K*-radiations from interchangeable x-ray fluorescence targets that you can put in an attachment for your low voltage x-ray tube.

Anyone who wants to make one like it can get a reprint from us of the paper, "Application of Fluorescence X-rays to Metallurgical Microradiography." Write X-ray Division, Eastman Kodak Company, Rochester 4, N. Y.

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

Kodak
TRADE-MARK

SCIENCE AND



End of an Observatory?

HARVARD University has decided it can no longer afford to operate its South African Observatory, Boyden Station. The station has been engaged in an important survey of the Milky Way with a new Schmidt-type telescope set up two years ago ("The Southern Sky," by Bart J. Bok; SCIENTIFIC AMERICAN, July, 1952). But it is to be closed in June, 1954, unless some other institution or financing can be found to support it. Harvard's decision was made after an outside committee of scientists headed by J. Robert Oppenheimer had surveyed the University's astronomy program and declared it overextended for its resources.

Industrial Research

LAST year the U. S. spent $3.5 billion on research and development. About two-thirds of this activity took place in industrial laboratories. Some details of the big industrial research program have just been reported by a Department of Defense survey, the first to be made in this field.

About half of the money spent on industry's research was provided by the Federal government, nearly all of it through the Defense Department and the Atomic Energy Commission. Aeronautical research was 85 per cent government-supported, electronics research 58 per cent, chemical research only 7 per cent.

The electrical machinery and aircraft industries each spent more than $400 million, the chemical and motor vehicle manufacturers more than $200 million. Some 20 companies account for about half of the total industrial expenditure. Each of these companies employs more than 1,000 professional research workers, and among them they hire more than a third of the 94,000 scientists and engineers covered by the Defense Department's survey.

Although about one fourth of these workers are subject to military draft, only three out of every 100 were actually called for duty in 1951. But the year's turnover of scientists and engineers in industry averaged 16 persons per 100 employed, mainly because of competition among companies for brain power.

Raw Materials for the U. S.

IN the past four decades the U. S. has consumed more metals than the entire world had used from the beginning of the Bronze Age to the First World War. So says the Defense Production Administration in a recent report called *Raw Materials Imports: Area of Growing Dependency*. Although the U. S. still produces far more raw materials than any other country, it is now importing 9 per cent of its total requirements. The report lists shortages in 27 important raw materials, including:

Asbestos: 95 per cent imported. Supply inadequate.

Bauxite: 65 per cent imported. Supply adequate.

Beryllium ore: 90 per cent imported. Supply very tight.

Chromium ore: 99 per cent imported. Supply inadequate.

Columbium (for high-temperature alloys): 100 per cent imported. Supply scarcer than any other alloying metal.

Copper: 35 per cent imported. Supply inadequate.

Nickel: 99 per cent imported. Supply critically short.

Tin: 100 per cent imported. Supply inadequate.

Zinc: 35 per cent imported. Supply adequate.

For Psychological Research

A FUND of $6 million for research in psychiatry, the largest sum ever made available for studies in this field, has just been set up at Yale University. Frederick C. Redlich, head of the Department of Psychiatry at Yale and chairman of the fund, hailed the grant as helping to fill a great need. "There has been insufficient research in psychiatry," he said. "Most of the money for mental health in the past has been used for much-needed mental hospitals and for treatment, leaving very little for basic research."

The fund was set up by the Social Research Foundation of New York, an organization of Yale alumni. It has a self-perpetuating board of seven directors

THE CITIZEN

which includes Redlich, Vernon Lippard, dean of the Yale School of Medicine; Charles Aring of the University of Cincinnati; John Benjamin of the University of Colorado; David Shakow of the University of Illinois; George Thorn of Harvard University and John Whitehorn of The Johns Hopkins University.

UNESCO's Science Program

FOR 1953 and 1954 the United Nations Educational, Scientific and Cultural Organization will devote about $1,335,000 of its $18 million budget to science. It will spend $800,000 on natural science and $535,000 on social science.

UNESCO's function in science is mainly to encourage governments and other organizations to undertake needed projects. It was instrumental in organizing the European Center for Nuclear Research but will not operate or support the center financially. It is now trying to organize an International Computation and Applied Mathematics Laboratory to be established in Rome.

To promote international scientific cooperation UNESCO gives financial help to scientific societies and each year makes grants for one or two special activities. This year it is supporting a symposium on oceanography.

During 1953 and 1954 it will continue its sponsorship of research on problems of arid zones and initiate new researches in problems of the humid tropical zones and in oceanography. The oceanographic studies will emphasize the development of sources of food from the sea.

To improve and expand science teaching in backward countries the organization distributes teaching manuals, audiovisual aids and plans and instructions for equipping laboratories. It has set up traveling scientific exhibitions which visit many of these countries.

Among the social science projects that will be continued in 1953 and 1954 are: publication of pamphlets against racial discrimination for teachers and students; studies on fertility changes and family structure and on differential fertility and the intelligence of the next generation; an evaluation of the effects of industrialization on African natives; studies on the educational opportunities for women in various countries.

AEC Shifts

GORDON E. DEAN has resigned as chairman of the Atomic Energy Commission, a post he has held since July, 1950. He will stay on the job until the middle of this year. Dean's resignation left two vacancies on the five-man board, the other being the place of T. Keith Glennan, who quit late last year.

When this issue of SCIENTIFIC AMERICAN went to press, the new Congress had still not been able to agree on a chairman for the Joint Congressional Committee on Atomic Energy. The Senate was determined that the chairmanship should again go to a Senator, the House equally insistent that it should be given to a Representative. Pending a decision, the acting chairman was Representative Carl T. Durham, North Carolina Democrat.

It was reported last month that President Eisenhower planned to appoint Lewis L. Strauss, a former member of the AEC, as an executive assistant to advise him on atomic energy matters.

Quiet, Please!

A NEW classification of secrecy was ferreted out last month by the syndicated newspaper columnist Marquis Childs. At the NATO Defense College of the North Atlantic Treaty countries in Paris, the most delicate matters are now classified "Cosmic Top Secret."

For External Use

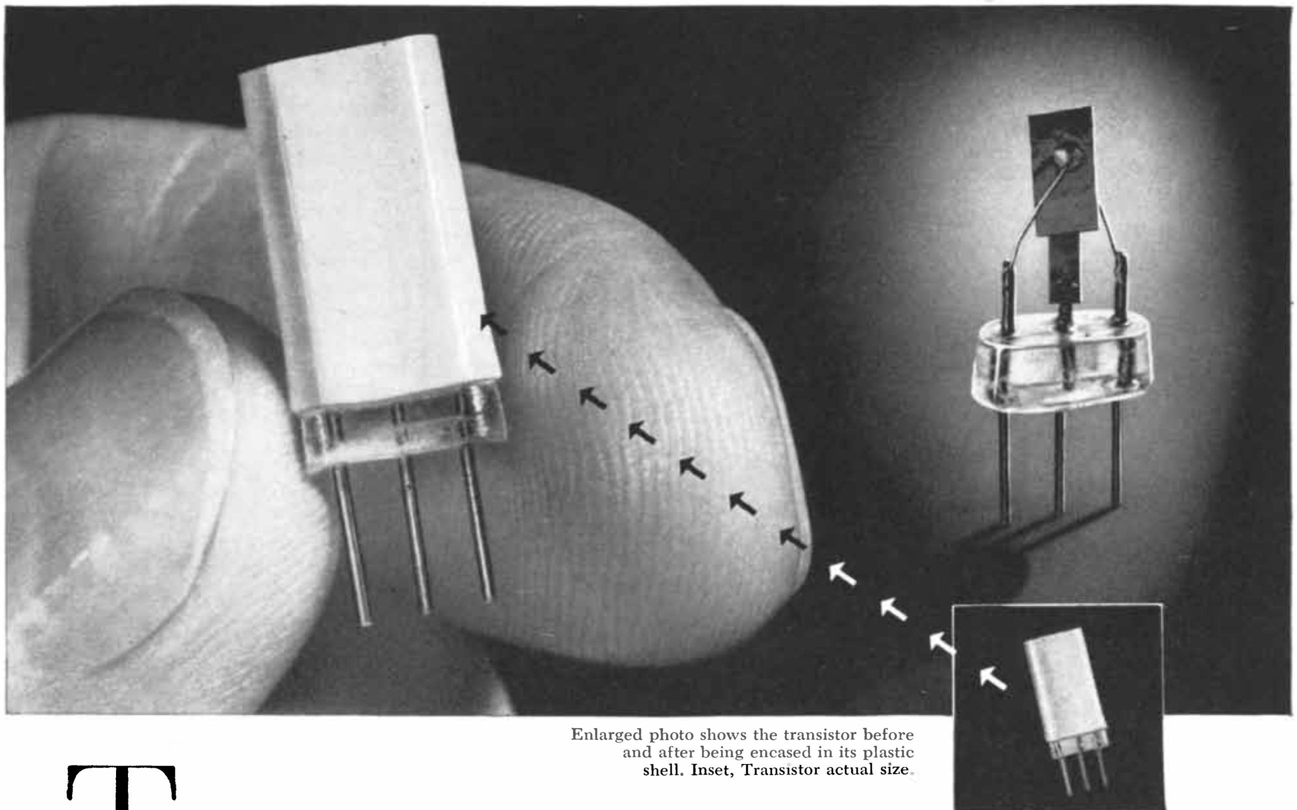
A LARGE consignment of vintage European wines is on its way to the University of Chicago. There Willard F. Libby, the originator of the radiocarbon dating method, will test the wine—not with his palate but with Geiger counters. His object: to determine its tritium content. Libby and his colleagues believe they may be able to date ancient agricultural products, including wine, by the amount of tritium they contain.

Tritium, the radioactive isotope of hydrogen, is continuously formed in the upper atmosphere by cosmic ray bombardment. It then combines with oxygen to form water. All rain contains some tritium, and growing vegetable matter should have its share of the isotope. By measuring the amount of tritium (half-life: 12.5 years) remaining in old agricultural products, it should be possible to tell how old they are. Libby plans to check his hypothesis with wines of known age.

He has started working with domestic wines. The European shipment will be available as soon as he convinces the customs officials that he is not going to drink it, and that it should therefore be admitted tax-free.

Better Spectra

A NEW spectrograph, claimed to have the highest resolving and light gathering power of any instrument in the world, has been put on the market by the Bausch & Lomb Optical Company. It uses a light-spreading element called



Enlarged photo shows the transistor before and after being encased in its plastic shell. Inset, Transistor actual size.

Transistor—

mighty mite of electronics

Increasingly you hear of a new electronic device — *the transistor.* Because of growing interest, RCA—a pioneer in transistor development for practical use in electronics—answers some basic questions:

Q: ***What is a transistor?***
A: The transistor consists of a particle of the metal germanium imbedded in a plastic shell about the size of a kernel of corn. It controls electrons in solids in much the same way that the electron tube handles electrons in a vacuum. But transistors are not interchangeable with tubes in the sense that a tube can be removed from a radio or television set and a transistor substituted. New circuits as well as new components are needed.

Q: ***What is germanium?***
A: Germanium is a metal midway between gold and platinum in cost, but a penny or two will buy the amount needed for one transistor. Germanium is one of the basic elements found in coal and certain ores. When painstakingly prepared, it has unusual electrical characteristics which enable a transistor to detect, amplify and oscillate as does an electron tube.

Q: ***What are the advantages of transistors in electronic instruments?***
A: They have no heated filament, require no warm-up, and use little power. They are rugged, shock-resistant and unaffected by dampness. They have long life. These qualities offer great opportunities for the miniaturization, simplification, and refinement of many types of electronic equipment.

Q: ***What is the present status of transistors?***
A: There are a number of types, most still in development. RCA has demonstrated to 200 electronics firms—plus Armed Forces representatives—how transistors could be used in many different applications.

Q: ***How widely will the transistor be used in the future?***
A: To indicate the range of future applications, RCA scientists have demonstrated *experimental* transistorized amplifiers, phonographs, radio receivers (AM, FM, and automobile), tiny transmitters, electronic computers and a number of television circuits. Because of its physical characteristics, the transistors qualify for use in lightweight, portable instruments.

* * *

RCA scientists, research men and engineers, aided by increased laboratory facilities, have intensified their work in the field of transistors. The multiplicity of new applications in both military and commercial fields is being studied. Already the transistor gives evidence that it will greatly extend the base of the electronics art into many new fields of science, commerce and industry. Such pioneering assures finer performance from any product or service trademarked RCA and RCA Victor.

RCA

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World leader in radio—first in television

"echelle"—a flat glass plate in which a series of comparatively deep (1/200 of an inch), stepped grooves has been cut. In contrast to a diffraction grating, with tens of thousands of machine-ruled, shallow lines to the inch, the echelle contains only about 200 cuts to the inch. They are made by hand. George R. Harrison, physicist at the Massachusetts Institute of Technology, first suggested the high dispersive power of this design.

As used in the Bausch & Lomb instrument, the echelle is crossed with a prism, so that light is dispersed in two dimensions. This gives a greater separation between adjacent wavelengths, making it possible to distinguish spectral lines separated by a fraction of an angstrom unit.

"There are perhaps 10 grating spectrographs in the world," the company states, "which can approximate the performance of the echelle spectrograph. All of these instruments have been custom-made and most have been built into large rooms with concrete piers and complicated pressure and temperature controls." The echelle spectrograph, Bausch & Lomb declares, can be used in any laboratory.

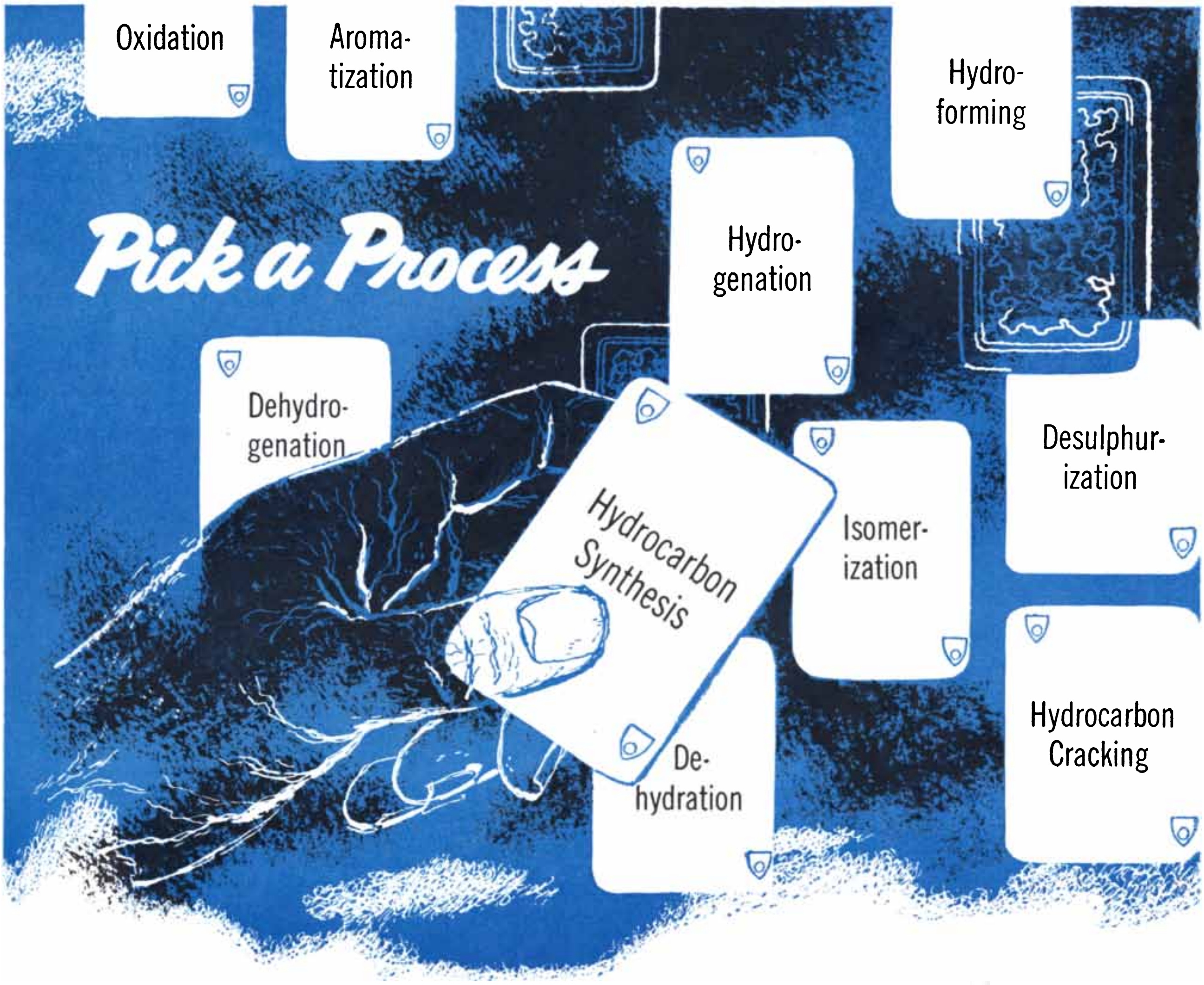
Alcoholics in Industry

ENCOURAGING results in treating problem drinkers are reported by the New York University-Bellevue Consultation Clinic for Alcoholism at the end of its first year's operation. The clinic was established in February, 1952, with financing from the Consolidated Edison Company of New York, whose employees were its first patients. Of 51 Con Edison workers treated, 41 now have their drinking under control, said Arnold Z. Pfeffer, the clinic's director.

Pfeffer observed that although it is too early to judge how many of the cures will be permanent, he expects the long-term results with this group to be better than the average in treatment of alcoholics. His patients had been employed for an average of 23 years and were caught in relatively early stages of their alcoholism. "Our experience," said S. Charles Franco, associate medical director of Consolidated Edison, "leads us to dissent from the constantly expressed opinion that an alcoholic can be helped 'only if he wants to be.' If we wait for this desire to develop, his illness may progress to a late critical stage. . . . Our Company procedure . . . brings the problem drinker to an early awareness of his illness."

The clinic tailors its treatment to individual needs. It uses individual or group psychotherapy and such drugs as antabuse. Some patients have been sent to Alcoholics Anonymous. The treatment varies from a few visits to almost daily sessions extending over months.

The clinic is an outgrowth of Consolidated Edison's own program for



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give **bigger yields . . .**

better quality

If you want to up-grade your catalytic process yields, or simply reduce losses from contamination and side reactions, you'll find it advantageous to insist on ALCOA Aluminas for your catalysts and catalyst supports.

ALCOA Aluminas—*Activated, Tabular* and *Calcined*—help produce better end products at lower costs because they permit close control over rates of reaction . . . reduce carbon-deposit difficulties . . . often lower operating temperatures.

ALCOA Aluminas are uniform in structure and chemical purity . . . stable at elevated temperatures . . . have high resistance to erosion and crushing . . . and are moderate in cost.

Let us send you further information and samples for testing in your own plant. Write to ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION, 729-D Alcoa Building, Pittsburgh 19, Pa.

See our advertisement in Refinery Catalog and Chemical Materials Catalog. For corrosion-resistant heat exchanger tubes, instrument tube, process equipment and architectural items, investigate ALCOA *Aluminum.*

Alcoa Chemicals

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handling alcoholic employees. After trying for several years to treat these cases in its own medical department, the company saw that a more complete service was needed. It then offered to underwrite the N.Y.U.-Bellevue clinic, hoping that other corporations would join later. Now the Standard Oil Company of New Jersey, the Metropolitan Life Insurance Company and the New York Telephone Company are sending patients and contributing to the clinic's support.

Milk and Malaria

MALARIA parasites are notoriously difficult to kill, but it may be possible to starve them to death. B. G. Maegraith of the Liverpool School of Tropical Medicine has found that rats fed only on milk show extremely high resistance to a rodent-malaria parasite. His experiments, reported in the *British Medical Journal*, indicate that milk lacks certain food elements necessary to the parasite.

The rats were fed both cow's milk and human milk. As good results were obtained with dried or frozen milk as with the fresh product. The *Journal* suggests that the treatment may be applicable to man. It is known that even in areas of highest incidence infants under three months rarely contract malaria. This immunity has been tentatively attributed to antibodies received from the mother before birth. It now seems possible that children are immune as long as they subsist entirely on milk. The rats at Liverpool received milk enriched with vitamins. An adult could presumably live on a similar formula—at least long enough to starve out the malaria parasites in his system.

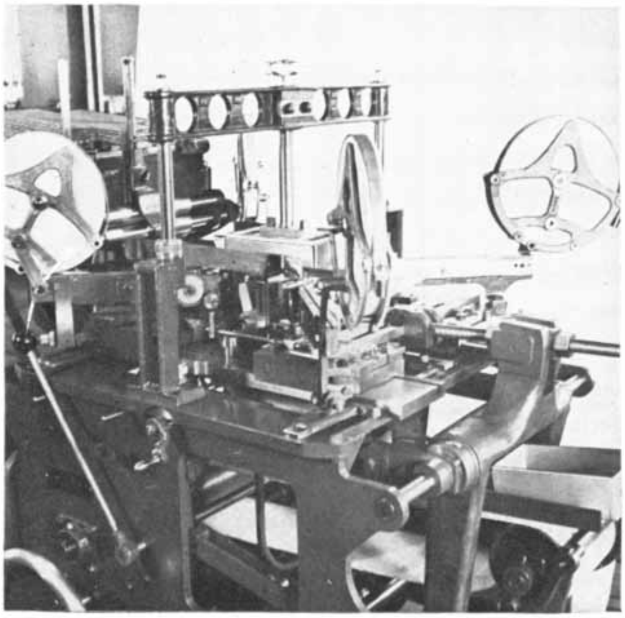
Long-Wave Seismograph

NEW evidence that the earth's core is liquid has been reported by W. Maurice Ewing and Frank Press, of Columbia University's Lamont Geological Laboratories. With an improved seismograph of their own design they have been exploring the core by means of earthquake waves that travel around it rather than through it.

Explaining the procedure, the geologists compared earthquake waves with water waves. An ocean wave traveling toward the shore undulates regularly until it reaches the shallow shelf. There it begins to "feel" the bottom and to change its behavior. But a deeper wave can feel a deeper bottom. In the case of earthquake waves, an ordinary seismograph can detect only ripples—100 miles long at most. The new Columbia instrument records waves more than 1,000 miles in length, and these can feel the earth's core 2,000 miles down.

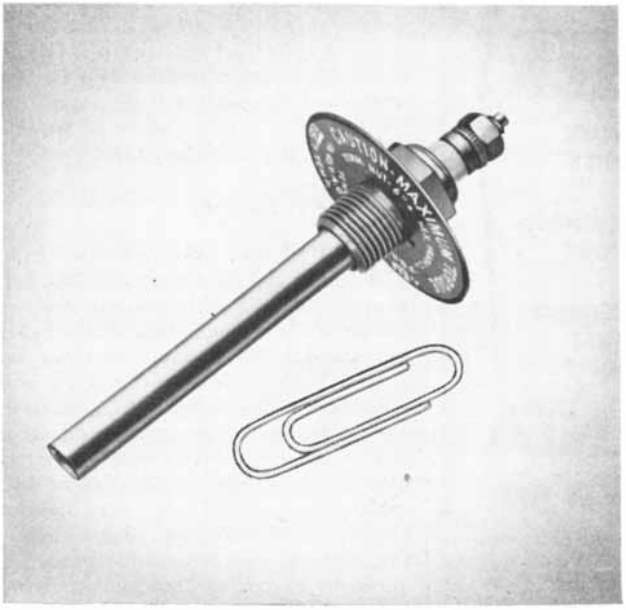
They have concluded that the core is liquid because the long waves with which they are probing it do not gain in

Mighty Midget THERMOSWITCH® Unit bosses temperature in tight spots

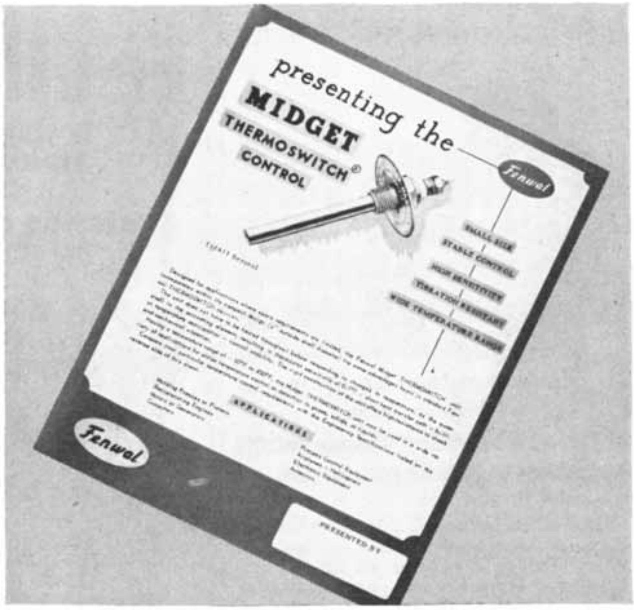


1. THE HEAT'S ON in this box making machine — heat-sealing box corners. Speed of boxes passing through determines desired temperature. Four Fenwal Midget THERMOSWITCH units control the four heaters precisely — yet must do their work in very tiny space. Only Fenwal Midgets could do it!

2. SHOULD OVERHEAT OCCUR in this transport plane's cabin heater the Fenwal Midget THERMOSWITCH Thermostat would detect it instantly and positively. It snuggles into a tiny space — the heating system's fuel accessories box; measures only ¼″ diameter by 3⅛″ but does its job like a Marine.



3. THE SHELL TELLS ALL on a Fenwal THERMOSWITCH because the shell itself is the heat-sensitive element. It expands or contracts instantly when a temperature change occurs, opening or closing electrical contacts. It is rugged, resistant to corrosion and vibration, compact and always dependable. This is why they are in use on so many control and safety devices.



4. FOR FREE BULLETIN on Fenwal Midget THERMOSWITCH units just write. It gives detailed information and engineering specifications on this new versatile THERMOSWITCH unit for use in confined spaces. Fenwal engineers are glad to assist on your application problems. **Write Fenwal Incorporated, 304 Pleasant St., Ashland, Mass.**

Fenwal

THERMOSWITCH®

Electric Temperature Control and Detection Devices

SENSITIVE . . . *but only to heat*

speed with increases in wavelength.

"If the center of the earth were solid," they explain, "velocity should increase with wavelength as the transmitting medium becomes more dense."

The new seismograph was finished about a year ago but could not be tested until last November because there were no earthquakes strong enough to send out 1,000-mile waves. Then came a violent quake in Siberia. When tuned in on the shock wave, the seismograph proved so sensitive that it continued to pick them up after they had gone eight times around the globe, 182,000 miles.

Preserving Blood

When plasma is prepared from whole blood, the separated red cells are thrown away because there is no way of preserving them. This enormous waste may soon be corrected. Scientists in the U. S. and in England have nearly perfected a way to freeze red blood cells so that they may be stockpiled for long periods, just as plasma is.

Frozen blood cells ordinarily burst on thawing. The new trick is to impregnate them with glycerin before freezing them. Apparently this avoids formation of ice crystals. Glycerin-treated cells have been kept frozen for many months and, when thawed and transfused into experimental subjects, a high percentage have survived in the bloodstream for about as long as fresh cells.

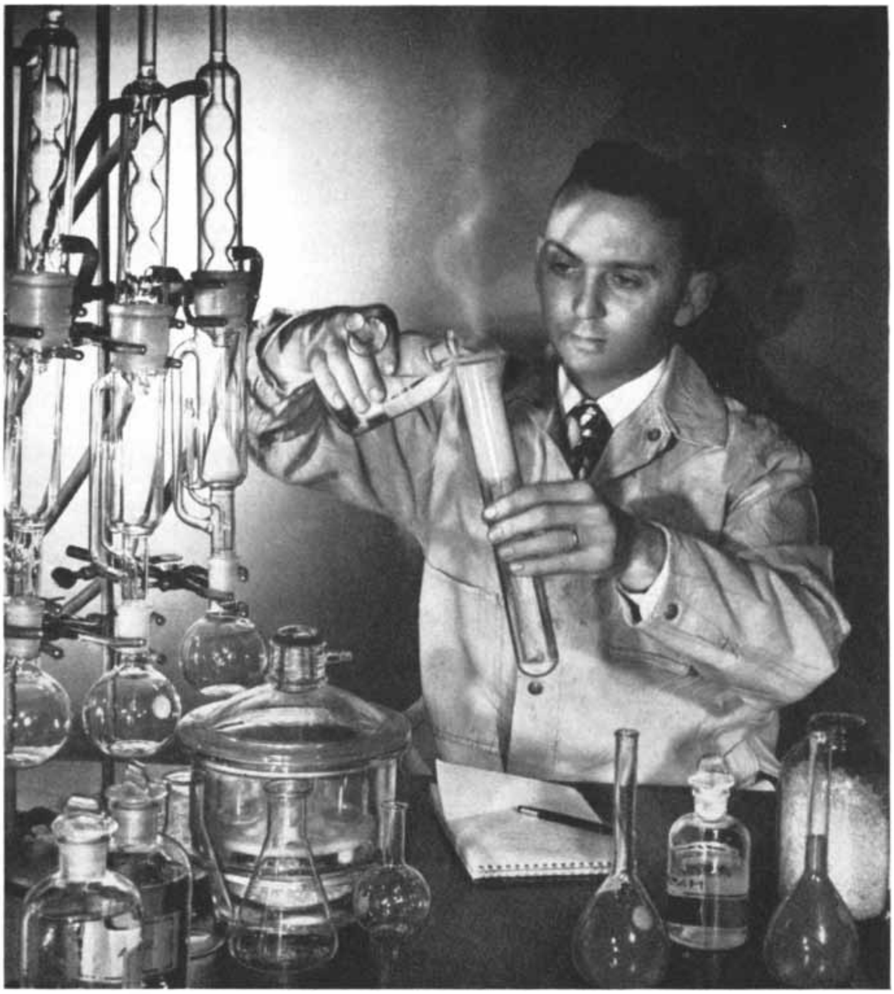
One problem remains to be solved before the method becomes practicable for large-scale application. The present method of removing the glycerin from the thawed cells, by a series of osmotic diffusions, is clumsy and slow.

Fungus v. *Fungus*

Most of the antibiotics come from fungi that fight bacteria. Now Selman Waksman's laboratory at Rutgers University has found a fungus that fights fungi, and it shows promise as a weapon against fungus diseases. Tried on animals and in test tubes, the substance, named candicidin, has proved effective against such important fungi as *Histoplasma capsulatum* (responsible for histoplasmosis). Candicidin was discovered by a research team, under Hubert Lechevalier, who were looking for an antibiotic to combat Dutch elm disease. Its effectiveness against this blight is still to be determined, but the scientists are now more interested in its possibilities for treating human infections. Whether its toxicity is low enough remains to be determined.

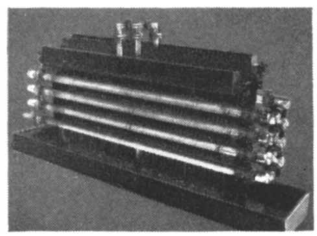
First Bone

A human rib that probably belonged to a Folsom man was recently dug up by an amateur archaeologist on a New Mexico ranch. If authentic, it



Because glass always looks new, it's a natural for consumer products of all kinds. Let Corning engineers work with your engineers on your new lines.

The right use of glass can do a lot to improve product performance. Glass pump housings and impellers, once thought impossible, now take hot corrosives in stride much to the relief of chemical engineers.



Users of PYREX brand heat exchangers get *double economy from glass.* They can use low-cost sea or river water as a coolant. They assure extra-long service life.

Glass passes this acid test every day

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is the first bone of these early prehistoric Americans to be found. Until now Folsom man has been known only indirectly from his stone implements, particularly the flint points he used as spear tips.

Oscar Shay, the amateur digger, found a Folsom point among the bones of a huge, prehistoric wolf in the New Mexico site. Digging further, he came on the rib. He took it to Frank C. Hibben, University of New Mexico archaeologist, who identified it as human and probably from a Folsom man. Hibben hopes to find more of the skeleton by further digging.

Paradox

A MAN is sentenced to be executed. "You will be hanged at noon on one of the next seven days," the judge tells him, "but you will not know which day it is to be until you are told at nine o'clock on the morning of the hanging." The man is led away to his cell, where he begins to wonder how many days he has left on earth. At length he smiles broadly and lies down to an untroubled sleep. He has figured out that, under the terms of his sentence, he cannot be hanged at all.

"They can't hang me on the seventh day," he reasons, "because if I don't hear anything by nine o'clock on the sixth morning I will then know that I am to be hanged the next day, and this violates the conditions. This leaves only six days. But, by the same reasoning, it can't be the sixth day, nor, come to think of it, the fifth, fourth, third or second. So it must be tomorrow. But it can't be tomorrow because I would already know it today."

This "paradox" is discussed by the Harvard University philosopher W. V. Quine in a recent issue of the British journal *Mind*. Is there a fallacy in the argument, and, if so, where? Is it in the same class with the paradoxes that have been plaguing logicians since Aristotle? (If the barber shaves everyone in town who does not shave himself, who shaves the barber?) Quine holds that the hanging case is not a true paradox.

He points out that the condemned man assumes temporarily, for the purposes of the argument, that the decree will be carried out, and then arrives at the conclusion that it will not be. Quine argues that both possibilities must be taken into account at the beginning, and the man should have reasoned: "We must distinguish four cases: first, that I shall be hanged tomorrow noon and I know it now (but I do not); second, that I shall be unhanged tomorrow noon and know it now (but I do not); third, that I shall be unhanged tomorrow noon and do not know it now, and fourth, that I shall be hanged tomorrow noon and do not know it now. The latter two alternatives are the open possibilities, and the last of all would fulfill the decree."

FIELD THEORY

The physicist speaks of classical fields and quantum fields. Exactly what are they, and what is their role in modern physics and in our present view of reality?

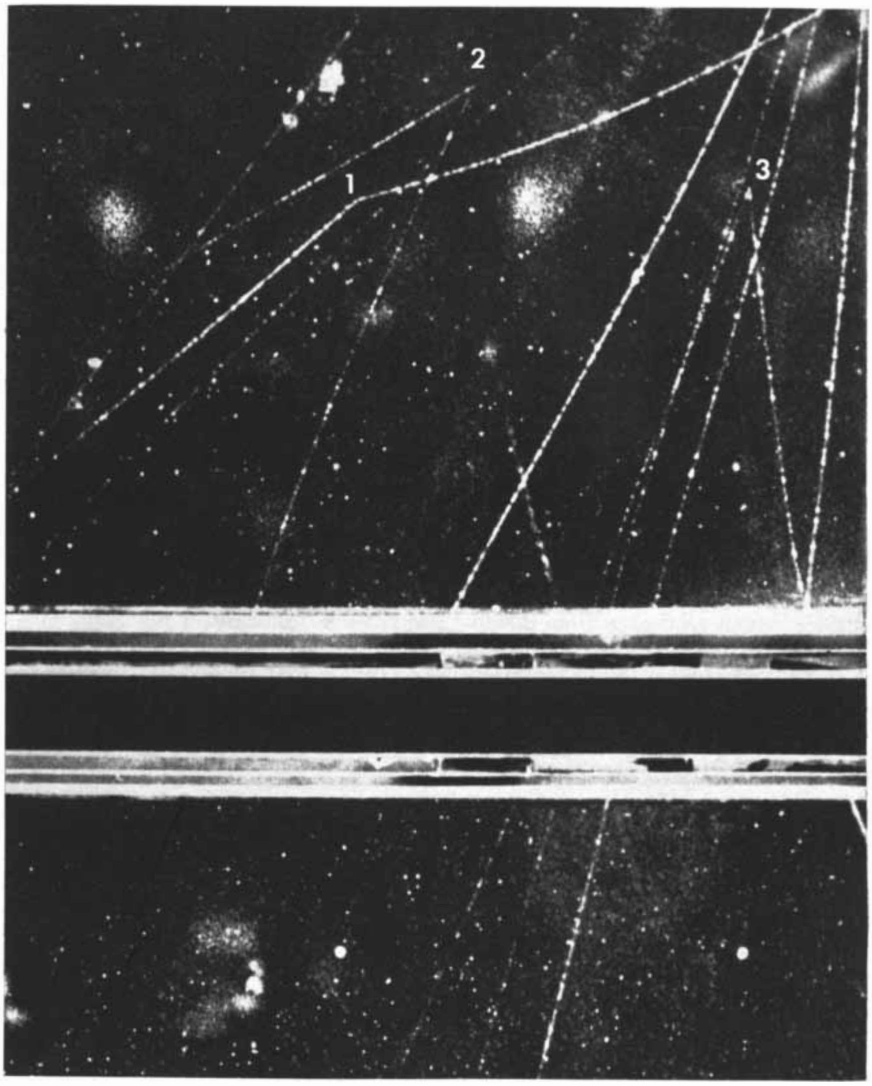
by Freeman J. Dyson

"IT IS perhaps surprising that no new meson was reported during the symposium, though almost a month had passed since a previous meeting of nuclear physicists in Copenhagen."

This learned joke in the British journal *Nature*, commenting on an international physics conference last summer, sums up very well the present chaotic situation in theoretical physics. We have become accustomed during the last few years to the discovery of new particles. About 20 different kinds are now known. Everybody expects that many more will be discovered as experimental techniques are improved. Yet nobody has had any success in classifying the known particles, or in predicting the properties of unknown ones. Nobody understands why such and such particles exist, why they have the particular masses that are observed or why some of them strongly interact and some do not.

How do the theoretical physicists spend their time, if they are not able to attack the fundamental problem of the nature of elementary particles? Of what use can the existing atomic theories be, if they do not throw light on this basic problem? These awkward questions are asked rather frequently when experimental and theoretical physicists come together. I shall try to answer them and to explain why we theoretical physicists believe that our theories are useful even though there is so much we do not understand.

First it is necessary to make one point clear: there *is* an official and generally accepted theory of elementary particles, known as the "quantum field theory." While theoretical physicists often disagree about the finer details of the theory, and especially about the way in which it should be applied to practical problems, the great majority of them agree that the theory in its main features is correct. The minority who reject the theory, although led by the great names of Albert Einstein and P. A. M. Dirac, do not yet have any workable alternative to put in its place. In this article I shall adopt the point of view of the majority. When I talk about the concept of field, I mean specifically the concept as it is used in the present-day official quantum field theory. The majority believes that this concept is so useful and illuminating that it will survive the changes and revolutions which the theory will inevitably undergo in the future. Henceforward I shall omit the phrase "in the



NEUTRAL V-PARTICLES gave rise to the three V-shaped tracks in this cloud-chamber photograph by R. B. Leighton of the California Institute of Technology. Below the center of the photograph is the edge of a lead plate.

opinion of the majority," or "in my opinion," which strictly ought to stand at the beginning of every sentence.

A Descriptive Theory

It is important to make a second general remark about the theory at the outset. This concerns the failure of the theory to give us an understanding of why the observed elementary particles exist and no others. The point is that the theory is in its nature descriptive and not explanatory. It describes how elementary particles behave; it does not attempt to explain why they behave so. To draw an analogy from a familiar branch of science, the function of chemistry as it existed before 1900 was to describe precisely the properties of the chemical elements and their interactions. Chemistry described how the elements behave; it did not try to explain why a particular set of elements, each with its particular properties, exists. To answer the question "why," completely new sciences were needed: atomic and nuclear physics. Looking backward, it is now clear that 19th-century chemists were right to concentrate on the "how" and to ignore the "why." They did not have the tools to begin to discuss intelligently the reasons for the individualities of the elements. They had to spend a hundred years building up a good quantitative descriptive theory before they could go further. And the result of their labors—the classical science of chemistry—was not destroyed or superseded by the later insight that atomic physics gave.

The quantum field theory treats elementary particles just as 19th-century chemists treated the elements. The theory starts from the existence of a specified list of elementary particles, with specified masses, spins, charges and specified interactions with one another. All these data are put into the theory at the beginning. The purpose of the theory is simply to deduce from this information what will happen if particle A is fired at particle B with a given velocity. We are not yet sure whether the theory will be able to fulfill even this modest purpose completely. Many technical difficulties have still to be overcome. One of the difficulties is that we do not yet have the complete list of elementary particles. Nevertheless the successes of the theory in describing experimental results have been striking. It seems likely that the theory in something like its present form will describe accurately a very wide range of possible experiments. This is the most that we would wish to claim for it.

Our justification for concentrating attention so heavily on the existing theory, with its many arbitrary assumptions, is the belief that a working descriptive theory of elementary particles must be established before we can expect to reach a more complete understanding at a deeper level. The numerous attempts to by-pass the historical process, and to understand the elementary particles on the basis of general principles without waiting for a descriptive theory, have been as unsuccessful as they were ambitious. In fact, the more ambitious they are, the more unsuccessful. These attempts seem to be on a level with the famous 19th-century attempts to explain atoms as "vortices in the ether."

Classical Fields

Physicists talk about two kinds of fields: classical fields and quantum fields. Actually we believe that all fields in nature are quantum fields. A classical field is just a special large-scale manifestation of a quantum field. But since classical fields were discovered first and are easier to understand, it is necessary to say what we mean by a classical field first, and go on to talk about quantum fields later.

A classical field is a kind of tension or stress which can exist in empty space in the absence of matter. It reveals itself by producing forces, which act on any material objects that happen to lie in the space the field occupies. The standard examples of classical fields are the electric and magnetic fields, which push and pull electrically charged objects and magnetized objects respectively. Michael Faraday discovered that these two fields also exert effects on each other. He found that a changing magnetic field produces electric forces (an effect now known as induction), and his finding made possible the development of practical electric generators. Later the exact laws of behavior of electric and magnetic fields were formulated mathematically by James Clerk Maxwell. He found that in any space where a changing magnetic field exists, an electric field must exist also, and *vice versa*. In order to describe completely the state of the fields in a given region of space, it is necessary to specify the strength and the direction of both the electric and magnetic fields at every point of the region separately. This is the characteristic mathematical property of a classical field: it is an undefined something which exists throughout a volume of space and which is described by sets of numbers, each set denoting the field strength and direction at a single point in the space.

Maxwell was the first to realize that electric and magnetic fields could exist not only near charges and magnets but also in free space completely disconnected from material objects. From his equations he deduced that in empty space such fields would travel with the velocity of light. Hence he made the epoch-making guess that light consists of traveling electromagnetic fields. We now know that his guess was correct, and we are even able to manufacture traveling electromagnetic fields ourselves and use them for various purposes. These artificial traveling fields we call radio.

Another example of a classical field is the gravitational field. This has the special property that it acts on all material objects in a given region of space. It is very difficult to experiment with, because the gravitational field produced by any object of convenient laboratory size is absurdly weak. For this reason we have never been able to detect any effects of freely traveling gravitational waves, which presumably exist in the neighborhood of a rapidly oscillating mass. It is also impossible to measure any possible interactions of the gravita-

NAME	SYMBOL
PHOTON	γ
GRAVITON	G
NEUTRINO	ν
ELECTRON	e
POSITRON	p
POSITIVE MU MESON	μ^+
NEGATIVE MU MESON	μ^-
NEUTRAL PI MESON	π^0
POSITIVE PI MESON	π^+
NEGATIVE PI MESON	π^-
ZETA MESON?	ζ
NEUTRAL V-PARTICLE	V_2^0
TAU MESON	τ
KAPPA MESON	κ
POSITIVE CHI MESON	χ^+
NEGATIVE CHI MESON	χ^-
PROTON	P
NEUTRON	N
NEUTRAL V-PARTICLE	V_1^0
POSITIVE V-PARTICLE?	V^+

CHART of the fundamental particles has been revised since a similar chart appeared in this magazine for

HARGE	MASS	SPIN	STATISTICS	LIFETIME (SECONDS)	DECAY SCHEME
0	0	1	BOSE-EINSTEIN	STABLE	
0	0	2	BOSE-EINSTEIN	STABLE	
0	0	½	FERMI-DIRAC	STABLE	
—	1	½	FERMI-DIRAC	STABLE	
+	1	½	FERMI-DIRAC	STABLE	
+	210	½	FERMI-DIRAC	2.1×10^{-6}	$\mu^+ \rightarrow p + 2\nu$
—	210	½	FERMI-DIRAC	2.1×10^{-6}	$\mu^- \rightarrow e + 2\nu$
0	265	0	BOSE-EINSTEIN	10^{-15}	$\pi^0 \rightarrow 2\gamma$
+	276	0	BOSE-EINSTEIN	2.6×10^{-8}	$\pi^+ \rightarrow \mu^+ + \nu$
—	276	0	BOSE-EINSTEIN	2.6×10^{-8}	$\pi^- \rightarrow \mu^- + \nu$
±	550	?	?	10^{-12}	$\zeta \rightarrow \pi + ?$
0	850	?	?	10^{-10}	$V_2^0 \rightarrow \pi^+ + \pi^- + ?$
±	975	?	BOSE-EINSTEIN	10^{-8}	$\tau \rightarrow 3\pi$
±	1100	?	?	?	$\kappa \rightarrow \mu + ?$
+	1400	?	?	10^{-9}	$\chi^+ \rightarrow \pi^+ + ?$
—	1400	?	?	10^{-9}	$\chi^- \rightarrow \pi^- + ?$
+	1836	½	FERMI-DIRAC	STABLE	
0	1838.5	½	FERMI-DIRAC	750	$N \rightarrow P + e + \nu$
0	2190	?	FERMI-DIRAC	3×10^{-10}	$V_1^0 \rightarrow P + \pi^-$
+	2200	?	?	10^{-9}	$V^+ \rightarrow P + ?$

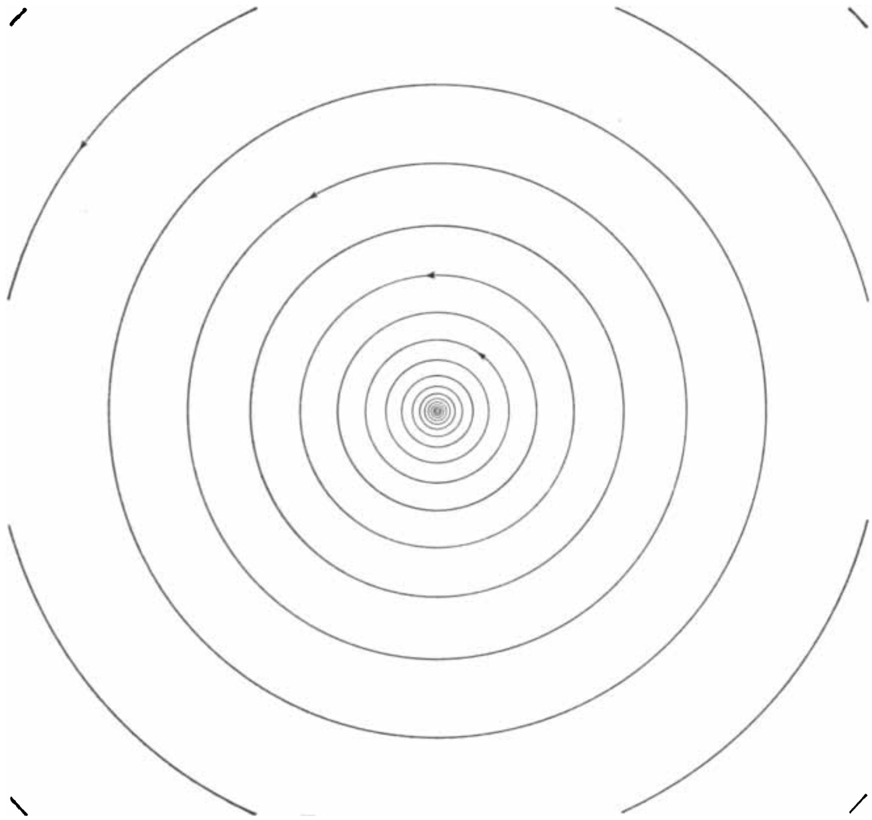
January, 1952. Among the changes are the addition of the chi mesons and a second variety of neutral V-particle. The particles are listed in the order of their mass. The existence of the zeta meson and the positive V-particle is doubtful. The masses and the lifetimes of all the newer particles listed in the chart are approximate.

tional and electromagnetic fields. This is most unfortunate, and it is the main reason why we know so much less about gravitation than about the other fields.

A Model of a Field

What, then, is the picture we have in mind when we try to visualize a classical field? Characteristically, modern physicists do not seriously try to visualize the objects they discuss. In the 19th century it was different. Then it seemed that the universe was built of solid mechanical objects, and that to understand an electric field it was necessary to visualize the field as a mechanical stress in a material substance. It was possible, indeed, to visualize electric and magnetic fields in this way. To do so men imagined a material substance called the ether, which was supposed to fill the whole of space and carry the electric and magnetic stresses. But as the theory was developed, the properties of the ether became more and more extraordinary and self-contradictory. Einstein in 1905 finally abandoned the ether and proposed a new and simple version of the Maxwell theory in which the ether was never once mentioned. Since 1905 the idea that everything in the universe should be visualized mechanically has gradually become ridiculous. We now find that mechanical objects themselves are composed of atoms held together by electric fields, and therefore it makes no sense to try to explain the electric fields in terms of mechanical models.

It is still convenient sometimes to make a mental picture of an electric field. For example, we may think of it as a flowing liquid which fills a given space and which at each point has a certain velocity (strength) and direction of flow. But nobody nowadays imagines that the liquid really exists or that it explains the behavior of the field. The flowing liquid is just a model—a convenient way to express our knowledge about the field in concrete terms. It is a good model only so long as we remember not to take it too seriously. We must not, for example, expect that the equations of motions of the electric field will be the same as those of any self-respecting liquid. To a modern physicist the electric field is a fundamental concept which cannot be reduced to anything simpler. It is a unique something with a



CLASSICAL FIELD is schematically depicted as a series of concentric rings around a point. These rings might show the magnetic field around an electric current traveling along a wire perpendicular to the surface of this page.

set of known properties, and that is all there is to it. This being understood, the reader may safely think of the flowing liquid as a fairly accurate representation of what we mean by a classical electric field. The electric and magnetic fields must then be pictured as two different liquids, both filling the whole of space, moving separately and interpenetrating each other freely. At each point there are two velocities, representing the strengths of the electric and magnetic components of the total electromagnetic field.

It is characteristic of a classical field that its strength at a given point varies smoothly as the point moves around in space. Therefore the liquid model must be imagined as an ideal liquid, not composed of atoms but filling all space uniformly and having a well-defined velocity at every point.

The new idea that Einstein introduced in 1905, and that killed the ether, was the principle of relativity. This principle states that the properties of empty space are always the same, regardless of the velocity with which an experimenter is moving through it. Thus even if there is a material ether filling space, the experimenter is unable to measure the velocity of himself relative to it; for all practical purposes the ether is unobservable. All that we can certainly say about it is that if it does exist, it is of no interest to us. Our picture of the world becomes much simpler if we abandon the ether and speak only about electric and magnetic fields in empty space.

Einstein made a complete theory of the classical electromagnetic field and its interactions with matter, using the principle of relativity as his starting point. In 1916 he extended the idea of relativity to construct his theory of the classical gravitational field. These theories stand today substantially as Einstein left them.

The classical field theories of Einstein—electromagnetic and gravitational—together give us a satisfactory explanation of all large-scale physical phenomena. That is to say, they explain everything in the physical world that can be explained without bringing into view the fact that the world is built of elementary particles. There is every reason to believe that the classical field theories are correct so long as we are talking about objects much bigger and heavier than a single atom. But they fail completely to describe the behavior of individual atoms and particles. To understand the small-scale side of physics, physicists had to invent quantum mechanics and the idea of a quantum field.

Quantum Fields

Unfortunately the quantum field is even more difficult to visualize than the classical field. The basic axiom of quantum mechanics is the uncertainty principle. This says that the more closely we look at any object, the more the object is disturbed by our looking at it, and the less we can know about the subsequent state of the object. Another less precise way of expressing the same principle is this: All objects of atomic size fluctuate continually; they cannot maintain a precisely defined position for a finite length of time. Their quantum fluctuations are never precisely predictable, and the laws of quantum mechanics tell us only the statistical behavior of the fluctuations when averaged over a long time. The universal existence of these fluctuations, and the general correctness of the laws of quantum mechanics, have been verified by a wealth of experiments during the last 30 years.

How do the quantum fluctuations affect the classical field? The answer is: not at all. The fluctuations are not observable with any ordinary large-scale equipment, for they average out to produce no effect on these instruments. Looked at with large-scale apparatus, the quantum field behaves exactly like a classical field. Only when we measure the effects of an electromagnetic field on a single atom do the quantum fluctuations of the field become noticeable.

The physicists Willis Lamb and Robert C. Retherford at Columbia University have observed the effects of electromagnetic fields on single hydrogen atoms with a piece of apparatus known to radar experts as a microwave cavity resonator [see "Radio Waves and Matter," by Harry M. Davis; SCIENTIFIC AMERICAN, September, 1948]. Using the techniques of microwave spectroscopy, they were able to measure the effects of the fields with great accuracy. The effect of the quantum fluctuations, itself a small part of the total effect of the fields, was measured to an accuracy better than one part in a thousand, and within this margin of possible error the effect agreed with the conclusions of the quantum field theory. The Lamb-Retherford experiment is the strongest evidence we have for believing that our picture of the quantum field is correct in detail.

At the risk of making some professional quantum theoreticians turn pale, I shall describe a mechanical model which may give some idea of the nature of a quantum field. Imagine the flowing liquid which served as a model for a classical electric field. But suppose that the flow, instead of being smooth, is turbulent, like the wake of an ocean liner. Superimposed on the steady average motion there is a tremendous confusion of eddies, of all different sizes and overlapping and mingling with one another. In any small region of the liquid the velocity continually fluctuates, in a more or less random way. The smaller the region, the wilder and more rapid are the velocity fluctuations. In a real liquid these fluctuations are finally limited by two factors: (1) the viscosity, or stickiness, of the liquid, which damps out the turbulent motions, and (2) the atomic structure of the liquid, which sets a minimum size for the eddies, since it is meaningless to talk about eddies containing only a few atoms. In our model of the quantum field, however, we assume that neither of these factors operates. There is no dissipation of energy by viscosity, or any minimum size of eddies. Consequently the velocity in a given region can continue to fluctuate without diminution forever, and the fluctuations grow more and more intense without limit as the size of the region is reduced.

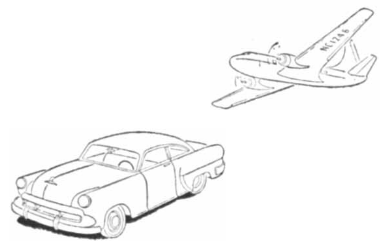
The model does not describe correctly the detailed quantum-mechanical properties of a quantum field; no classical model can do that. But it does seem to me to give a reasonably valid picture of the general appearance of the thing. In particular, the model makes clear that it is strictly meaningless to speak about the velocity of the liquid at any specific point. The fluctuations in the neighborhood of the point become infinitely large as the neighborhood becomes smaller, and so the velocity at the point itself has no meaning. The only quantities that have meaning are averaged velocities, taken over a given region of space and over a given time interval. This property of the model is a true representation of a property of a quantum field. The strength of a quantum field at a point can never be measured. The whole quantum field theory is a theory of the behavior of field strengths averaged over finite regions of space and time.

The Particles Emerge

Now comes the climax of the story. We have put into the theory of the quantum field two big ideas: the idea of quantum mechanics and the idea of relativity. These two ideas force us to construct a mathematical theory which in its main lines is fixed; the only freedom left to us is in matters of detail. When we deduce the consequences of this mathematical theory, we find that a miracle has occurred: automatically there emerges a third big idea—that the world is built of elementary particles.

This idea is a consequence of the fact that in a quantum field energy can exist only in discrete units, which we call quanta. When we work out the theory of these quanta in detail, we find that they have precisely the properties of the elementary particles that we observe in the world around us.

It is not possible, in an article such as this, to explain how the elementary particles arise mathematically out of the fluctuations of a field. It cannot be understood by thinking about turbulent liquids or any classical model. All I can say here is that it happens. And it is the basic permanent reason for believing that the concept of a quantum field is a



valid concept and will survive any changes that may later be made in matters of detail.

The picture of the world that we have finally reached is the following: Some 10 or 20 qualitatively different quantum fields exist. Each fills the whole of space and has its own particular properties. There is nothing else except these fields; the whole of the material universe is built of them. Between various pairs of the fields there are various kinds of interaction. Each field manifests itself as a type of elementary particle. The particles of a given type are always completely identical and indistinguishable. The number of particles of a given type is not fixed, for particles are constantly being created or annihilated or transmuted into one another. The properties of the interactions determine the rules for creation and transmutation of particles.

In this picture of the world the electromagnetic field appears on an exactly equal footing with the other fields. The particle corresponding to it is the light quantum, or photon. The photon appears to be different from other elementary particles only because its laws of interaction make it especially easy to create and annihilate. So the photon appears to be less permanent than, for example, the electron. But this is only a difference of degree; all particles, including the electron, can be rapidly annihilated under suitable conditions.

The elementary particle corresponding to the gravitational field has been named the graviton. There can be little doubt that in a formal mathematical sense the graviton exists. However, nobody has ever observed an individual graviton. Because of the extreme weakness of the gravitational interaction, in practice only large masses produce observable gravitational effects. In the case of large masses, the number of gravitons involved in the interaction is very large, and the field behaves like a classical field. Consequently, many physicists believe that the individual graviton never will be observed. Whether the graviton has a real existence is one of the most important open questions in physics.

The electromagnetic and gravitational fields have one essential property in common. They are long-range fields which make their effects felt over great distances. This is connected with the fact that the photon and the graviton are particles which have no rest-mass and always travel at a fixed velocity—the velocity of light. Almost all other fields in nature have a short range, less than the size of an atom, and their effects cannot be felt beyond this distance. The short-range fields cannot be detected in a classical way by measuring their effects on large objects. They never behave like classical fields in any experimental situation. This is why, for example, the field corresponding to the

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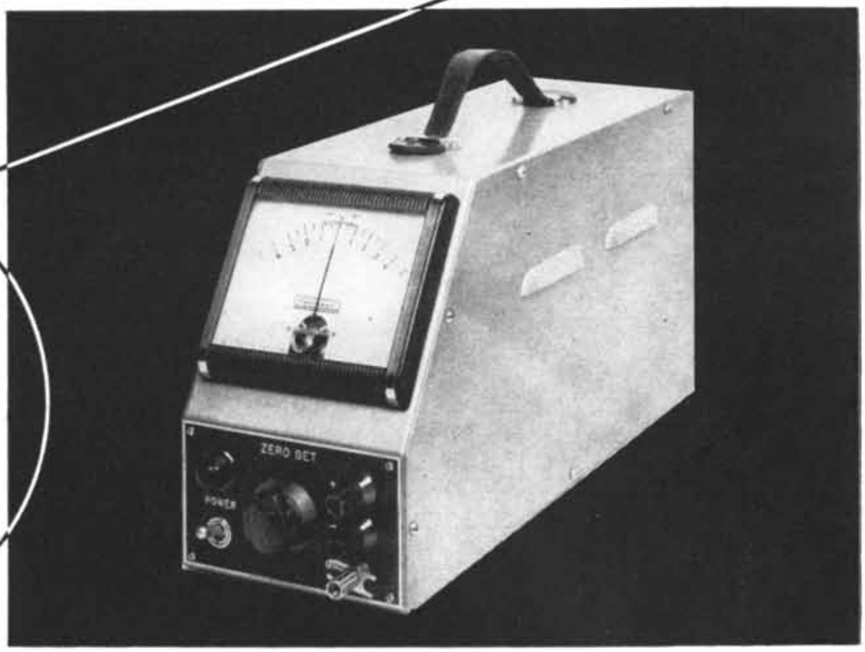

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electron was never recognized as a field until the quantum field theory was developed. And even now the electron field seems more peculiar and foreign to us than the electromagnetic field. Fundamentally the two are very similar. The main difference between them is the short range of the electron field, which has the consequence that the electron possesses a rest-mass and can travel with any velocity not exceeding the velocity of light. Most of the other known particles—protons, neutrons, the many varieties of mesons—also have a rest-mass and are associated with short-range fields.

Positive and Negative

Perhaps the most spectacular success of the quantum field theory is in its treatment of charged fields. According to the theory, a quantum field may or may not carry an electric charge. For example, the electron field carries a charge, while the electromagnetic field does not. The theory automatically predicts that any charged field must be represented by two types of particle, precisely alike in all respects except that one has a positive charge and the other negative. The theory also predicts that under suitable conditions a pair of such particles, one positively and one negatively charged, can be created or annihilated together in a single event. All these predictions of the theory have been completely confirmed in the case of the electron field. There exists a particle, the positron, which is exactly like an electron except that it has the opposite charge. It has also been proved that there are at least two varieties of meson that exist in positive and negative forms. The theory predicts that there should be an antiproton: a particle negatively charged but otherwise identical with a proton. The antiproton has not yet been detected. It presents an outstanding challenge to experimental physicists to discover it, or to theoretical physicists to explain why it should not exist.

Even to a hardened theoretical physicist it remains perpetually astonishing that our solid world of trees and stones can be built of quantum fields and nothing else. The quantum field seems far too fluid and insubstantial to be the basic stuff of the universe. Yet we have learned gradually to accept the fact that the laws of quantum mechanics impose their own peculiar rigidity upon the fields they govern, a rigidity which is alien to our intuitive conceptions but which nonetheless effectively holds the earth in place. We have learned to apply, both to ourselves and to our subject, the words of Robert Bridges:

Our stability is but balance, and
our wisdom lies
In masterful administration of the
unforeseen.

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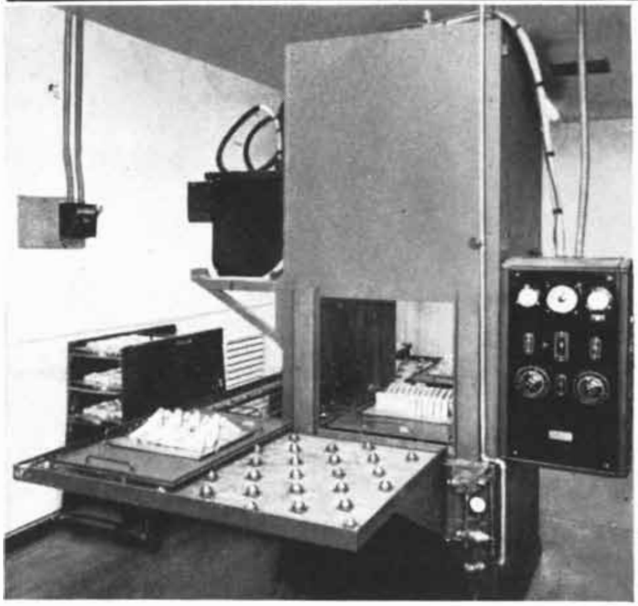

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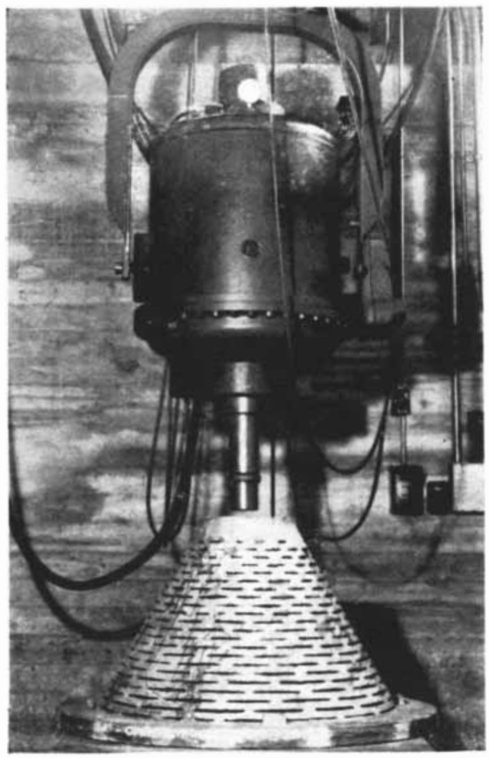

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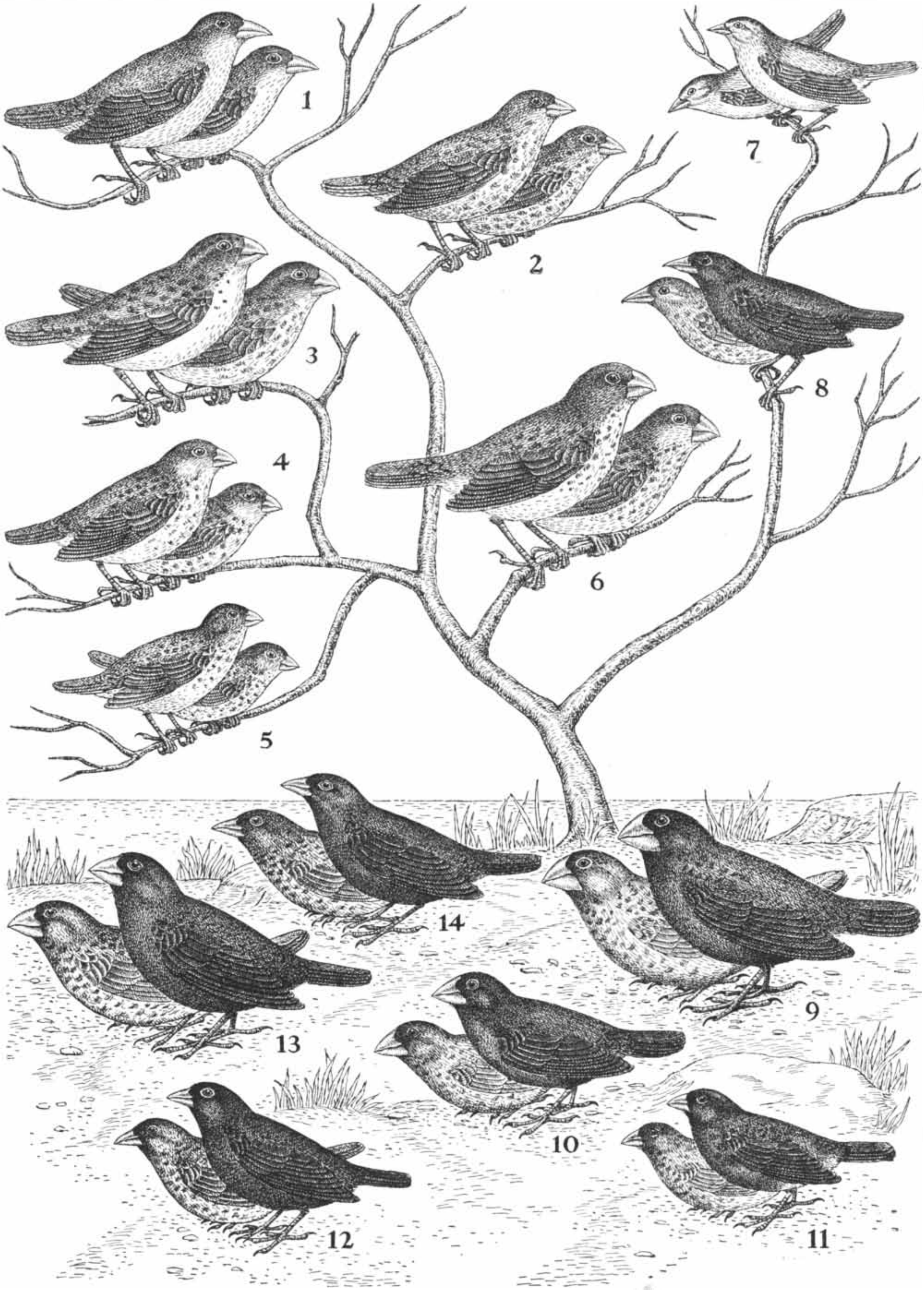
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Darwin's Finches

These drab but famous little birds of the Galapagos Islands are a living case study in evolution. Isolated in the South Pacific, they have developed 14 species from a common ancestor

by David Lack

ON THE Galapagos Islands in the Pacific Charles Darwin in 1835 saw a group of small, drab, finch-like birds which were to change the course of human history, for they provided a powerful stimulus to his speculations on the origin of species—speculations that led to the theory of evolution by natural selection. In the study of evolution the animals of remote islands have played a role out of all proportion to their small numbers. Life on such an island approaches the conditions of an experiment in which we can see the results of thousands of years of evolutionary development without outside intervention. The Galapagos finches are an admirable case study.

These volcanic islands lie on the Equator in the Pacific Ocean some 600 miles west of South America and 3,000 miles east of Polynesia. It is now generally agreed that they were pushed up out of the sea by volcanoes more than one million years ago and have never been connected with the mainland. Whatever land animals they harbor must have come over the sea, and very few species have established themselves there: just two kinds of mammals, five reptiles, six songbirds and five other land birds.

Some of these animals are indistinguishable from the same species on the mainland; some are slightly different; a few, such as the giant land-tortoises and the mockingbirds, are very different. The latter presumably reached the Galapagos a long time ago. In addition, there are variations from island to island among the local species themselves, indicating that the colonists diverged into variant forms after their arrival. Darwin's finches go further than this: not only do they vary from island to island but up to 10 different species of them can be found on a single island.

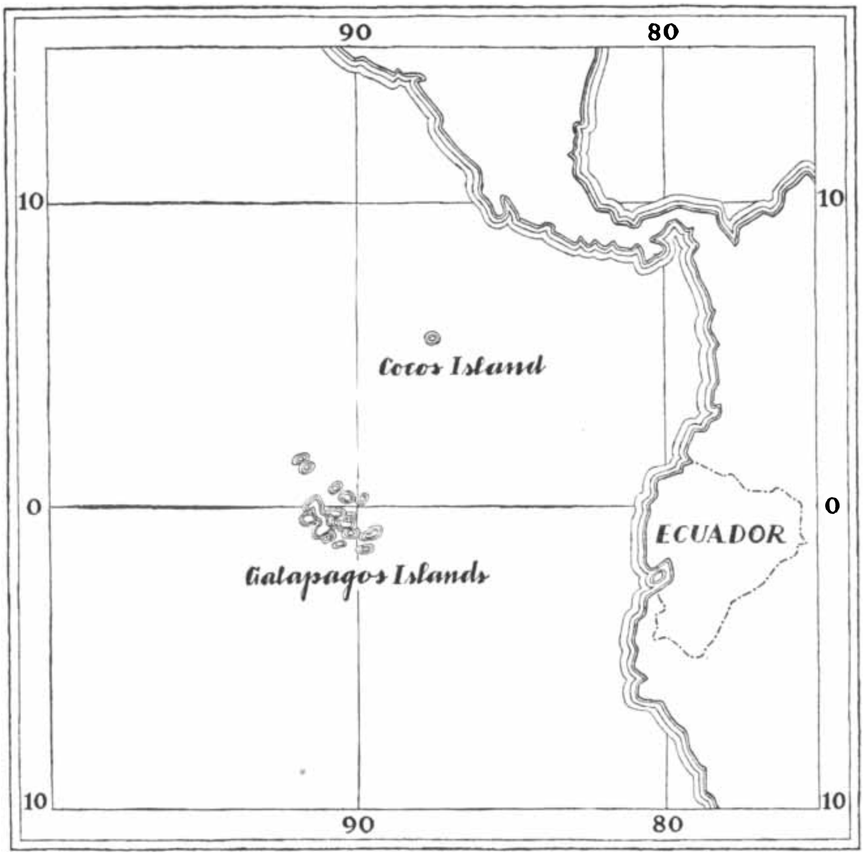
The birds themselves are less dramatic than their story. They are dull in color, unmusical in song and, with one exception, undistinguished in habits. This dullness is in no way mitigated by their dreary surroundings. Darwin in his diary succinctly described the islands: "The country was compared to what we might imagine the cultivated parts of the Infernal regions to be." This diary, it is interesting to note, makes no mention of the finches, and the birds received only a brief mention in the first edition of his book on the voyage of the *Beagle*. Specimens which Darwin brought home, however, were recognized by the English systematist and bird artist, John Gould, as an entirely new group of birds. By the time the book reached its second edition, the ferment had begun to work, and Darwin added that "one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends." Thus obscurely, as an afterthought in a travel book, man received a first intimation that he might once have been an ape.

THERE ARE 13 species of Darwin's finches in the Galapagos, plus one on Cocos Island to the northwest. A self-contained group with no obvious relations elsewhere, these finches are usually placed in a subfamily of birds named the *Geospizinae*. How did this remarkable group evolve? I am convinced, from my observations in the islands in 1938-39 and from subsequent studies of museum specimens, that the group evolved in much the same way as other birds. Consequently the relatively simple story of their evolution can throw valuable light on the way in which birds, and other animals, have evolved in general. Darwin's finches form a little world of their own, but a world which differs from the one we know only in being younger, so that here, as Darwin wrote, we are brought nearer than usual "to that great fact—that mystery of mysteries—the first appearance of new beings on this earth."

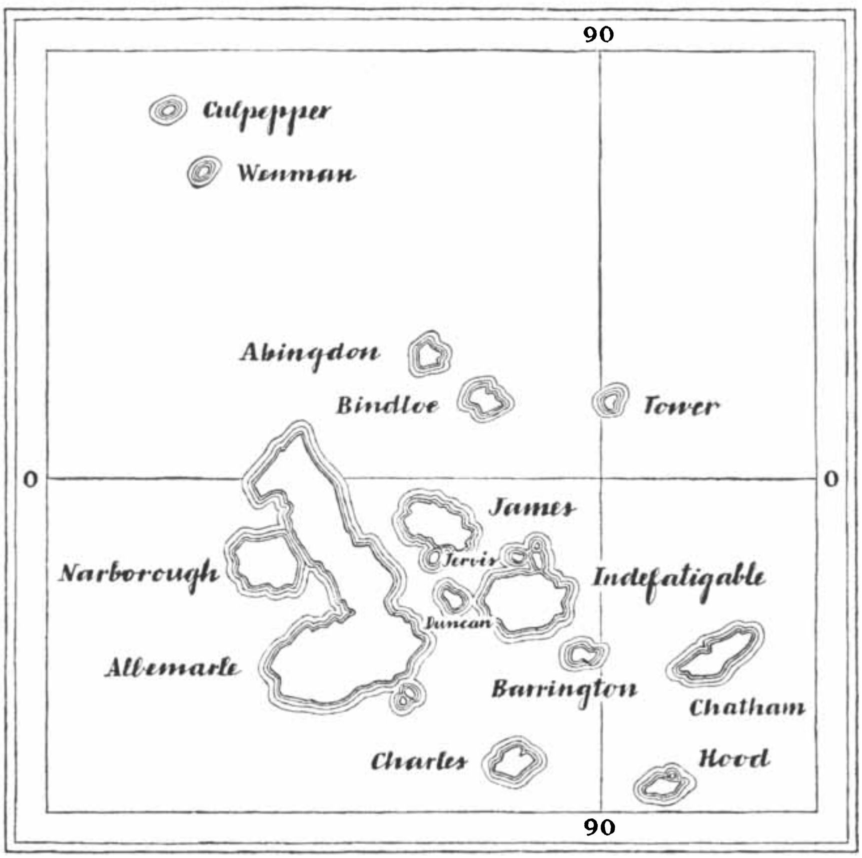
The 14 species of Darwin's finches fall into four main genera. First, there are the ground-finches, embracing six species, nearly all of which feed on seeds on the ground and live in the arid coastal regions. Secondly, there are the tree-finches, likewise including six species, nearly all of which feed on insects in trees and live in the moist forests. Thirdly, there is the warbler-like finch (only one species) which feeds on small insects in bushes in both arid and humid regions. Finally, there is the isolated Cocos Island species which lives on insects in a tropical forest.

Among the ground-finches, four species live together on most of the islands: three of them eat seeds and differ from each other mainly in the size of their beaks, adapted to different sizes of seeds; the fourth species feeds largely on prickly pear and has a much longer

THE 14 SPECIES of Darwin's finches are arranged at the left to suggest the evolutionary tree of their development. Grayish brown to black, all belong to the subfamily *Geospizinae*, divided broadly into ground finches (*Geospiza*), closest to the primitive form, and tree finches (mainly *Camarhynchus*), which evolved later. Of the tree species, 1 is a woodpecker-like finch (*C. pallidus*), 2 inhabits mangrove swamps (*C. heliobates*), 3, 4 and 5 are large, medium and small insect-eating birds (*C. psittacula, pauper* and *parvulus*), 6 is a vegetarian (*C. crassirostris*), 7 is a single species of warbler-finch (*Certhidea*) and 8 an isolated species of Cocos Island finch (*Pinaroloxias*). The ground-finches, mainly seed-eaters, run thus: 9, 10 and 11 are large, medium and small in size (*G. magnirostris, fortis* and *fuliginosa*), 12 is sharp-beaked (*G. difficilis*), 13 and 14 are cactus eaters (*G. conirostris* and *scandens*). All of the species in the drawing are shown about half-size.



THE GALAPAGOS are shown some 600 miles west of Ecuador, above, and close up below. Cocos Island is not in the group, but it has developed one species of finch, presumed to have come originally from the mainland.



and more pointed beak. The two remaining species of ground-finches, one large and one small, live chiefly on the outlying islands, where some supplement their seed diet with cactus, their beaks being appropriately modified.

Of the tree-finches, one species is vegetarian, with a parrot-like beak seemingly fitted to its diet of buds and fruits. The next three species are closely alike, differing primarily in body size and in the size of their beaks, presumably scaled to the size of the insects they take. A fifth species eats insects in mangrove swamps. The sixth species of tree-finch is one of the most remarkable birds in the world. Like a woodpecker, it climbs tree trunks in search of insects, which it excavates from the bark with its chisel-shaped beak. While its beak approaches a woodpecker's in shape, it has not evolved the long tongue with which a woodpecker probes insects from crannies. Instead, this tree-finch solves the problem in another way: it carries about a cactus spine or small twig which it pokes into cracks, dropping the stick to seize any insect that emerges. This astonishing practice is one of the few recorded cases of the use of tools by any animal other than man or the apes.

The warbler-like finch is in its own way as remarkable as the Galapagos attempt at a woodpecker. It has no such wonderful habit, but in its appearance and character it has evolved much closer to a warbler than the other finch has to a woodpecker. Thus its beak is thin and pointed like that of a warbler; its feeding methods and actions are similar, and it even has the warbler-like habit of flicking its wings partly open as it hunts for food. For nearly a century it was classified as a warbler, but its internal anatomy, the color of its eggs, the shape of its nest and other characteristics clearly place it among the finches.

The close resemblance among Darwin's finches in plumage, calls, nests, eggs and display suggests that they have not yet had time to diverge far from one another. The only big difference is in their beaks, adapted to their different diets. It is reasonably certain that all the Galapagos finches evolved from one original colonizing form. What is unusual about them is the existence of several distinct species on the same island. In this we may have an indirect clue to how separate species establish themselves.

LET US consider first how new forms of an animal may originate from a common ancestor. When a member of the original species moves into a new environment, it is likely to evolve new features adapted to the new local conditions. Such geographical variations among animals are commonly found; in

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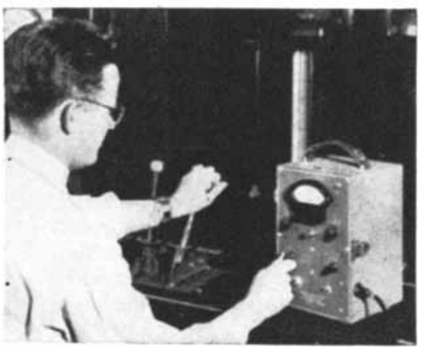

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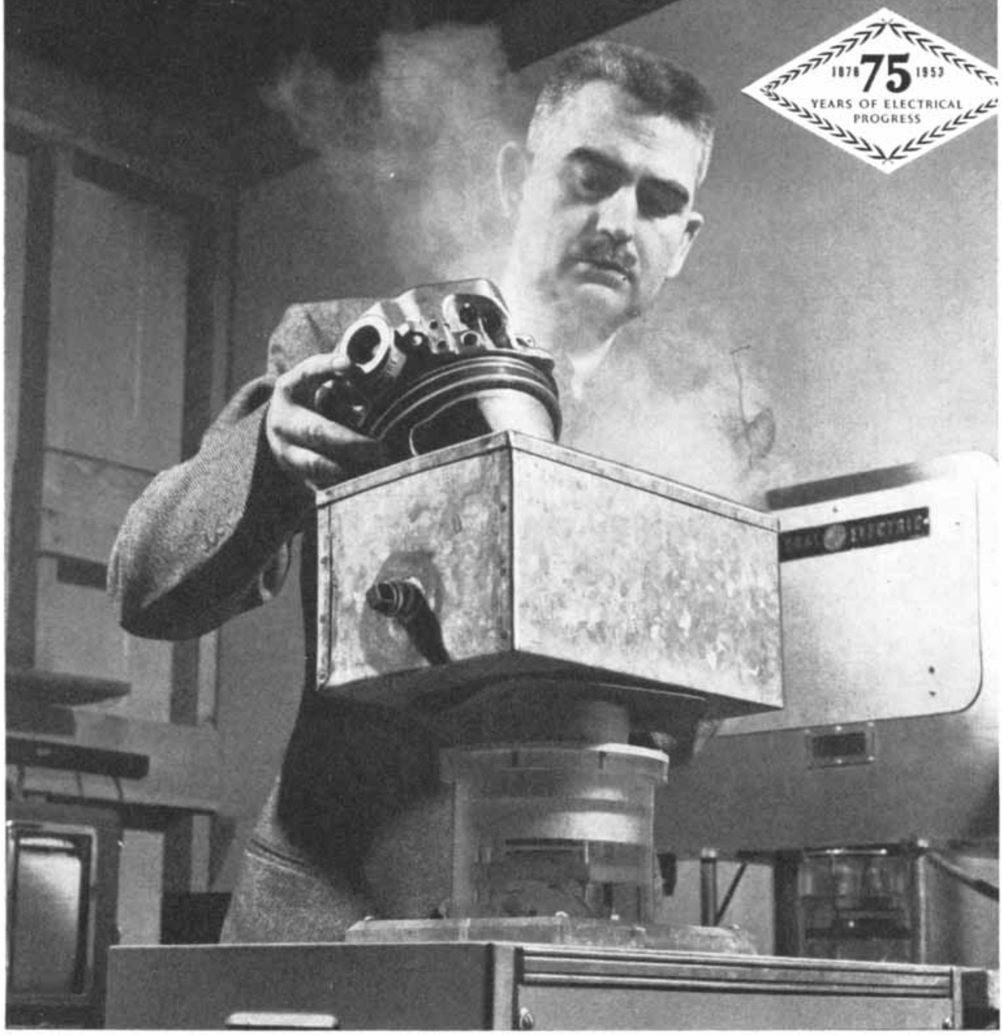

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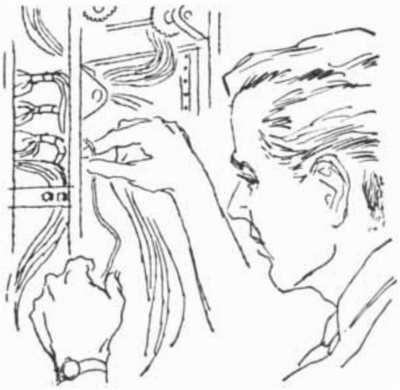

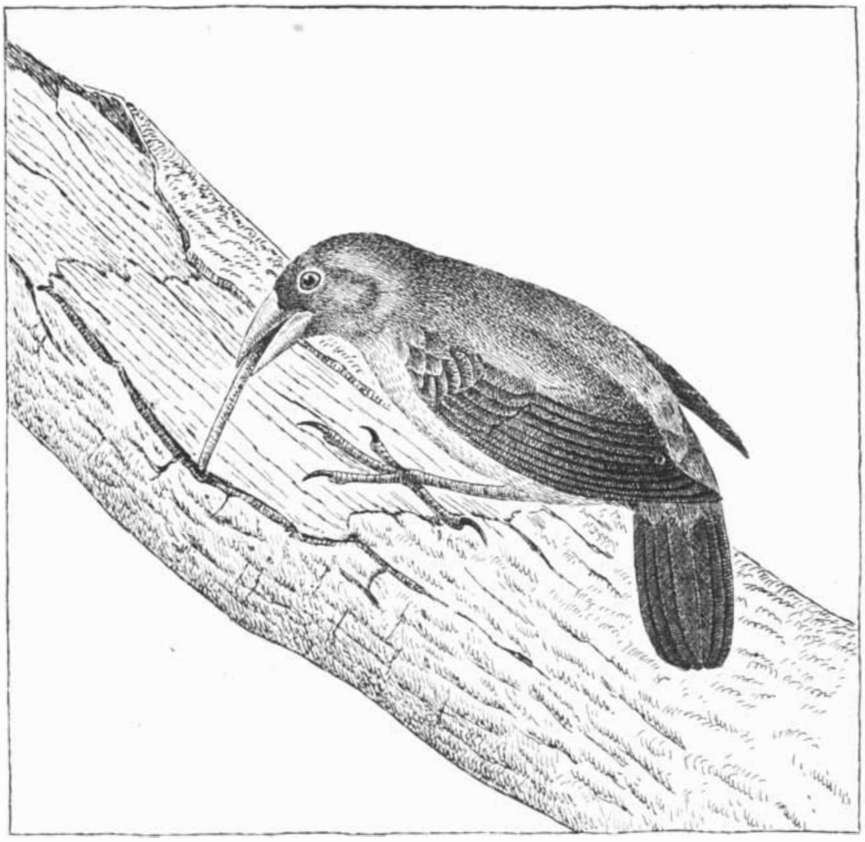

THE WOODPECKER-FINCH is the most remarkable of Darwin's finches. It has evolved the beak but not the long tongue of a woodpecker, hence carries a twig or cactus spine to dislodge insects from bark crevices.

the Galapagos, for instance, the land birds other than finches vary from island to island, with only one form on each island. These forms are not distinct species but subspecies, or geographical races. Their differences, however, are hereditary and not trivial or accidental. There are several examples of such geographical variation among Darwin's finches. Three common species of the ground-finch, for instance, are found on most of the islands; they are large, medium and small, feeding on large, medium and small seeds respectively. Now on two southern islands the large species is missing, and here the medium species has a rather larger beak than elsewhere, presumably an adaptation to the large seeds available to it in the absence of the large species. Again, on another islet the small ground-finch is absent, and the medium species fills the gap by being rather smaller than elsewhere. On still other islets the medium species is missing and the small species is rather larger than elsewhere.

It seems clear that the beak differences among the subspecies of Darwin's finches are adaptive. Further, some of these differences are as great as those distinguishing true species.

What is likely to happen if a subspecies evolved in isolation on one island later spreads to an island occupied by another race of the same species? If the two populations have not been isolated for long and differ in only minor ways, they may interbreed freely and so merge with each other. But evidence from the study of insects suggests that if two populations have been isolated for a long time, so many hereditary differences will have accumulated that their genes will not combine well. Any hybrid offspring will not survive as well as the parent types. Hence natural selection will tend to intensify the gap between the two forms, and they will continue to evolve into two distinct species.

DARWIN'S finches provide circumstantial evidence for the origin of a new species by means of geographical isolation. Consider three different forms of the large insectivorous tree-finch. On the most southerly Galapagos island is a small dark form with a comparatively small beak. On another island to the northwest is a rather larger and less barred form. On the central islands is a yet larger and paler type with a larger, more parrot-like beak. Evidently these three forms had a common ancestor and evolved their differences in geographical isolation. The differences among them do not seem great enough to set them apart as separate species, and they would be classed as subspecies but for one curious circumstance: on the southernmost island the two extremes—the

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Air Turbine Refrigeration · Heat Transfer Equipment · Electric Actuators · Gas Turbines · Cabin Superchargers · Pneumatic Power Units · Electronic Controls · Cabin Pressure Controls · Temperature Controls small dark form and the largest pale form—live side by side without merging. Clearly these must be truly separate species. It seems likely that the large pale form spread from the central islands to the southern island in comparatively recent times, after both it and the small dark form had evolved into distinct species.

If differentiated forms are to persist alongside each other as separate species, two conditions must be met. First, they must avoid interbreeding. In birds this is usually taken care of by differences in appearance (generally in the color pattern) and in the song. It is no accident that bird-watchers find male birds so easy to recognize: correct identification is even more important for the female bird! Darwin's finches recognize each other chiefly by the beak. We have often seen a bird start to chase another from behind and quickly lose interest when a front view shows that the beak is that of a species other than its own.

The second requirement for the existence of two species together is that they must not compete for the same food. If they tend to eat similar food, the one that is better adapted to obtain that food will usually eliminate the other. In those cases where two closely related species live side by side, investigation shows that they have in fact evolved differences in diet. Thus the beak differences among the various Galapagos finches are not just an insular curiosity but are adapted to differences in diet and are an essential factor in their persistence together. It used to be supposed that related species of birds overlapped considerably in their feeding habits. A walk through a wood in summer may suggest that many of the birds have similar habits. But having established the principle of food differentiation in Darwin's finches, I studied many other examples of closely related species and found that most, if not all, differ from one another in the places where they feed, in their feeding methods or in the size of the food items they can take. The appearance of overlap was due simply to inadequate knowledge.

NOW the key to differentiation is geographical isolation. Probably one form can establish itself alongside another only after the two have already evolved some differences in separate places. Evolutionists used to believe that new species evolved by becoming adapted to different habitats in the same area. But there is no positive evidence for that once popular theory, and it is now thought that geographical isolation is the only method by which new species originate, at least among birds. One of Darwin's species of finches provides an interesting illustration of this. The species on Cocos Island is so different from the rest that it must have been isolated there for a long time. Yet despite this long isolation, along with a great variety of foods and habitats and a scarcity of other bird competitors, the Cocos finch has remained a single species. This is because Cocos is an isolated island, and so does not provide the proper opportunities for differentiation. In the Galapagos, differentiation was possible because the original species could scatter and establish separate homes on the various islands of the archipelago. It is significant that the only other group of birds which has evolved in a similar way, the sicklebills of Hawaii, are likewise found in an archipelago.

Why is it that this type of evolution has been found only in the Galapagos and Hawaii? There are other archipelagoes in the world, and geographical isolation is also possible on the continents. The ancestor of Darwin's finches, for instance, must formerly have lived on the American mainland, but it has not there given rise to a group of species similar to those in the Galapagos. The answer is, probably, that on the mainland the available niches in the environment were already occupied by efficient species of other birds. Consider the woodpecker-like finch on the Galapagos, for example. It would be almost impossible for this type to evolve in a land which already possessed true woodpeckers, as the latter would compete with it and eliminate it. In a similar way the warbler-like finch would, at least in its intermediate stages, have been less efficient than a true warbler.

Darwin's finches may well have been the first land birds to arrive on the Galapagos. The islands would have provided an unusual number of diverse, and vacant, environmental niches in which the birds could settle and differentiate. The same may have been true of Hawaii. In my opinion, however, the type of evolution that has occurred in those two groups of islands is not unique. Similar developments could have taken place very long ago on the continents; thus our own finches, warblers and woodpeckers may have evolved from a common ancestor on the mainland. What is unique about the Galapagos and Hawaii is that the birds' evolution there occurred so recently that we can still see the evidence of the differentiations.

MUCH MORE is still to be learned from the finches. Unfortunately the wonderful opportunities they offer may not long remain available. Already one of the finches Darwin found in the Galapagos is extinct, and so are several other animals peculiar to the islands. With man have come hunters, rats, dogs and other predators. On some islands men and goats are destroying the native vegetation. This last is the most serious threat of all to Darwin's finches. Unless we take care, our descendants will lose a treasure which is irreplaceable.

Psychology and the Instrument Panel

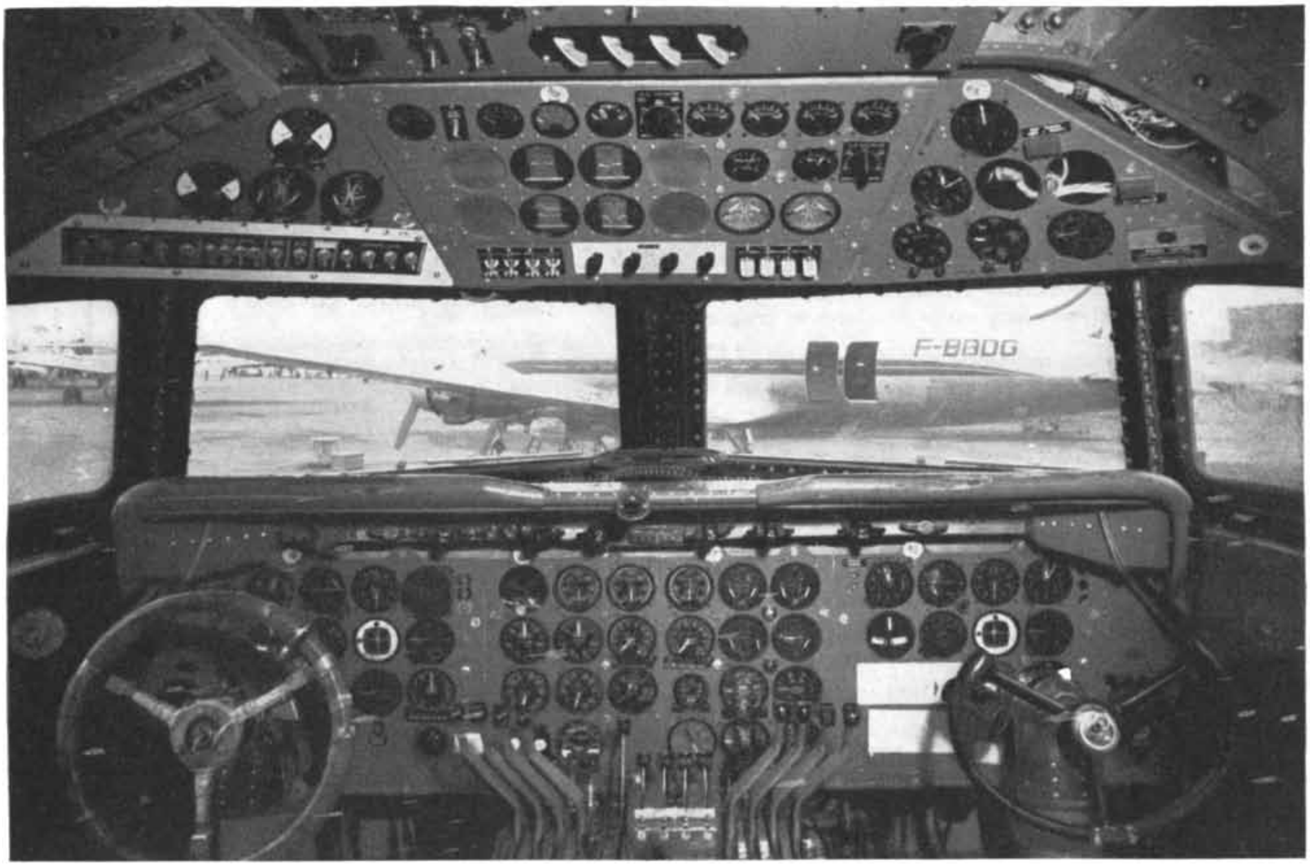
Designing indicators, switches and other controls to fit the abilities of the men who will use them is a joint problem for psychologists and engineers

by Alphonse Chapanis

OUR MACHINES have become so complicated that we have been forced in recent years to start a new branch of technology: namely, retailoring the machines to the abilities and limitations of human beings. This activity, called human engineering, is a new departure in the application of psychological principles to industry. Up to now the main emphasis has been on selecting and training the best man for the job. Human engineering tries to fit the job to the man—any man.

It received its big impetus during World War II, and anyone who looks at the instrument panel of a military plane will instantly know why. The maze of dials, indicators, switches and controls in a modern aircraft eloquently explains why human error is the largest single cause of accidents. Air Force psychologists have systematically interviewed many experienced pilots to probe the specific sources of errors. In one study they asked each man if he had ever made or seen anyone else make an "error in reading or interpreting an aircraft instrument, detecting a signal or understanding instructions." Here are two typical answers:

"It was an extremely dark night. My copilot was at the controls. I gave him instructions to take the ship, a B-25, into



INSTRUMENT PANEL of a four-engine transport reflects the enormous amount of information that a pilot must have to fly today's airplanes. To get the information quickly and accurately he needs the most readable dials; to act quickly and correctly he requires controls that are designed to fit the natural motions of his body.

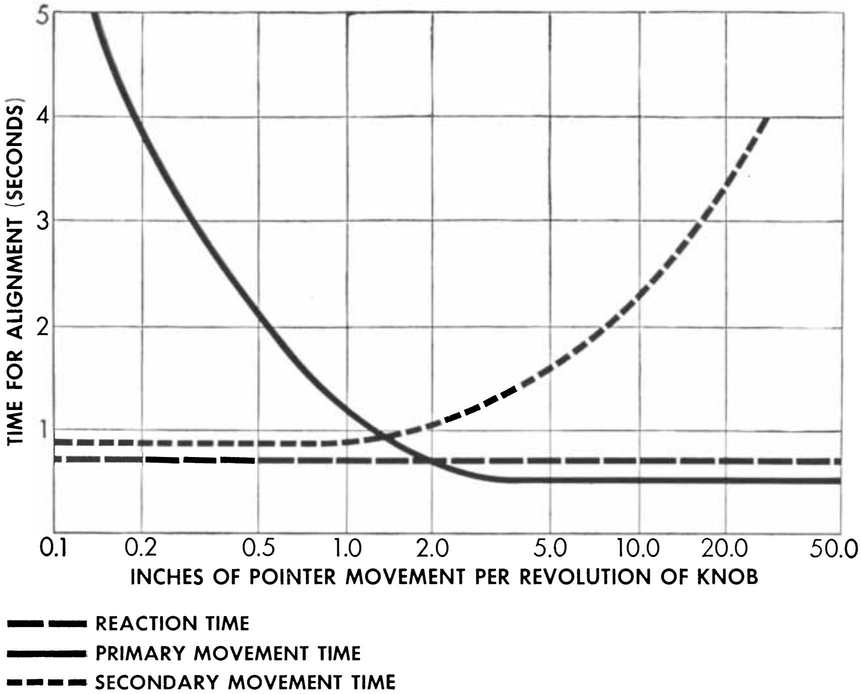
the traffic pattern and land. He began letting down from an altitude of 4,000 feet. At 1,000 feet above the ground, I expected him to level off. Instead, he kept right on letting down until I finally had to take over. His trouble was that he had misread the altimeter by 1,000 feet. This incident may seem extremely stupid, but it was not the first time that I have seen it happen. Pilots are pushing up plenty of daisies today because they read their altimeter wrong while letting down on dark nights."

"We had an alert one morning about 11 o'clock. About 35 Japanese planes had been picked up on the radar screen. In the mad scramble for planes, the one I happened to pick out was a brand new ship which had arrived about two days previously. I climbed in, and it seemed the whole cockpit was rearranged. . . . I took a look at that instrument panel and viewed the gauges around me, sweat falling off my brow. Just then the first Japanese bomb dropped. I figured then and there I wasn't going to get my plane up, but I could run it on the ground. That's exactly what I did—ran it all around the field, up and down the runway, during the attack."

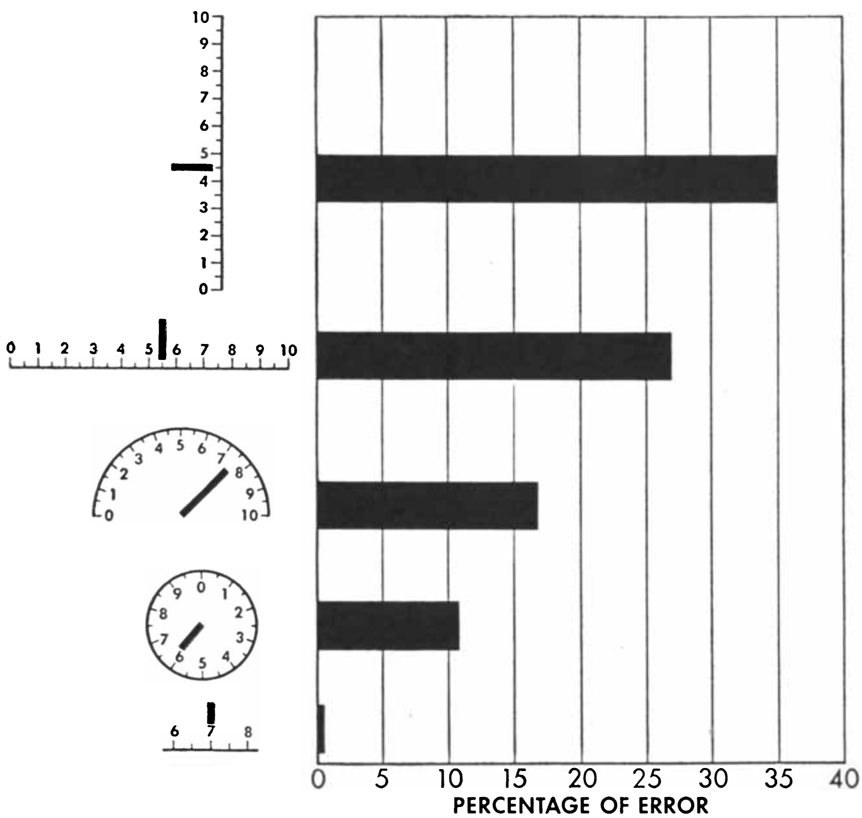
The 624 pilots questioned in the Air Force survey recounted 270 "pilot error" experiences like these; there were undoubtedly many more they had forgotten. Some errors are not important enough to be noticed; others are never reported because the pilots do not live to tell of them. Of the remembered errors the most common were misreading the pointers, reversals in interpretation of the readings, inability to see the instrument properly (because of dirt, poor position, poor lighting, etc.) and mistaking one instrument for another.

INSTRUMENT dials are not the only objects in an airplane that cause "human element" accidents. Many pilot errors stem from the design and position of controls. A recent study by Wright Field psychologists showed that by far the largest source of pilot error was in the confusion of controls. The pilot would pull the throttle when he intended to pull the propeller control, or change the gasoline mixture when he meant to pull the throttle. The reason is that the military planes of the late war were fiendishly inconsistent in the placement of controls. The throttle was on the left in the B-25, in the center on the C-47 and C-82. The propeller control was in the center on the B-25, on the left in the C-47, on the right in the C-82. The gas-mixture control was on the right in the B-25 and C-47, on the left in the C-82. Sometimes controls varied among models of the same airplane.

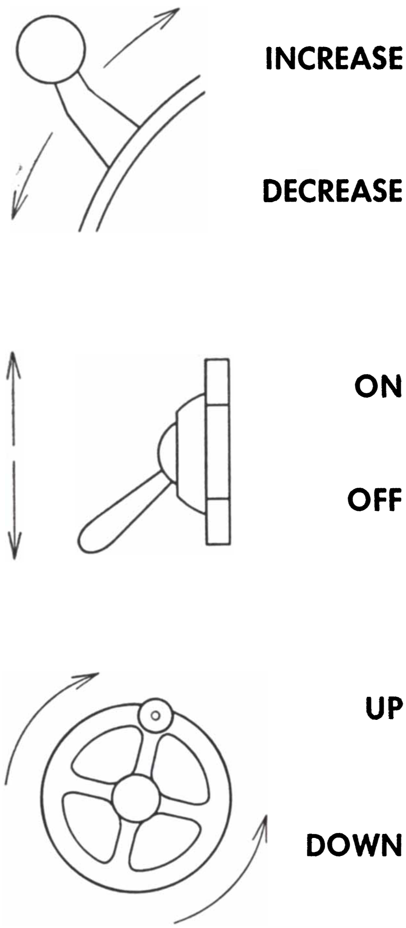
Another major source of trouble was that controls for opposite purposes were placed too close together. On many planes the controls for the wing flap and



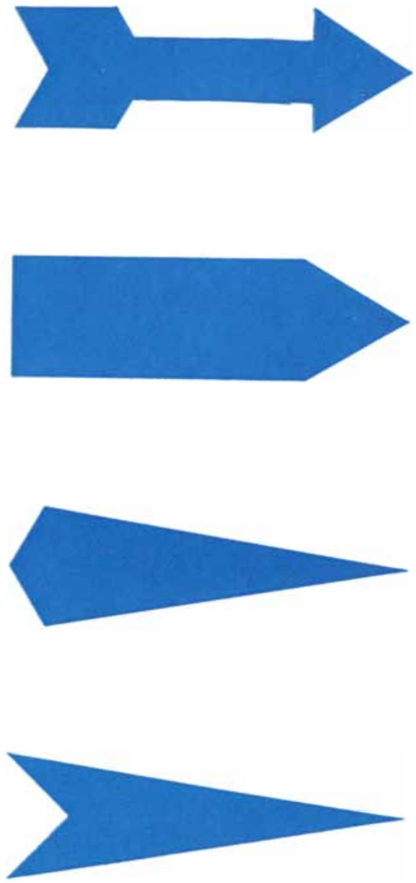
TUNING KNOB STUDY determines best gear ratio for fastest operation. Curves showing times for approximate setting and for fine adjustment indicate that the pointer should move about 1.5 inches per revolution of knob.



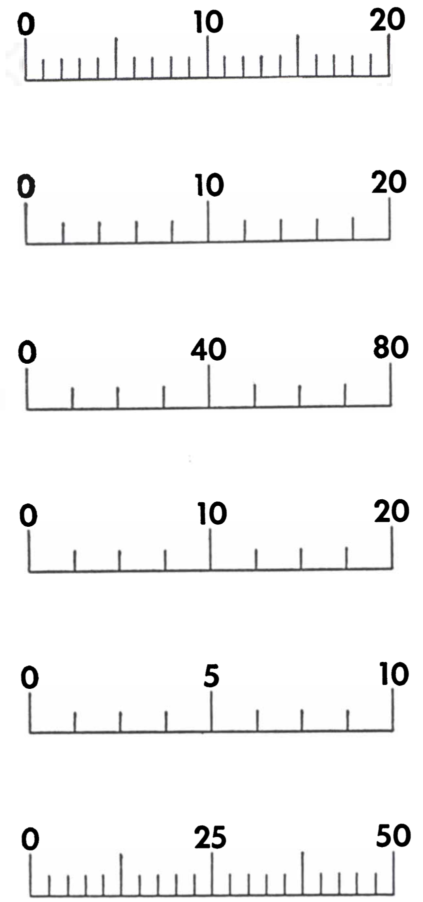
ERRORS IN READING different types of dials are plotted opposite diagrams of the dial faces. The most easily read type is the open-window dial (*bottom*), where only a small part of an entire horizontal scale is visible.



NATURAL DIRECTIONS in which controls should move are shown for levers, toggle switches and cranks.



TRAFFIC ARROWS of unusual design (*lower two*) can be recognized farther off than ordinary markers.



SCALE GRADUATIONS influence reading errors. Here, each scale is more readable than the one below it.

the landing gear were side by side. To land a plane, you must put one up and the other down; to take off, you do just the opposite. Serious accidents could be traced to confusing these two controls. Sometimes pilots moved controls in the wrong direction. This was not entirely the pilot's fault: he was required to move a control in an "unnatural" direction—to flip a lever to the right when he wanted to go left, to push one control in while he was pulling another control out.

Certain directions of movement are psychologically natural. At least they go along with other things we are doing. For instance, toggle switches should move up for *on*, *go* or *increase*, and down for *off*, *stop* or *decrease*. Above all, the motions of related controls should be consistent. If a man must flip one switch up to turn something on and another down to turn something else on, he is apt to make mistakes. The point seems obvious, but it is frequently disregarded.

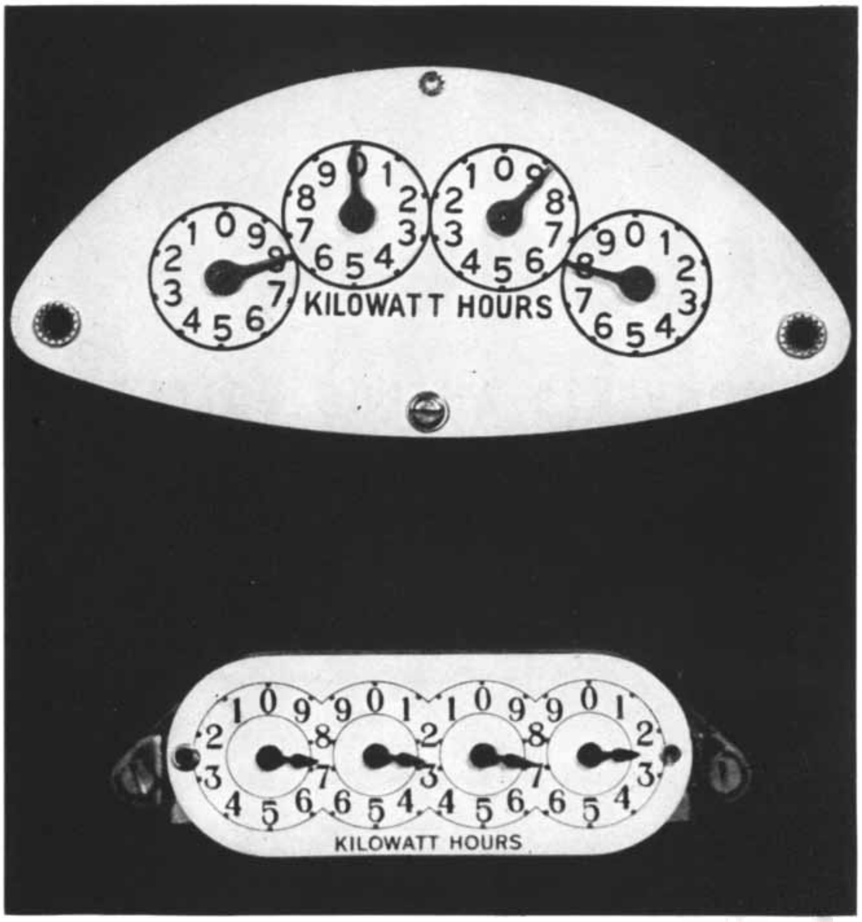
That is one kind of problem in control design. There are others that have no logic but must be solved by experiment. For example, what is the best gear ratio for a control knob and indicator, such as is used in radio tuning? We have two factors in opposition here: a fast-moving needle gets us to the neighborhood of the station quickly but makes precise tuning difficult, while a slow-moving needle is good for fine tuning but time-wasting for changing stations. By experiment we have found that the best compromise is reached when the pointer moves 1.5 inches for every revolution of the knob.

THE COMBAT information center (CIC) of modern warships has been extensively studied from the human engineering point of view. Into such a station pours information from various sources—sonobuoy, sonar, telephone, television, wireless telegraphy, radar, voice radio, teletype, infrared viewing devices and human observers. The system taxes the capabilities of the human beings working in it. In battle the gunnery officer must deal rapidly with a bewildering variety of information about targets. The air combat officer similarly has a host of things to think about—the number of combat patrols he has in the air, their reserves of fuel and ammunition, and so on. And decisions must be taken with somewhat less deliberation than was allowed to the captain of an 18th-century frigate. An officer in the CIC may consider himself lucky if he is given half a minute to make up his mind.

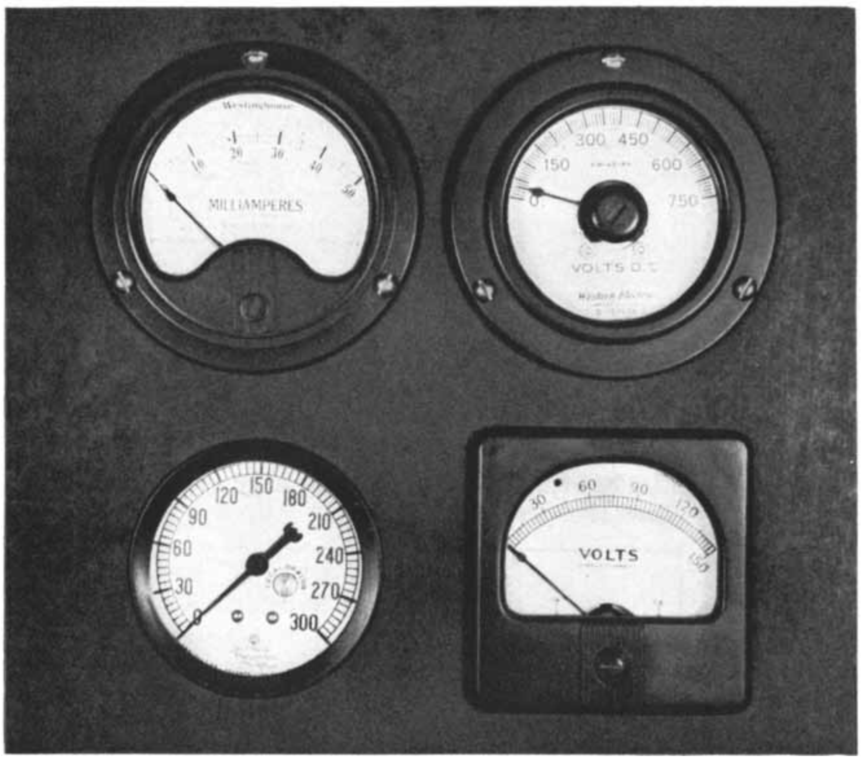
Let us say it takes 18 seconds from the moment a target is detected to communicate and evaluate the information and start firing. In that time a target traveling at 20 knots, which used to be considered fast, will have moved 200 yards. Today a gunnery officer must deal with speeds of a different order of magnitude. In 18 seconds a target traveling at 200 knots, which is slow as aircraft go, will have moved one nautical mile, and a target at 1,000 knots will have traveled five nautical miles!

To display the CIC information so that it can be grasped and acted upon quickly enough is a formidable problem in instrument design. The dials and indicators on the instruments must be analyzed in terms of psychological function. Engineering psychologists ask: Do these instruments tell the operator what he needs to know—and neither more nor less than he needs to know? Too much data can be as bad as too little; it slows communication and encourages errors.

Instruments provide three kinds of information. The simplest type merely indicates that something is or is not working. The turn-signaling lights on your



ELECTRIC METER seems designed to confuse. The reader is invited to check the meters in the photograph above. (Top, 7988; bottom, 7272).



CONFUSING VARIETY of scales is shown above. One division represents 1 (*upper left*), 10 (*upper right*), 5 (*bottom left*) and 3 (*bottom right*).

car are wired to a small blinking light on the instrument panel in front of you, to tell you that the signals are working. Instruments of this type have merely a yes-or-no function and rarely need a dial.

The next stage of complexity is an instrument that gives a qualitative reading; it tells you whether conditions are satisfactory, and if not, in what direction they are off. An example is the temperature gauge on your automobile. All you need to know is whether the engine is too hot or too cold; if the radiator springs a leak, you are warned of it by the temperature needle going up. As long as the temperature is within the allowable limits, you are not really interested in whether it is 130, 140 or 150 degrees. Most cars nowadays carry temperature gauges without numbers, and drivers do not miss them. Many instruments are essentially of this type, and engineers are surprised to find how often the fancy indicators and readings they put on machines turn out on analysis to be unnecessary.

The third type of instrument requires precise quantitative readings. A compass must tell direction exactly if the navigator is to bring his ship to port. The altimeter on an aircraft is both a qualitative and a quantitative instrument. Most of the time the pilot needs to know his altitude only in a general way. But when he comes in for a landing he must know just how far from the ground he is.

HAVING DECIDED on what information is needed, the human engineer next turns his attention to the problem of conveying it most effectively. In the past, dials have been designed for convenience or appearance, not necessarily for readability. The round dial is convenient because, as one engineer puts it, "you can wrap 10 inches of scale around a three-inch dial." Automobile speedometers are designed primarily to look nice. Some time ago the psychologist Robert Sleight, then at Purdue University, tested for readability the five dials shown on page 75. Notice that the size of numbers and pointers and the distance between numbers is the same on all the dials. Observers were given only .12 second—just long enough for a quick glance—to read a dial. The pointer was set either on a number or on a small mark between two numbers, and the subject was required to read the dial to the nearest half unit. Each dial was read a total of 1,020 times in Sleight's tests. He found statistically significant differences in their readability. The open-window dial was the best: in 1,020 trials the subjects made only five errors in reading it. The round dial was next best (112 errors); the horizontal and vertical dials were poorest.

The way in which the scale is graduated is even more important than the shape of the dial. I have studied this

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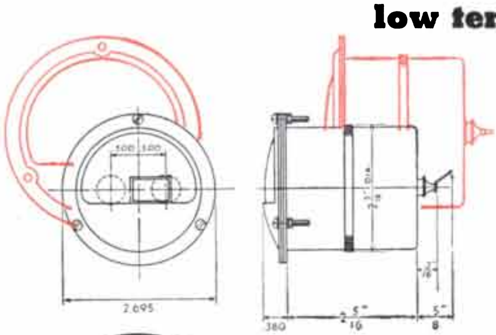

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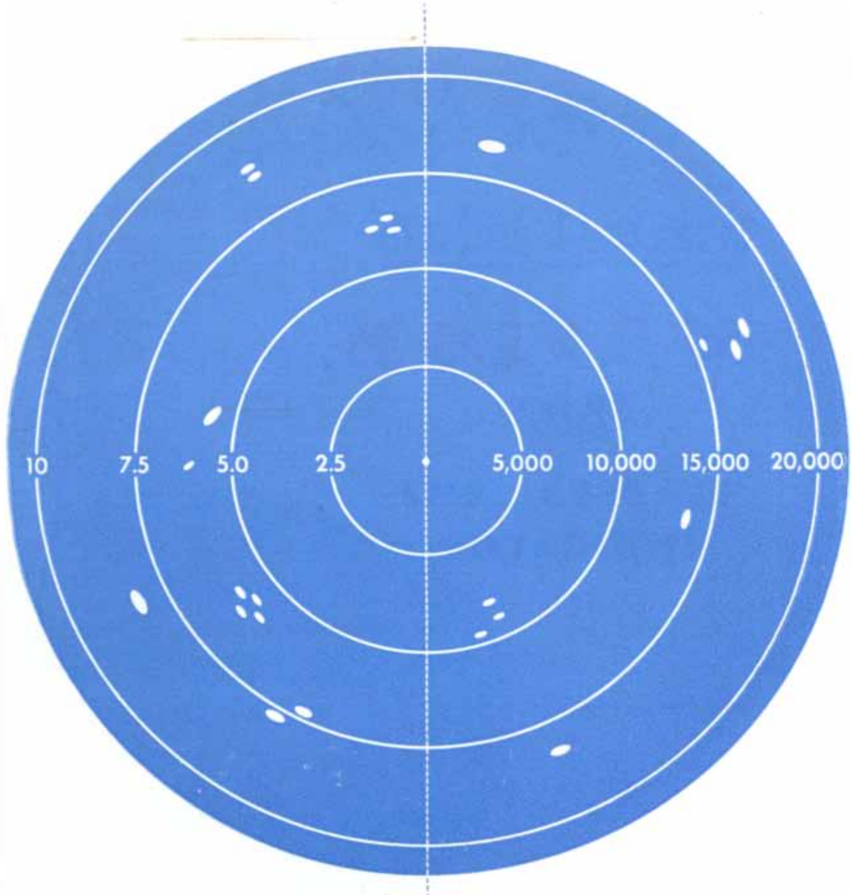
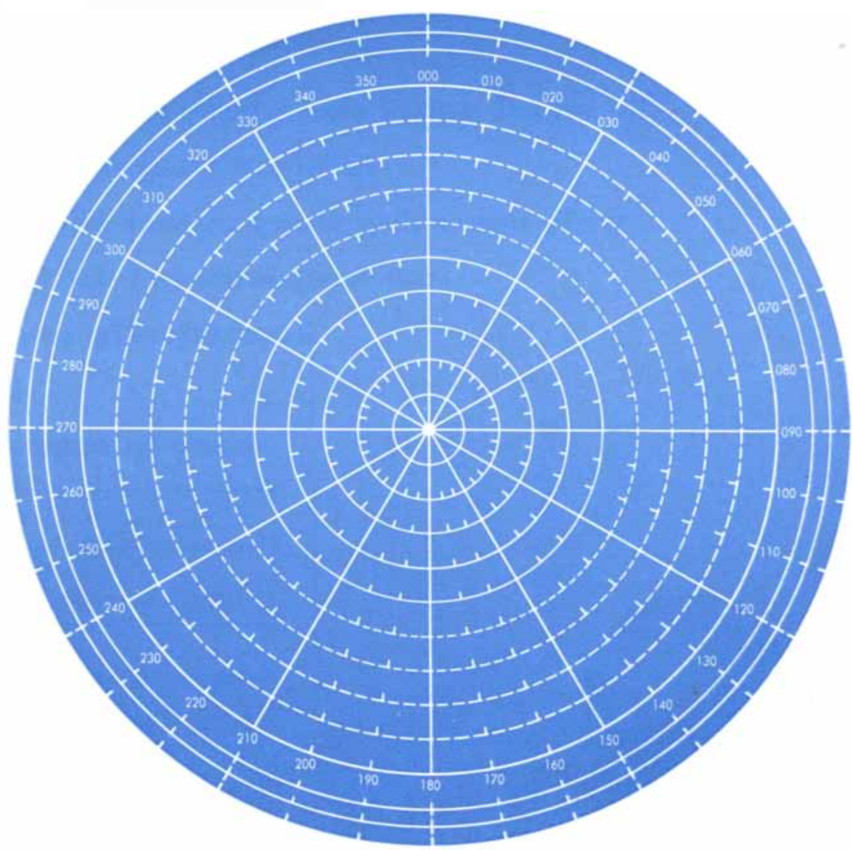


RANGE CIRCLES on radar scope make for better distance estimates when marked in units of 5,000 yards, as at right, than when in units of 2.5 miles.



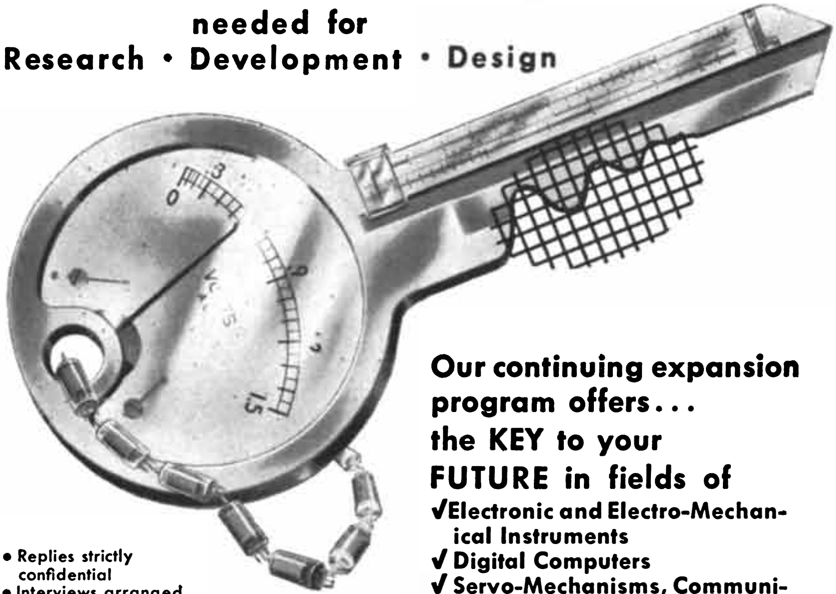
LESS COUNTING is required when range circles are separated by different markings into groups of four, as with solid and dotted circles shown above.

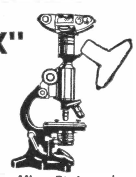
factor by testing different scales on radar scopes. In one such test I compared 2.5 miles with 5,000 yards as the unit of distance marked on the scope (the two distances are practically the same). The average error in estimating ranges was only about half as great with the 5,000-yard marking as with the 2.5-mile. We can read 10s, 100s and 1,000s much more rapidly and accurately than other units. In my radar-scope tests the four best scales were 1,000, 10,000, 2,000 and 5,000 yards, in that order.

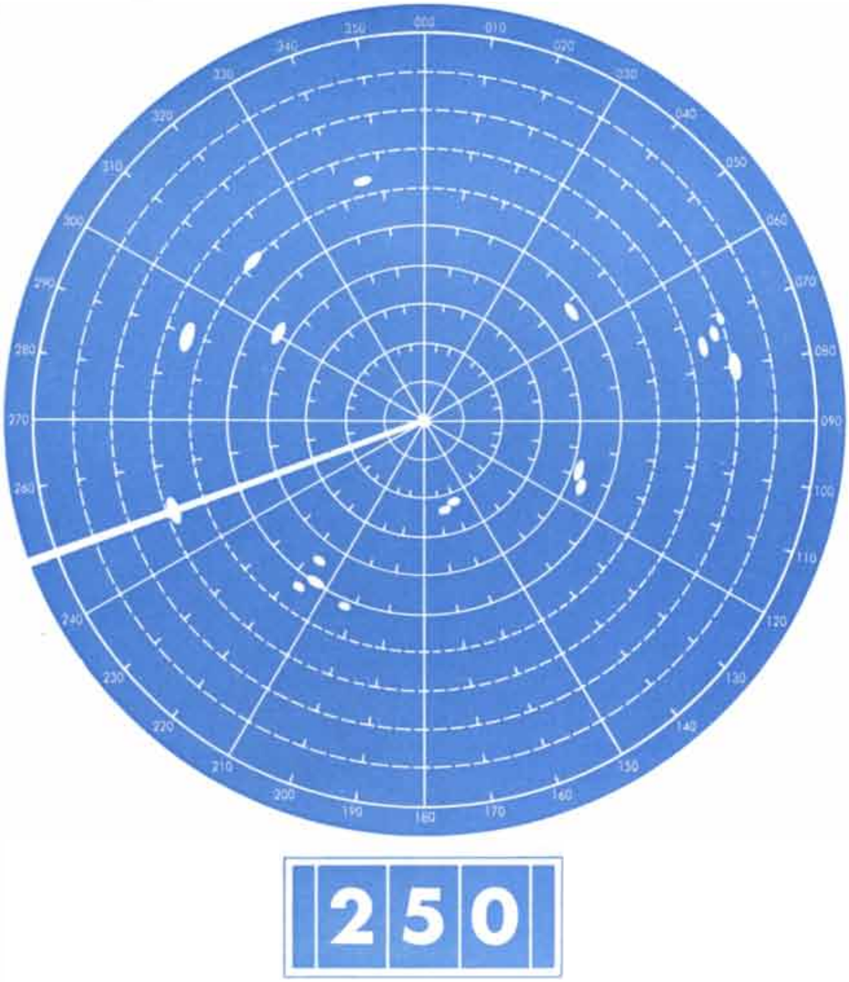
From many studies of scales, engineering psychologists have formulated some general principles about good and bad number systems. They have found that the scale of 10, subdivided into units of one, is the best of all. That scale-numbering is not a theoretical problem was impressed on me when I took a look around my own laboratory. There I found dials variously scaled with 1, 3, 5, 10 and 30 as the unit. The gas and electric meters in your own cellar are particularly frustrating examples of illegibility [*see photograph at the top of page* 78]. Part of the reading is indicated by pointers that turn clockwise, part by pointers that go counterclockwise. The meters violate two principles of efficient dial design: namely, that pointers should move clockwise to show increases, and that all in a group should go in the same direction. During the war, when there was a shortage of meter-readers, some utilities companies asked the public to read its own meters. The results were so chaotic that the companies quickly compromised by supplying cards on which the dials were printed and on which the householder was asked to draw the positions of the pointers. One wonders why the public should not be provided with meter dials it can understand.

SOMETIMES a dial is not as good as another kind of indicator. A case in point is the reading of the position of a target on a radar screen. To locate the direction of the target the operator rotates a cursor line until it falls on the bright spot made by the target. Usually he reads the bearing from a scale around the edge of the screen [*see drawing on next page*]. But a counter of the window type, which gives the degrees directly in numbers so that the operator need not read the scale, is more efficient. In a series of tests I found that the substitution of a direct-reading counter for the circular scale reduced reading errors from 10 per cent to 2 per cent and the time required for the reading from 3.3 seconds to 1.7 seconds.

The scope at the bottom of the opposite page illustrates another simple improvement in design. The concentric circles on a radar scope indicate distances from the observer. Generally he has to count the circles to the target pip to find its distance. But if, as in the







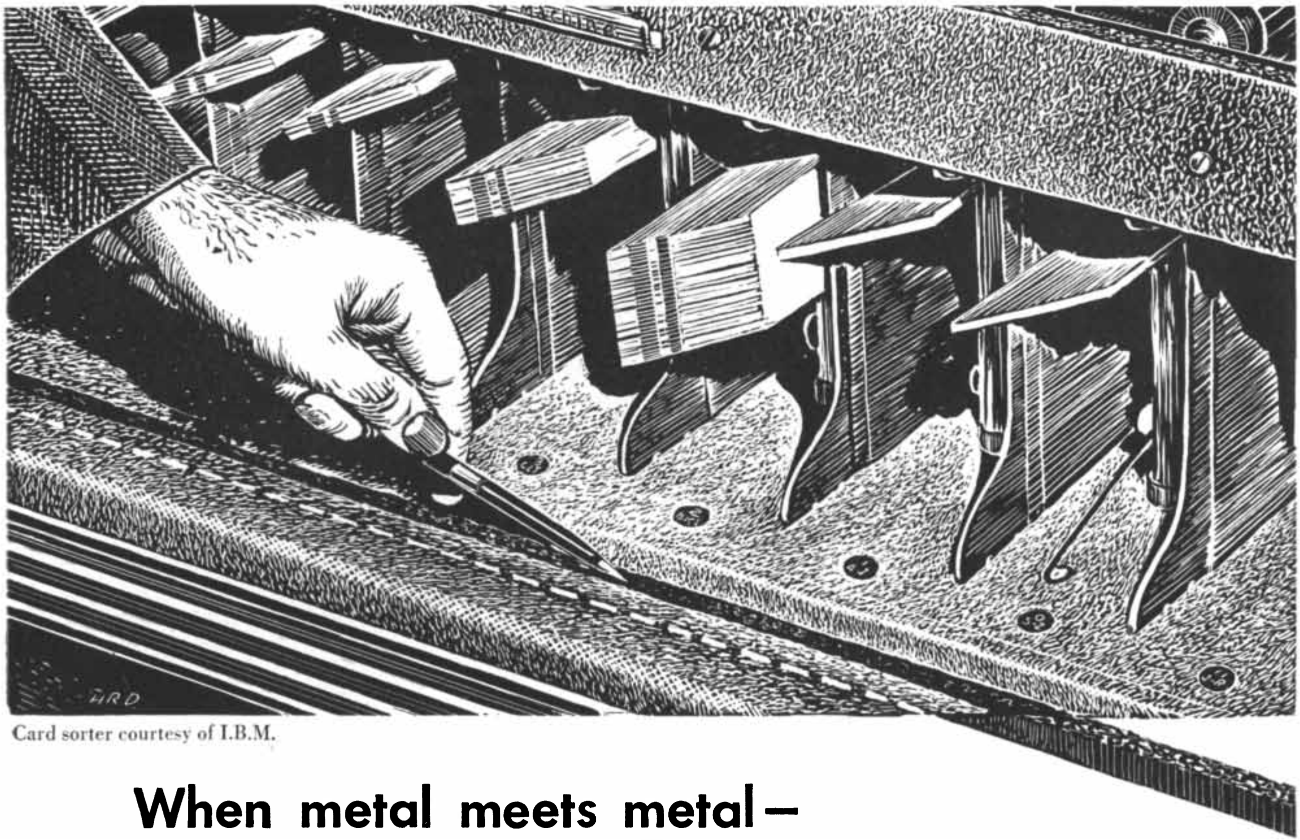
TARGET DIRECTION is read more quickly and accurately from window counter giving the bearing in numbers than from scale around edge of screen.

screen illustrated, the circles are drawn differently, the first four with solid lines and the next four with dotted lines, he can read the distance much more quickly. Most of us can grasp four or five identical objects at a glance; beyond that number we must count.

Human engineering has also done a good deal of work in redesigning symbols, such as are used, for example, on road signs. For reading with maximum speed and accuracy the symbols should suggest the objects they stand for and be clearly distinguishable from one another. Coding systems based on shape, color, size and brightness have been developed, but we are not yet certain which type will produce the best results. One practical outcome of this research was Sleight's design of traffic arrows which, size for size, can be recognized twice as far away as the ones now commonly seen [*see drawings in center of page 76*].

Human engineering has already reached a breadth of investigation that can only be suggested here. It covers auditory studies for the improvement of voice communication, explorations of conditions in the working environment, investigations of the design and size of machines. An operator must be able not only to see the dials and reach the controls but to find space for his knees and toes!

Engineering psychologists are also attempting to answer some broader questions. Most of the cases discussed in this article apply to separate components in man-machine systems, but engineering psychology has much to contribute to the over-all design of these systems. The automatic machines of which we have heard so much lately open up a new host of man-machine problems. In what sense is man superior to computing machines; in what sense inferior? What should man's role be in complex man-machine systems? Should he be simply a monitor? Should he be used as an integrator of sensing mechanisms? Should he be in a position to exercise executive decisions? These and many similar questions must be answered before we can design the most efficient man-machine combinations. The human engineer already has a great deal of information to work with, for psychologists have been studying capacities for over 70 years.



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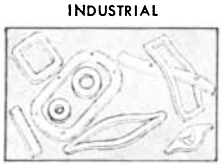

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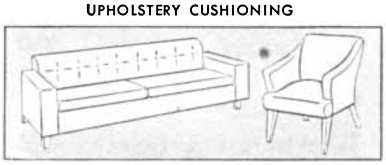

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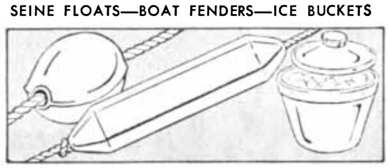

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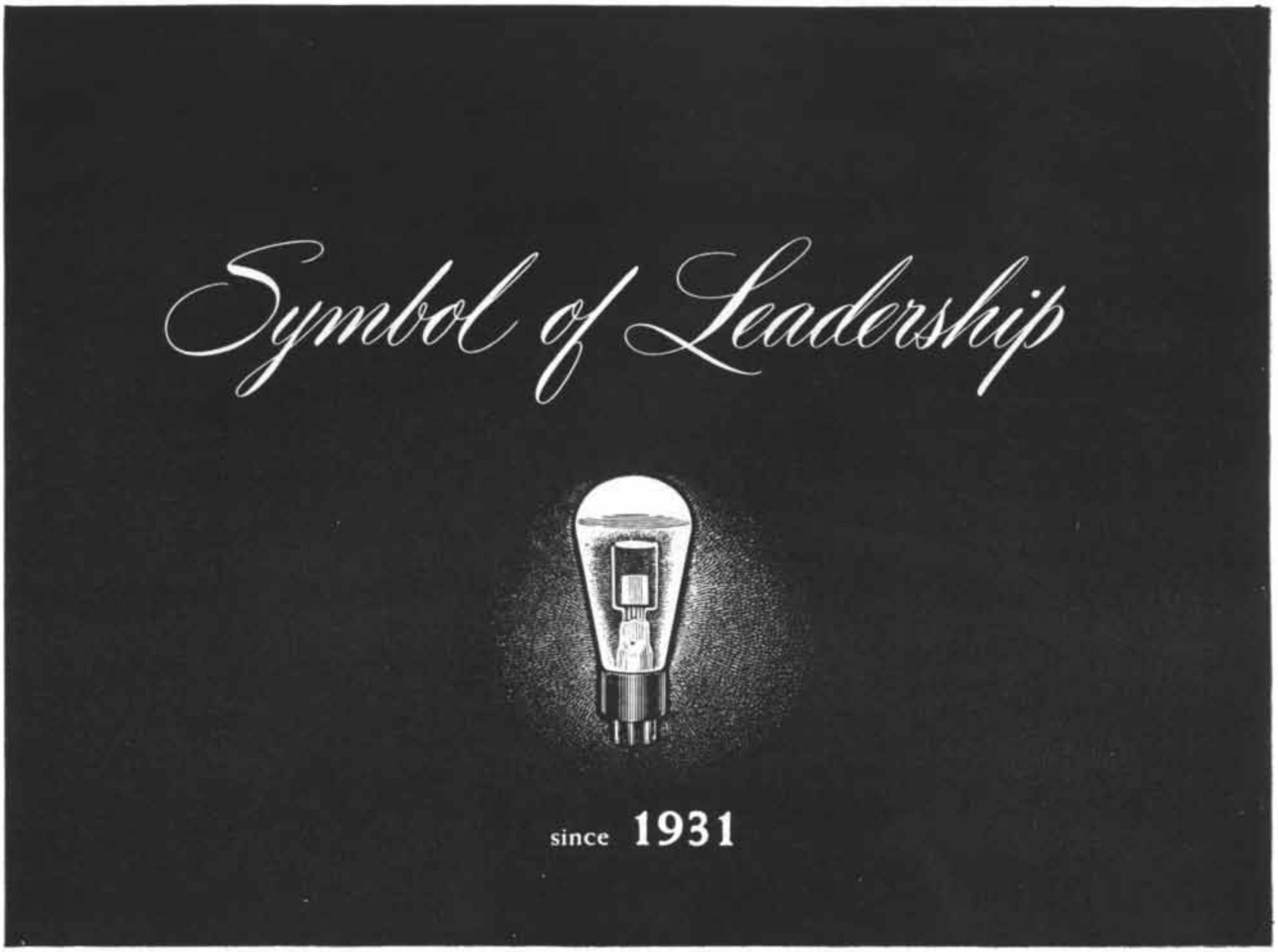

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ATP

The initials stand for adenosine triphosphate, the substance that provides energy for muscle contraction, for fermentation of sugar by yeast and for a host of other biological processes

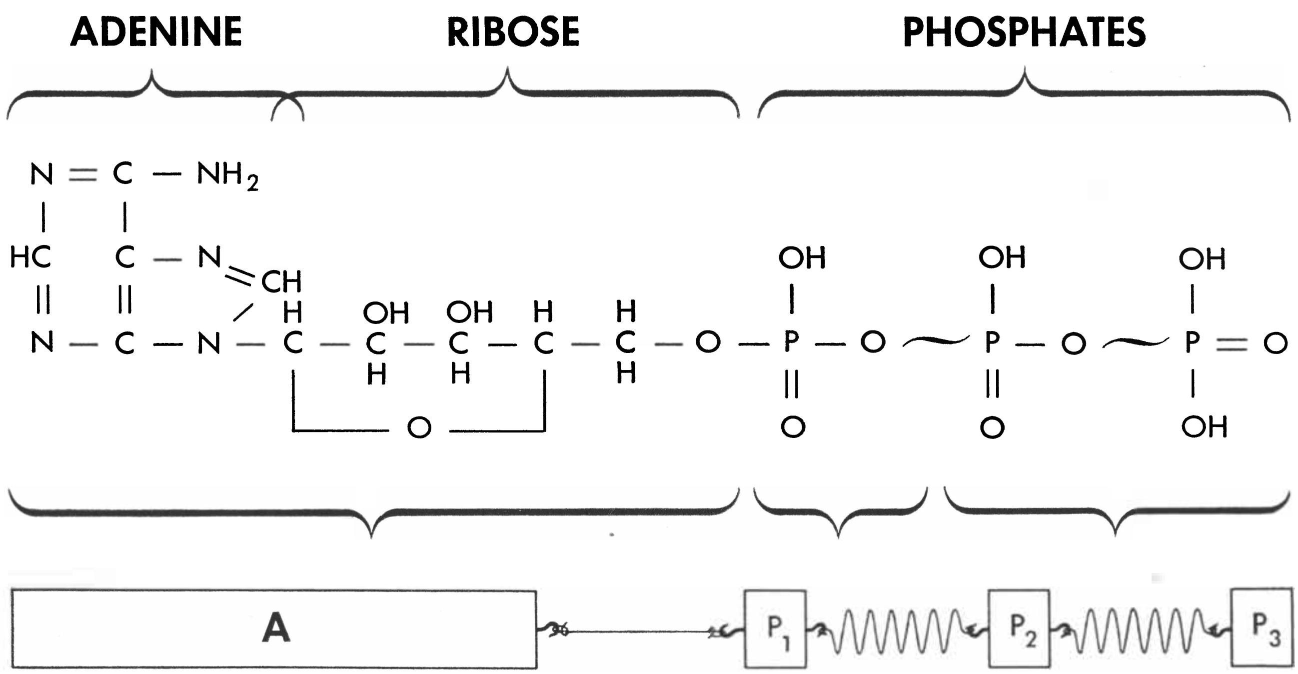
by Paul K. Stumpf

BIOLOGISTS wish that they knew as much about how living organisms generate energy as we do about how we get energy from fuels like gasoline and coal. They know that green plants take energy from sunlight, that some bacteria generate energy by oxidizing inorganic substances such as sulfur, that most of the animal kingdom obtains energy by consuming complex organic substances such as carbohydrates, proteins and fats. But one of the great problems in modern biochemistry is to ascertain precisely how organisms convert the energy into useful form. Green plants, sulfur-oxidizing bacteria and animals, different as they are, all trap, store and transfer energy by a complex series of similar reactions. And in the energy cycle of all of them a key role is played by the same specific compound—adenosine triphosphate, called ATP.

The trail of ATP leads back to 1860 when Louis Pasteur, completing one of his remarkable studies on yeast, enunciated the principle that yeast's ability to break down sugar into carbon dioxide and alcohol was a living ("vitalistic") function of the yeast cell. He supposed that, upon the death or destruction of the cell, the fermentation process would immediately cease. But in 1897 Eduard and Hans Buchner in Germany made a chance observation which corrected Pasteur's idea. Their discovery revolutionized the study of physiological systems and opened the modern era of biochemistry.

Searching for ways to obtain proteins for therapeutic uses, they ground a thick paste of freshly grown yeast and sand in a large mortar and then squeezed out the yeast cell juice in a hydraulic press. The viscous brown juice was unstable and could not be preserved by ordinary methods. One of the Buchners' assistants suggested the addition of large amounts of sugar—the same technique employed by housewives to preserve fruit. To their great surprise this *nonliving* juice from yeast cells converted the sugar to carbon dioxide and alcohol, in direct contradiction of Pasteur's dictum. This epoch-making finding, which earned Eduard the Nobel prize, enabled experimenters to design new and daring methods to probe the mysterious processes of living tissue without resorting to the use of whole animals or intact organs.

THE NEXT CHAPTER was written by the British biochemists A. Harden and W. J. Young in 1905. They found, as



ATP MOLECULE shows two types of phosphate link. Bonds of outer pair of phosphate groups (*wavy lines*) release 12,000 calories when broken. Bond of inner group has only 2,000 to 3,000 calories to give up. Mechanical analogue (*below*) shows high-energy bonds as extended springs, the low-energy bond as a string.

ISOLATED ATP is a white powder. The identical substance is found in microorganisms, plants and animals ranging from worms to human beings.

did the Germans in further studies, that the fermentative ability of yeast juice decreased gradually and could be restored only by the addition of boiled fresh yeast juice or blood serum. What was responsible for this renewal, they discovered after long search, was inorganic phosphate, present in both blood serum and yeast juice, which was gradually depleted by entering into chemical reaction with the sugar. The products of the reaction were found to be a mixture of phosphate-containing derivatives of sugar. This observation was of paramount value in focusing attention on the phosphorylated forms of sugar as the important intermediate steps in the degradation of sugar to alcohol and carbon dioxide.

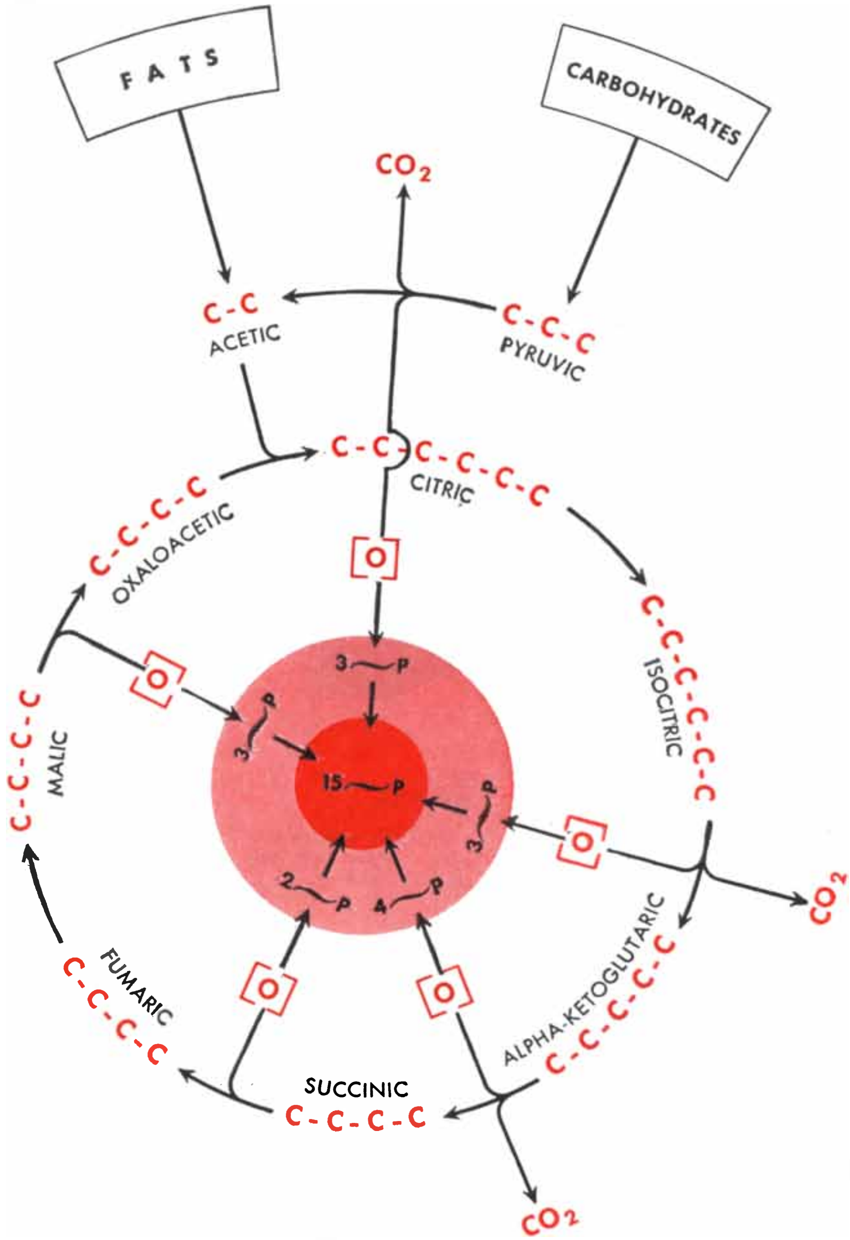
The third chapter also was the work of these British scientists. They found that when they filtered the crude yeast juice under pressure through a film of gelatin, they obtained a filtrate free of protein. This filtrate was completely inert. So was the protein, deposited on the gelatin film. But when the two components were mixed together again, vigorous fermentation took place. Harden and Young named the combination zymase; the filtrate, cozymase, and the protein residue, apozymase. Many years elapsed before the two fragments were accurately analyzed. We now know that cozymase is rich in certain compounds called coenzymes, which in many cases are derivatives of water-soluble vitamins, and that apozymase actually consists of many proteins, each a specific catalyst in one of the many reactions in the breakdown of sugar.

The next and key link in the chain of discoveries was made in 1929 by K. Lohmann, working in Otto Meyerhof's laboratory in Germany. To understand its significance it is necessary to remember that sugar does not undergo any real change until it is phosphorylated, but once in phosphorylated form it is readily split by specific enzymes into increasingly smaller fragments which are completely utilized by cellular mechanisms. Each step in the cleavage of the sugar molecule—and this applies also to all enzymic reactions—is governed by the energy requirements. What was the energy source for these reactions?

Still working with yeast juice, Lohmann found that an unstable, hitherto unknown substance in the cozymase filtrate was necessary for the phosphorylation of sugar; without it the reactions could not start. This substance was found to be what is now known as ATP. It consists of a nitrogen compound, adenine, linked up with a sugar named ribose and three phosphate groups. The energy is stored in the bonds that attach the all-important phosphate groups to the ATP molecule. Two of the phosphate groups are easily detached by simple hydrolysis of purified ATP with a dilute acid or specific enzyme. To pull off the third phosphate group requires more vigorous hydrolysis. Breaking one of the first two phosphate bonds releases 12,000 calories of energy; breaking the third releases about 2,000 to 3,000 calories. In other words, the first two terminal phosphate groups are very unstable, while the third is relatively stable. In 1940 Fritz Lipmann, then at Cornell University (now at Massachusetts General Hospital), put this rather complex bond-energy relationship into a kind of basic shorthand in an essay which is a classic of modern biochemistry. He called the unstable bond an "energy-rich phosphate bond" and the more stable one an "energy-poor phosphate bond."

ATP has since been found to be a ubiquitous compound in microorganisms, plants and animals ranging from nematodes to cockroaches to primates. Wherever it is found, it is always the same in structure.

HOW DOES ATP participate in biochemical reactions or cellular energy systems? These systems can be catalogued broadly into two groups. In the



CITRIC ACID CYCLE stores in the high-energy phosphate bonds of ATP the energy released by the oxidation of fats and carbohydrates. The cycle involves a series of acids which are symbolized by the number of carbon atoms (C) they contain. Malic acid, for example, has four carbons. Each turn of the cycle makes 15 high-energy phosphate bonds (*center*).

first, energy is released spontaneously; in the second, energy must be added from some source for the reaction to go. The first system is so organized that the energy released from the breakdown of foodstuffs is captured as high-energy phosphate bonds. These bonds are transferred to the ATP system, which, acting as a storage battery or transformer, shuttles the energy to the systems involved in biochemical syntheses.

The functions of ATP are bewildering in their variety. ATP either is involved in the synthesis or is actually part of the total structure of several coenzymes involved in tissue respiration. These coenzymes are derivatives of B vitamins. Vitamin B_2 (riboflavin) occurs in tissues in at least two forms. One contains an ATP residue as part of its structure, and the other is formed by an energy transfer of phosphate from ATP to riboflavin. Another vitamin, niacin, is part of two key respiratory coenzymes formed from ATP and other intermediates. The vitamin pantothenic acid combines with an ATP residue and another compound to make up the important coenzyme A. This substance, discovered by Lipmann about a decade ago, is of great importance for the utilization of acetic acid by living tissues. Acetate is the precursor

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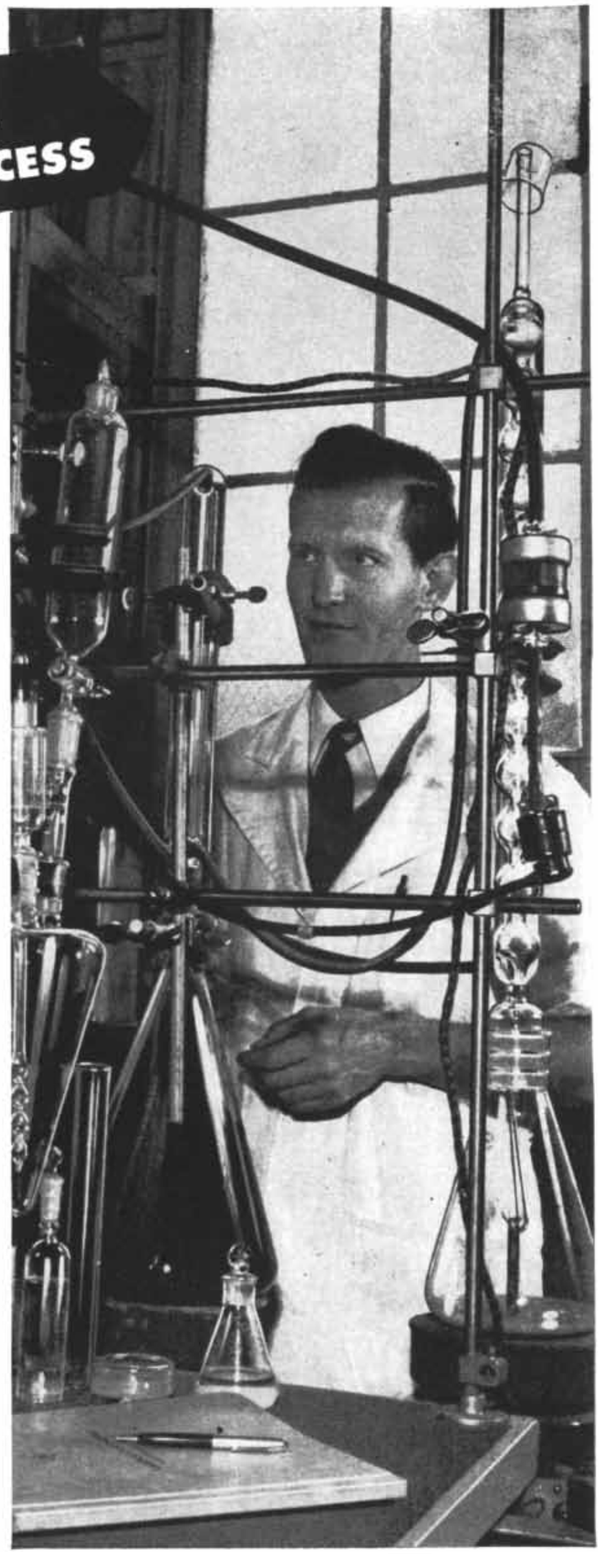

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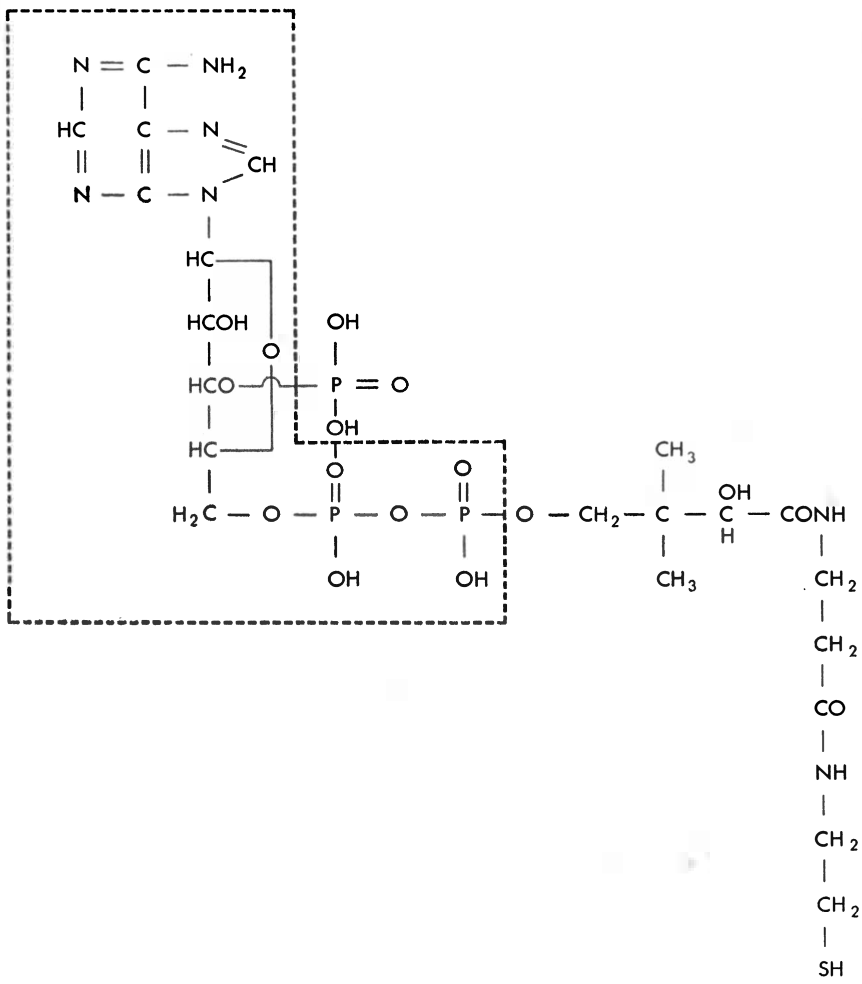
of fats, of sex hormones, of the nerve hormone acetylcholine and of a host of other extremely important compounds. The amazing versatility of ATP is one of the most impressive facts in biochemistry.

In addition to its active participation in vitamin action, ATP supplies the energy for muscle contraction. Muscles consist of innumerable bundles of fibers called fibrils. These in turn are made up of a complex protein called actomyosin, which is the actual contractile unit in muscle. Many investigators, including the Russians V. A. Engelhardt and M. N. Ljubimova, the Englishwoman Dorothy Needham and the Hungarian Nobel prize winner A. Szent-Györgyi, have explored the mysteries of muscle contraction. This research has shown that actomyosin threads contract when ATP is added. In contracting there is a simultaneous splitting and conversion of ATP into other phosphates. The energy derived from this cleavage is used for the contraction response of muscle protein. Here is a beautiful example of a biochemical reaction supplying energy for the performance of mechanical work.

It appears from recent investigations by W. E. McElroy and co-workers at The Johns Hopkins University that ATP also takes an active part in bioluminescence, the process that makes glowworms glow. It has been known for some time that oxidation of a fluorescent chemical called luciferin is responsible for the emission of light in bioluminescent organisms. The enzyme that catalyzes the reaction is luciferase. Newton Harvey of Princeton University had shown that a mixture of highly purified solutions of luciferin and luciferase obtained from *Cypridina*, a bioluminescent crustacean, produces light. No other additive is required. McElroy took extracts of luciferin and luciferase from the lantern organs of the firefly, but found that this mixture yielded no light. When, however, he added ATP and a trace of magnesium or manganese to the system, a flash of light appeared immediately! Here is a system which transforms chemical energy, derived presumably from ATP, into light energy.

Many other enzyme systems require as a crucial component ATP or one of its derivatives. In general, ATP systems are involved in fatty acid oxidation and synthesis, protein synthesis, sugar and



COENZYME A, which is important for metabolism of acetic acid, consists of ATP molecule (*dotted lines*) combined with pantothenic acid.

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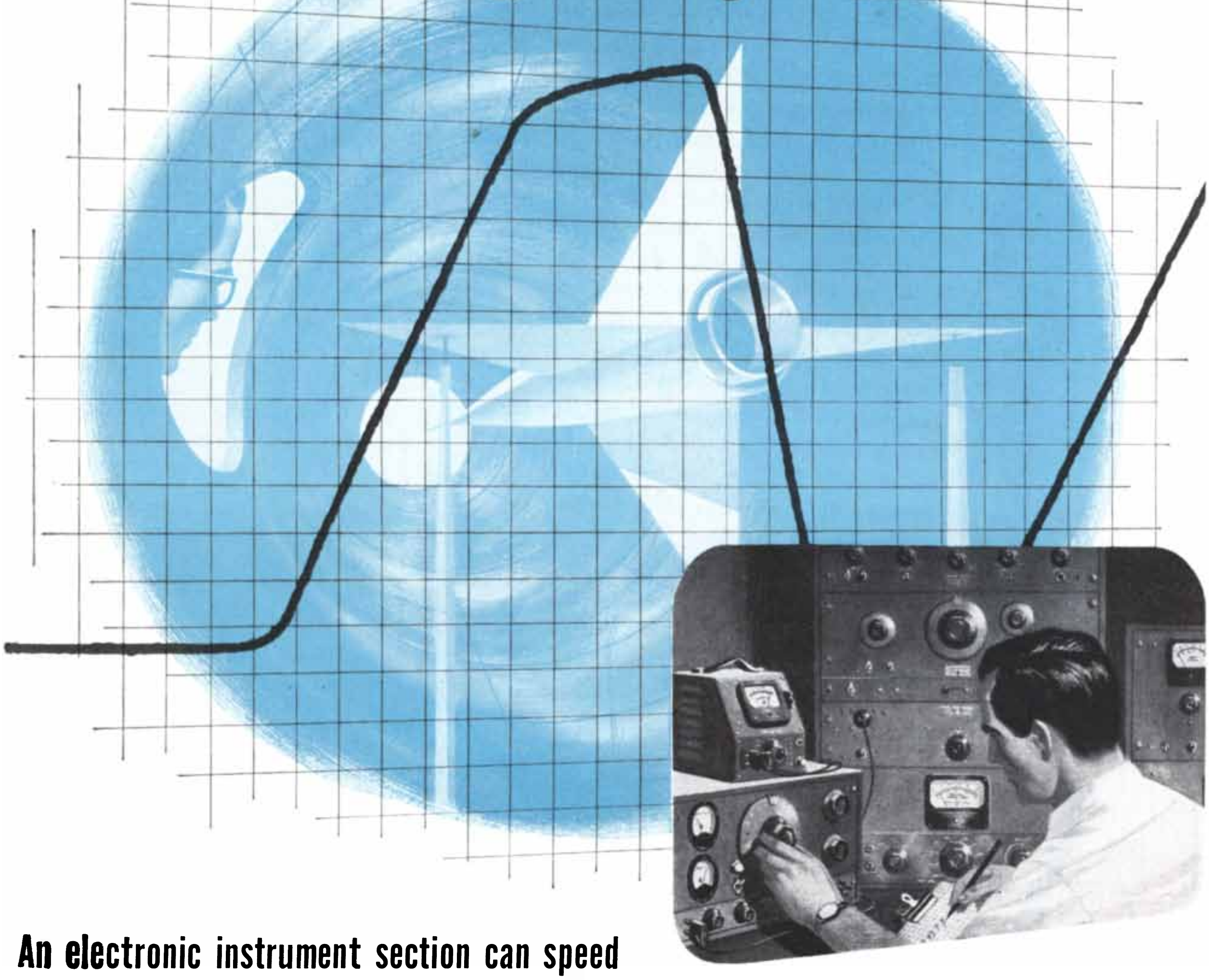

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starch formation, nerve conduction, kidney function and nucleic acid synthesis. Moreover, since ATP controls the rate of coenzyme synthesis, it indirectly governs the rate of many other biological reactions.

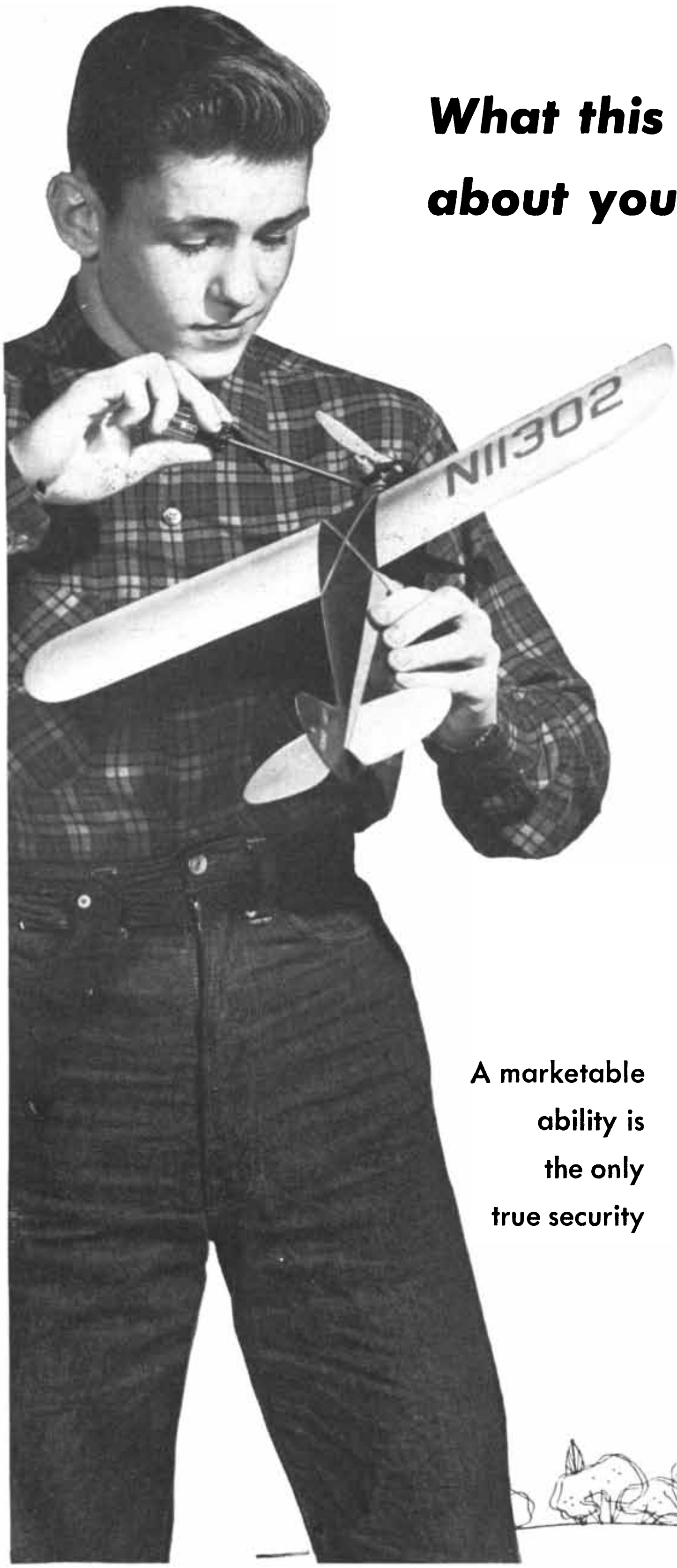
In VIEW of the importance of this substance, it is disconcerting to find that ATP occurs only in trace amounts. The utilization of ATP in the cell must be carefully balanced with its synthesis. Any disturbance in this balance would seriously undermine many fundamental biochemical reactions.

Only in the last few years have we gained some knowledge of how ATP is made and replenished in tissues. The yeast fermentation process is actually a highly inefficient method of storing and using energy: its conversion of one gram-molecule of sugar to alcohol forms only two ATP high-energy phosphate bonds, yielding about 24,000 calories, whereas there is enough potential energy in a gram-molecule of sugar to form about 56 such bonds. Recently a far more efficient system has been discovered. It operates in mitochondria, the tiny rod-shaped particles embedded in the cytoplasm of most living cells. The mitochondrion houses a highly organized galaxy of enzymes responsible for the oxidation of many compounds. One such system, called the citric acid cycle, burns pyruvic acid, the principal product of sugar fermentation. The cycle is like an endless belt composed of a series of specific enzyme systems. Pyruvic acid, carried on this belt, is gradually disintegrated and converted to CO_2 and water—the end products in the metabolism of all carbonaceous material in living cells. The energy produced by its oxidation is not lost as heat but is captured by parallel reactions which convert inorganic phosphate to organic phosphate of a high energy content. This phosphate is transferred to the ATP system to become available for the many cellular reactions requiring ATP. The mechanism is known as oxidative phosphorylation.

Biochemists have shown that oxidative phosphorylation traps about 40 high-energy phosphate bonds in ATP for each gram-molecule of glucose burned to CO_2 and water. In other words, the cell can fix 40 out of the theoretically possible 56 bonds.

However, the oxidative phosphorylation system is extremely sensitive. It vanishes when mitochondria are isolated and put in distilled water or kept at room temperature. And it is obstructed by poisons such as azide, by antibiotics such as aureomycin and gramicidin, and by dinitrophenol, once widely used as a reducing drug. These observations undoubtedly will provoke valuable new approaches in the biochemical study of health and disease.

What this boy can tell you about your own child's future



A marketable ability is the only true security

Even at his age, this boy knows that the only true security a man can have is a marketable ability—knowledge and training that industry wants, needs and is ready to buy.

For that reason, he is studying mathematics and the physical sciences in high school to equip himself for college engineering and enter business with a special skill. These studies are every high school student's open door to the great opportunities engineering and science offers youth today.

Next June, 23,000 engineering graduates will enter their profession where starting salaries are high. Some of them will process and package foods, some will design airplanes, some will set out in search of oil or go into manufacturing or invent new machines. They will lay out stores and factories, build new roads, plan whole towns. Many of them will become technically-trained salesmen.

All of them will be doing useful work, all will have a good chance for steady employment and advancement. Many will enter their own business. Their specialized, professional training will be needed for years to come to meet this generation's tremendous shortage of trained engineering personnel.

Don't foreclose on your child's future. See that he takes the high school courses that will qualify him to study engineering if he cares to when he reaches college age. For information, see your high school math or science teacher, guidance counsellor, the personnel department at your place of business, a prominent engineer in your community, or write to the Engineering Manpower Commission, 29 West 39 Street, New York 18, New York, for the free booklet, "Engineering As A Career."

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ATOMIC BOMB BLAST WAVES

They are shaped by weather and by acoustical laws to hop, skip and jump over long distances. At focal points they can suck out windows and crack plaster

by Everett F. Cox

WHEN the Atomic Energy Commission began in 1951 to test some of its explosives at its Nevada Proving Grounds, it was faced with the problem, among others, of minimizing the danger of blast damage to surrounding communities. The nearest sizable town is Las Vegas, over 60 miles away, but blast damage had been known to occur at widely erratic points and great distances from the site of even ordinary explosions. Study of this problem has amassed much new and useful information about acoustical and meteorological phenomena.

Sound waves sometimes hop long distances in an odd manner—a phenomenon first observed at the funeral of Queen Victoria in 1901. On that occasion a battery of guns fired in London was heard far off in Scotland, but the noise skipped a wide zone in between. The atomic blasts have exhibited the same hop, skip and jump principle of sound propagation, and the reasons why this happens have been a fascinating subject of research.

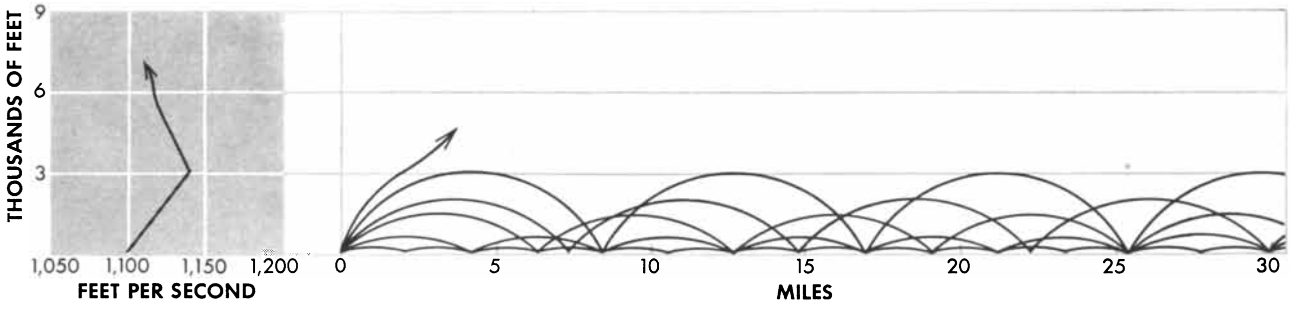
Of the 20 atomic explosions set off at the Nevada Proving Grounds since 1951, only three have caused indisputable blast damage to private property, and none has directly or indirectly injured human life. Of the three damaging blasts, two occurred in the first series of tests early in 1951 and one in the second series later that year. By now Carroll L. Tyler and his staff have learned to predict blast effects, insofar as weather is predictable, and know reasonably well when and when not to shoot.

At the site of an atomic explosion air-pressure perturbations are of a different order from those we ordinarily regard as sound. The smallest sound distinguishable by the average human ear consists of pressure changes of 100 millionths of an ounce per square yard. Loud noises, such as those from a riveting hammer, contain fluctuations up to one half pound per square foot. Near an atomic explosion there are really large changes in pressure. One mile from a burst, 2,500 feet above ground, the air pressure suddenly jumps from a normal 15 pounds per square inch to 23 pounds, then drops to 12 pounds, and finally returns to normal.

Out to 15 miles from a burst this shock-wave pattern generally holds: a heavy condensation of pressure crammed into a short interval, followed by a dip below normal, the heavy pressure diminishing with distance. On an ultrafast barograph, graphically recording variations of atmospheric pressure in time, the pattern appears as a continuous line which may show a quick pressure jump of only five hundredths of a pound per square inch at this distance, falling smoothly in three seconds to an almost equal amount below normal, then climbing back evenly to normal in another two seconds. At 15 miles, however, the return to normal is sometimes abrupt, making the barograph record look like the letter N. These two sudden changes in pressure are heard as two distinct thumps, and this double shock is the beginning of what we normally regard as sound. Sound signals usually consist of multiple condensations and rarefactions. At 30 miles or more from a detonation there are always five or more pairs of them.

Exactly how a double-shock or N-type wave is converted into multiple-cycle sound is unknown. Fortunately, at least for the Nevada Proving Grounds, the area of ignorance lies somewhere between 10 and 20 miles from a blast, which in this case is uninhabited.

WHEN an atomic explosion occurs in the air or on a tower, blast waves start out in all directions. If they proceeded on straight lines, it would be fairly easy to predict their paths. Practically all the blast energy that strikes the earth, however, is reflected off at an angle. In the atmosphere the waves meet other deflecting factors. Contrary to popular belief, particularly around Las Vegas, blast waves do not bounce down from clouds. The speed of sound through clouds differs but slightly from that through clear air, hence shock waves pass through clouds as if they were not there. The path of a blast wave is shaped by air temperatures, wind velocities and, to a minor extent, humidity. Indeed, the location and extent of blast damage depends upon weather conditions much more than on the size of the bomb.



LOW ALTITUDE ray-bending is shown in the sound speed plus wind-velocity graph (*left*). A layer of warm air at 3,000 feet causes the blast waves to bounce out in a series of relatively short hops (*right*) like jackrabbits.

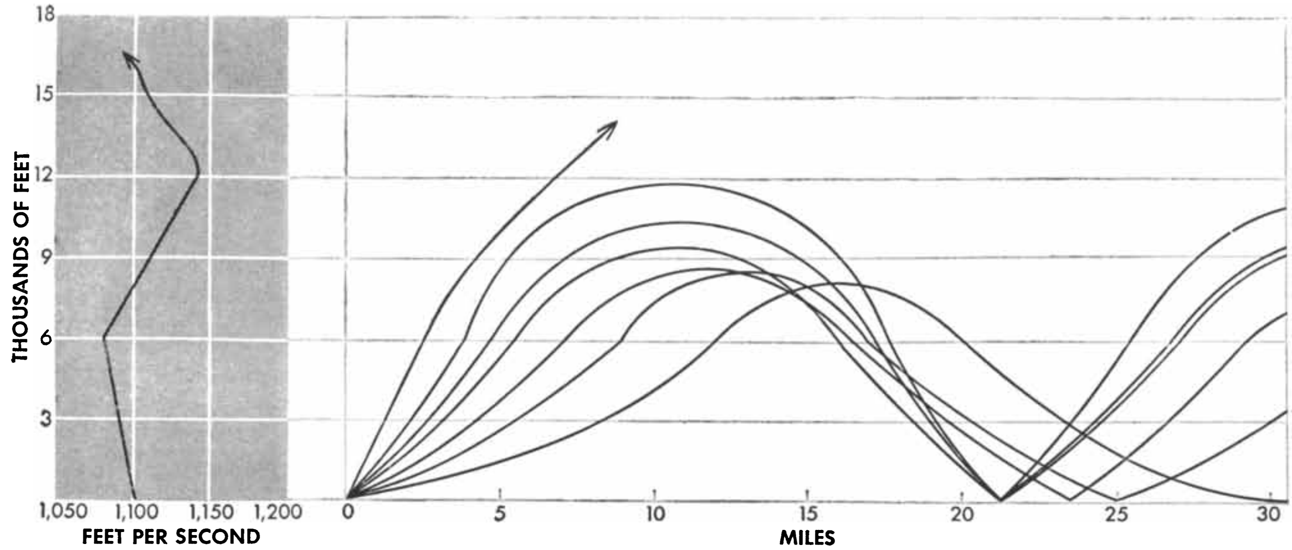
Since these conditions vary with altitude and change rapidly with time, predictions of blast-wave paths are not easy. The problem may be considered in two parts. The first deals with short distances, up to 100 miles or so, and the bottom six miles of the atmosphere. There the ordinary laws governing sound propagation apply. The second part will deal with greater distances and heights, where so-called abnormal transmission of sound takes over.

Two main sets of weather data go into the Nevada staff's computations on how the blast wave from an atomic explosion will travel through the lower atmosphere. Since the speed of sound in still air depends mainly on temperature (humidity is not a factor in the Nevada desert), the staff first prepares a graph showing the expected sound speeds at various altitudes on the basis of temperature forecasts for the range from ground level to 40,000 or 50,000 feet. This graph is then corrected for the wind factor by adding the second set of data: forecasts of wind velocities and directions along the paths toward inhabited areas, which in Nevada means only five directions. The result is a set of five graphs showing the sound velocity as a function of altitude in each of the five directions from the explosion site.

The shapes of these graphs govern whether the blast waves will shoot up or down or curve up and then smash down. A blast wave swings upward when the bottom of the wave front is traveling faster than its top, downward when the top is traveling faster.

CONSIDER a blast wave moving southwest from the shot point when the speed of sound is 1,100 feet a second at ground level, increases to 1,140 feet a second at 3,000 feet altitude and decreases above that height. Under these conditions the blast rays in the southwest direction that start off at a low angle—within 15 degrees of the earth plane—will be bent down sufficiently to hit the ground. This assortment of rays will hit all ground points in the southwest direction from the source to 8.5 miles away. After striking the ground, a ray bounces off with little loss of energy. It is again bent down, and goes on skipping over the terrain. Any spot within 8.5 miles will be hit by one direct ray and by reflected rays that may have bounced once, twice, three times or more. Beyond 8.5 miles all rays have bounced one or more times.

This pattern occurs when gentle breezes are blowing and a layer of warm air 2,000 to 3,000 feet high hangs over the proving grounds. That frequently is the case at dawn. The layer forms a channel through which the blast rolls out like a tumbleweed. Generally the air aloft is cooler than that close to the earth, and this would tend to curve blast



HIGH ALTITUDE ray-bending is shown here. High wind shear above 6,000 feet plus declining temperature bend blast waves into long looping curves. At focal points on the ground these curves pile up destructive energy.

rays harmlessly upward, were it not for winds. If the wind velocity increases with height at a rate of more than three miles an hour for each thousand-foot increase in altitude, the wind pattern will drive the blast back to the ground. This wind effect may focus many blast rays on one spot, and it accounted for all three of the damaging blasts so far experienced from the Nevada explosions.

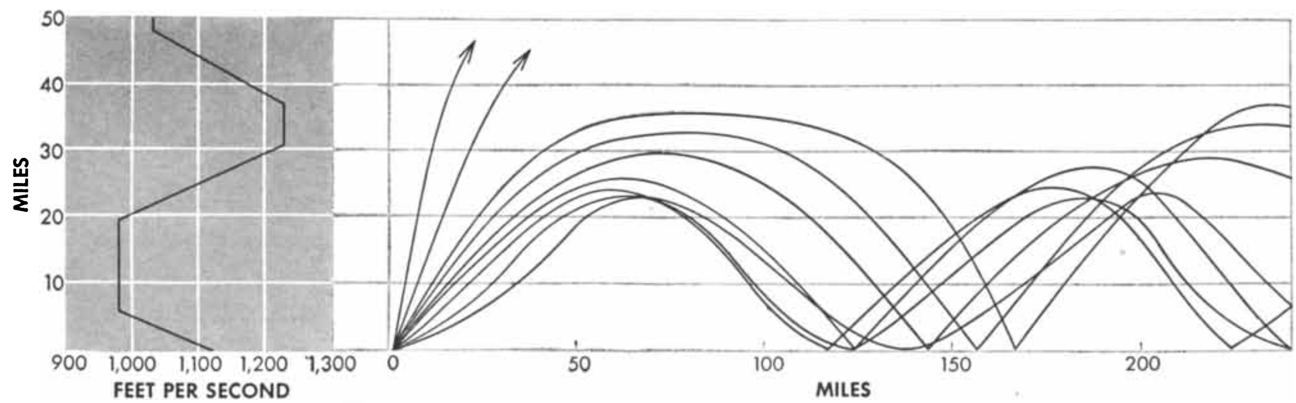
On February 6, 1951, low winds brought such a concentration of blast rays tumbling in upon the tiny settlement of Indian Springs, 25 miles from the A-bomb test explosion. The blast shattered dozens of windows in an auxiliary Air Force base there and tore loose from its hinges the open door of a nearby ranch house.

Four days earlier the blast from another explosion at the same site had skipped Indian Springs and struck at Las Vegas, 40 miles farther away. The primary focus of the blast rays was 11 miles from the blast, at a spot where it could only rupture the eardrums of rattlesnakes. But the desert floor acted as a mirror, and the bouncing blast struck at 22, 33, 44, 55 and 66 miles. On that sixth hop it cracked or shattered many large display windows in downtown Las Vegas. To guard against a repetition of this pattern the AEC later that year moved its primary test site to a point 80 miles from Las Vegas. But nature contrived to bring Las Vegas into range anyway. This time the winds created two foci, one 6.6 miles and the other 40 miles southeast from the shot point. Both foci socked Las Vegas, the longer one on the first bounce. Eleven big windows in Las Vegas succumbed, and crockery fell from the shelves in the Desert Inn's warehouse.

The pressure changes measured during these disturbances were really very small: about five pounds per square foot, which is no more than the pressure fluctuations created by a 45-mile-an-hour wind. Store windows, however, are very vulnerable to blast. They are fortified against inward pressure by strong steel beams, but only thin bronze frames hold them on the outside. Hence the rarefaction phase of a blast wave easily sucks them out. The remedy is simple: open windows or swinging doors will let air be sucked out of a building and spare the glass.

UP TO this point we have been dealing with blast waves bent down from relatively low levels, within the bottom six miles of atmosphere. Rarely do their first focal points lie further than 30 or 40 miles from an explosion, and severe wind shear must be present to make this happen. At each focal area of high energy concentration, loud noise is heard only on the side toward the explosion. If a primary focus is established 21 miles east from ground zero, for instance, the first noise zone may extend from there to 30 miles. On the second bounce the second zone of noise will spread from 42 to 60 miles, the third from 63 to 90, the fourth from 84 to 120, and so forth. The skipped regions, except for the first 15 miles from the explosion site, are zones of silence.

Observers 100 to 150 miles from the Nevada Proving Grounds are more likely to hear the blasts than the numerous watchers who drive up Charleston Peak,



IN THE STRATOSPHERE a warm ozone layer 30 to 40 miles up, called the ozonosphere, sends high blast waves back to earth at intervals of 120, 240, even 640 miles, creating alternate zones of silence and noise.

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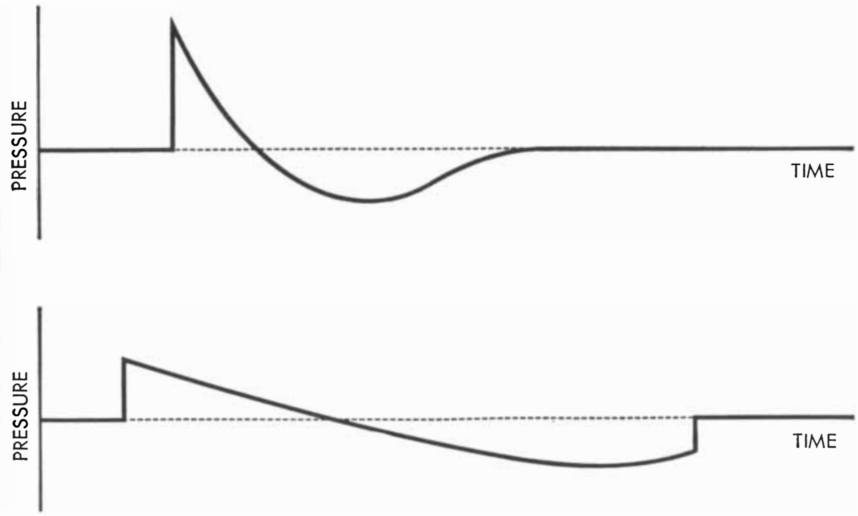

HIGH SPEED BAROGRAPH records changes in air pressure from two atomic blasts 15 miles away. Top, only one sharp change is registered; bottom, two sharp changes from normal are heard as two separate bangs.

40 miles south, each morning of an announced shot. This peculiarity has a counterpart in the familiar skip-distance phenomenon in radio transmission. It also takes us back to Queen Victoria's funeral guns and to other occasions, notably an explosion in Moscow on May 9, 1920, in which a zone of audibility, 90 miles out, completely ringed a zone of silence.

This consistent skip-distance of approximately 100 miles and the formation of a *ring* of audibility at 90 miles distance are hard to explain. Obviously a deflecting medium in the upper atmosphere must have something to do with it. It seems unlikely that winds are responsible. They could not explain the creation of a distant ring of sound, for winds do have direction. And at the low temperatures six miles up sound waves would travel so slowly that a wind of 85 miles or more per hour would be needed to bend them back to earth. Rarely do we find such high-speed winds.

What further confused early observers of far-jumping sound, and caused the British to dub it "abnormal sound," was that it apparently defied physical laws. It took longer to reach an observer than sound should. Up to 60 miles from an explosion, sound waves, given the right wind and temperature, will travel at the expected speed: 10 miles in 47 seconds. But at 80 and 100 miles observers may hear nothing or hear two booms spaced apart. And listeners at 120 and 140 miles will find that the sound travels slower to them: 10 miles per 52 seconds.

Observations of shooting stars by British astronomers supplied the clue that solved this puzzle. The only way to explain the measured brightnesses of meteorites was to assume there was a layer of hot air 30 to 75 miles above earth. This discovery, overthrowing the idea that the atmosphere steadily became colder at higher altitudes, provided the British meteorologist F. J. W. Whipple with a normal explanation of "abnormal" sound. At 30 to 40 miles altitude, air need be only slightly warmer than at the ground in order to bend sound waves down 80 to 180 miles from an explosion. Furthermore, alternating rings of silence and noise could be formed, since, unlike wind, the effect of temperature on sound velocity is non-directional. And the high arc of sound waves through first cold, then warm layers would account for the time lag.

UPPER-AIR measurements made since World War II by high altitude rockets have confirmed these assumptions about temperature. At 30 to 40 miles altitude a concentration of ozone absorbs certain wavelengths of sunlight and warms the air. Blast waves bent back by this zone are called ozonosphere signals. At 50 miles lies another warm zone—the ionosphere E-layer. This zone, even warmer than the ozonosphere, also deflects sound back to the earth.

Blast waves bent down from the ionosphere apparently are never strong enough to cause damage. But those from the ozonosphere are another story. As early as 1931 it was noticed that blast from practice firing of the guns of the Navy's Pacific fleet off Catalina Island skipped Los Angeles and broke windows in Bakersfield 150 miles away. Ozonosphere returns of atomic-bomb blasts in Nevada have not smashed windows, but they have cracked plaster. Damage claims against the AEC have come from St. George and Cedar City, Utah—cities 130 to 150 miles from the shot points. These cities heard many more A-bomb bursts than Las Vegas, half as far away.

Ozonosphere signals bounce and skip after they strike ground. As a result people in Los Angeles, Salt Lake City and even Albuquerque, N. M., 640 miles from the shot point, have heard some of the

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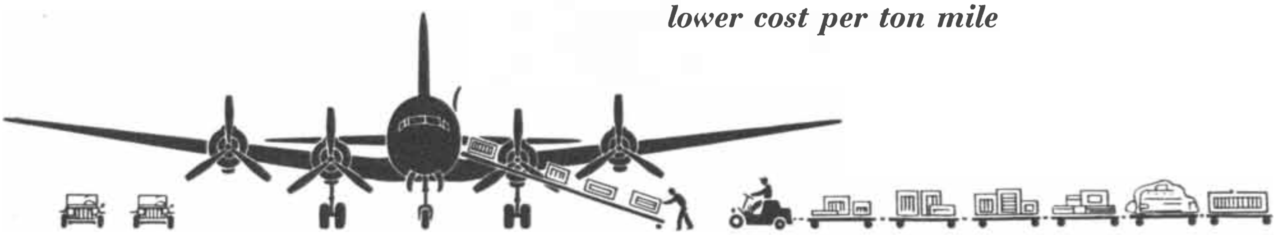

—the Douglas Liftmaster

Flying for the Air Force as C-118A and for the Navy as R6D, the Douglas Liftmaster delivers 14-ton payloads 2850 miles non-stop—at the lowest cost.

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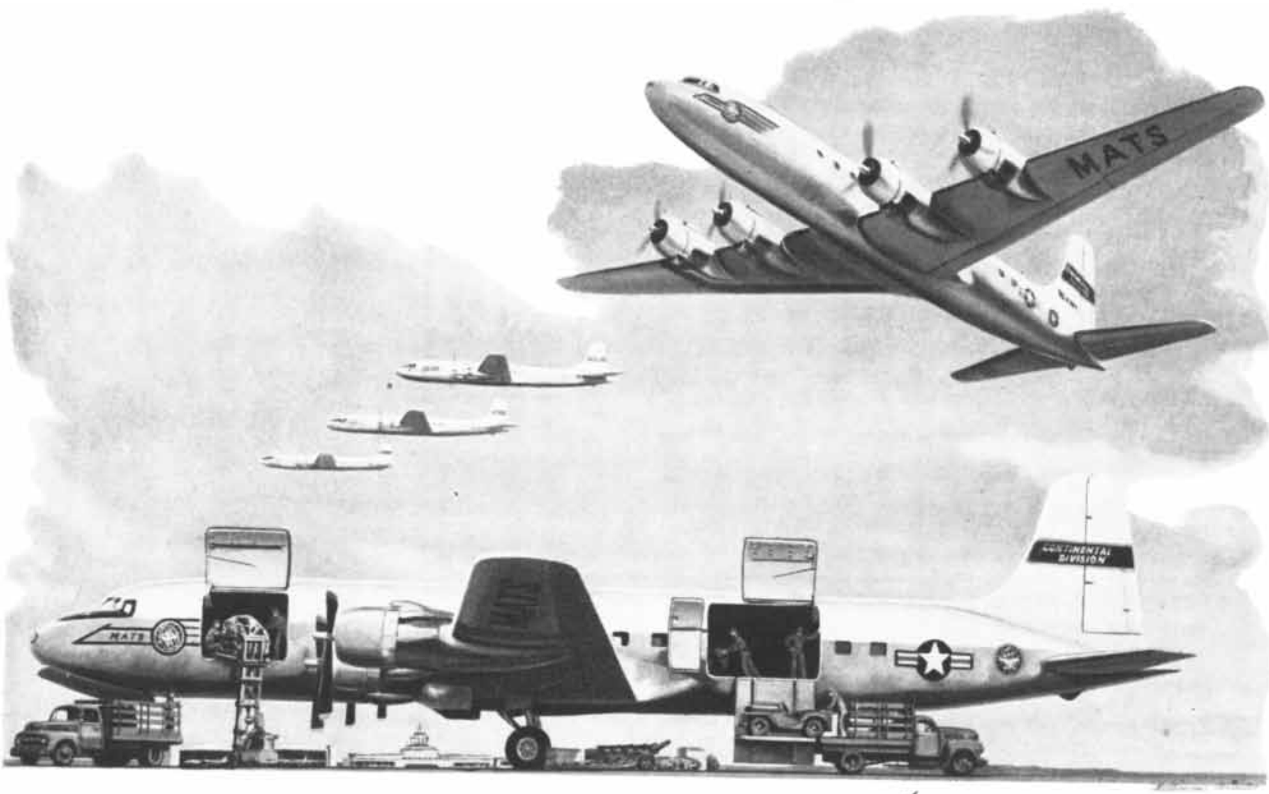

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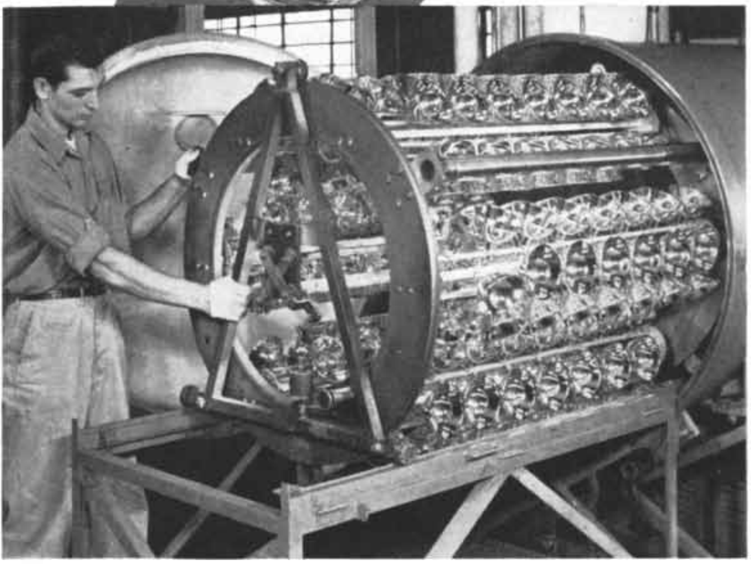
Nevada atomic shots. On one occasion ozonosphere-borne noises, after three reflections from the ground, reached Albuquerque 48 minutes after the explosion. On another, the ozonosphere signal, after bouncing once from the sands of the Mojave Desert, shook Los Angeles, causing an "earthquake" alarm. Blast waves sent back from the ozonosphere usually hit the earth first about 70 to 80 miles from the explosion site in midwinter and from 120 to 150 miles away in midsummer. But these figures are only approximate, and it will not be possible to predict more accurately where the shocks are likely to land until we have better information about wind and temperature fluctuations in the at-

FLAG in Las Vegas automobile dealer's window was sucked through break by atomic bomb blast wave.



After molding, the Tenite 2(MH Grade) reflector shells are given a lacquer undercoat and placed in a CVC 48 inch horizontal coater (Model LC1-48A). In less than half an hour, they are metallized and ready for another coating of lacquer. (Reliance Varnish Company supplied the undercoat and topcoat lacquers used).

As with all CVC vacuum coating units, this one comes equipped with all necessary controls, is easy to operate, requires little maintenance.

a CVC vacuum coater puts the gleam on a butyrate flash reflector

Most plastics are easy to vacuum metallize. But not all grades of butyrate.

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mosphere at heights of 35 to 50 miles. Today's weather balloons cannot go beyond 24 miles.

Microbarographs and operators with two-way radios are spotted throughout the Nevada-Utah-California area a few days before each test series. Two hours before the possible or probable "zero hour" of an atomic explosion and again at minus-one hour, a stack of TNT is detonated at the proving ground. The sensitive microbarographs record the strengths of these comparatively puny blast waves, and the operators radiophone their readings to the control point. Here the all-important comparison is made: How do their observations compare in magnitude with those from more than a hundred similar TNT explosions since September, 1951? From that series of records theoretical relations between troposphere weather and blast propagation have been thoroughly confirmed.

Theory predicts, and test authenticates, that under constant weather conditions the peak blast pressure reaching an observer will vary in proportion to the square root of the size of the shot. But nature can and does alter this ratio considerably. The blast pressure from a given charge of TNT, as recorded in Indian Springs, has varied as much as 3,000 to 1 under different weather conditions; that is, a one-ton shot on one day hits Indian Springs with as strong a blast as a 10-million-ton shot could produce on another day! The strength of the blast rays sent back from the ozonosphere probably also increases as the square root of the charge, weather conditions being equal, but since in this instance the "weather" is beyond the reach of our observation, there can be no conclusive check.

THE ENERGY released by a nominal A-bomb such as that first detonated at Alamogordo has been stated as equal to that from 20,000 tons of TNT. The experimental atomic explosives tested in Nevada of course have been of various sizes. This makes it difficult to predict the blast effects. There is no problem when the microbarograph readings are so large that a shot will definitely be dangerous, or so small that it is definitely safe; the tough cases are those in which the microbarograph readings are in-between. Until the blast scientists have had more experience with big explosions, they must find recourse in omphaloskepsis to predict the fate of distant windows on such occasions. But on the whole they have not done too badly. Blast-damage claims paid in Nevada and Utah for the 20 fission-weapon experiments so far have amounted to a little less than $43,000. Compared with other costs of the tests—uranium, plutonium and tall steel towers which evaporate in the fireballs—this is pin money.

What General Electric people are saying . . .

I. F. KINNARD

Mr. Kinnard, with GE since 1922, is manager of the Engineering, Meter, and Instrument Department.

". . . The importance of development engineering to business and industry in general can hardly be overestimated. Successful development engineers are constantly bringing along new products for a new age.

Sometimes developments occur in time-tested and proved products, where they are least expected. Over the past half century G.E. has produced many millions of watthour meters. They have undergone a gradual evolution and refinement so that many considered this a barren field indeed for the development engineer. Yet, as recently as 1948, a completely new watthour meter was developed. It successfully employed for the first time in the engineering world the principle of magnetic suspension of a rotating part. The maintenance-free life of the meter was increased manyfold by this development—a development that was the product of close collaboration of development engineers and materials specialists, particularly metallurgists working on new permanent magnet alloys.

An important part of the development engineer's job is to take that believed to be possible and prove it practical. And in doing this job, he contributes significantly to the evolution of new and better products for a constantly rising standard of living. And whether he realizes it or not, he is one of the vital links in our American economy. His developments are helping to win acceptance throughout the world for the kind of system that brings them forth.

General Electric Review

J. E. BURKE

Dr. Burke is manager of the Metallurgy Section of the Knolls Atomic Power Laboratory

". . . Nuclear reactors are new, but many of the design problems facing the metallurgist are strictly old-fashioned. Such properties as strength, formability, thermal conductivity, resistance to corrosion at high temperatures, and of course, cost and availability, are as important in controlling the selection of materials for nuclear reactors as they are in controlling the selection of materials for other applications.

In addition to these properties, however, it is necessary to consider the interaction of the materials with neutrons. Everything enclosed in the heart of the reactor interacts to some extent with the neutrons, and a very careful control of materials that are included in the reactor is thus necessary.

Since vanadium appeared to be a possible material for use in nuclear reactors, a program to investigate its properties was undertaken several years ago. Although nominally pure vanadium had been available for a number of years, it was brittle and could not be fabricated. Some ductile vanadium had been prepared by calcium reduction of the oxide, but only beads and small pellets were produced. In improving this product, additions of iodine were made to the mixture of V_2O_5 and calcium. Upon heating this charge in a closed pressure vessel, the additional heat provided by the combination of iodine and calcium raised the temperature enough so that a large ductile button of vanadium was obtained. Unfortunately, subsequent runs yielded buttons that were brittle. After extensive investigation it was finally found that the brittleness was due to nitride in the oxide, and the final procedure used involved a careful denitriding of the vanadium oxide by heating in moist oxygen for several hours. The product as now produced can be rolled into thin foil, drawn to wire, or given any of the standard metallurgical treatments except hot working. Because it avidly absorbs oxygen to become brittle, it cannot be heated in air.

There are, of course, a vast number of other metallurgical problems encountered. As in other fields, improvements in materials are imperative if important advances in reactors are to be made. These require continuing work not only directly in the development of better materials but also on the fundamental studies that pave the way for the applied developments.

General Electric Review

C. W. LaPIERRE

Mr. LaPierre is a Company vice president and is general manager of the Aircraft Gas Turbine Division

". . . In 1952 the Aircraft Gas Turbine Division produced over 90% more engines than it did in 1951. And with this increase in production, the General Electric Company became the world's largest known producer of jet engines.

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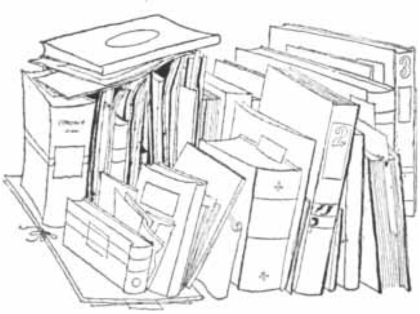


BOOKS

A new history of women, with special reference to their oppression by men

by Abraham Stone

The Second Sex, by Simone de Beauvoir. Edited and translated by H. M. Parshley. Alfred A. Knopf ($10.00).

SIMONE DE BEAUVOIR, a French novelist and a noted exponent of existentialist philosophy, presents in this volume of more than 700 pages a remarkable dissertation on woman. It is erudite; it is penetrating; it is brilliant and challenging. In describing the development of woman and her present status, she has drawn upon an amazing fund of knowledge of biology, psychology, anthropology and sociology, as well as on an extensive acquaintance with European and American *belles-lettres*. Her literary style often scintillates with dramatic phrase, poetic expression and Gallic wit. She has supported her theme with a mass of pertinent references and literary allusions, and has given it freshness and vitality.

Praiseworthy also is the editing and translation of the volume. This task fortunately fell to Dr. H. M. Parshley who for more than 30 years has himself observed and studied the "second sex" from his vantage point on the faculty of Smith College. His excellent preface and annotations and comments add much to the value of the book for the American reader.

In his preface Dr. Parshley summarizes its theme:

"The central thesis of Mlle. de Beauvoir's book is that since patriarchal times women have in general been forced to occupy a secondary place in the world in relation to men, a position comparable in many respects with that of racial minorities, in spite of the fact that women constitute at least half of the human race, and further that this secondary standing is not imposed of necessity by natural 'feminine' characteristics but rather by strong environmental forces of educational and social tradition under the purposeful control of men. This, the author maintains, has resulted in the general failure of women to take a place of human dignity as free and independent existents, associated with men on a plane of intellectual and professional equality, a condition that not only has limited their achievements in many fields but also has given rise to pervasive social evils and has had a particularly vitiating effect on the sexual relations between men and women."

In short, Mlle. de Beauvoir's theme is that through masculine manipulation woman has been reduced to an inferior position in life: she is the "second" sex. Because our society affords fewer possibilities to the female than to the male, she has in fact *become* inferior. Mlle. de Beauvoir, believing that this state of affairs should not continue, addresses herself to the question: How can woman obtain fulfillment, recover independence, achieve liberty?

In her discussion two existentialist terms recur again and again: "immanence" and "transcendence." Woman, says the author, is immanent: she is concerned chiefly with the maintenance of self, preoccupied with daily routines, the narrow round of repetitious details. Man is transcendent: he is progressive, creative, passes beyond immediate interests into a wider world. The objective is to achieve a state of society where woman, too, will be "transcendent."

The author ascribes the difference in status and situation between men and women entirely to environment—to training, upbringing, social attitudes and above all to man's domination and manipulation. She recognizes basic biological differences between the male and the female, but these, she holds, should not influence the status of woman in society. In sexual union neither sperm nor egg is superior; when they unite they both lose their individuality in the fertilized egg. It is true that the egg is passive, motionless, rounded with nutrient material, while the sperm is slender, agile, motile; but both of them lose their individuality in the act of fusion. The two cells play a fundamentally identical role. It is therefore illogical to deduce, as some have done, from the structural and functional differences between the ovum and sperm that the woman's place is in the home.

Woman, says the author, is the victim of the species. This is a great tragedy. All through life she has to go through crises. "Crises of puberty and the menopause, monthly 'curse,' long and often difficult pregnancy, painful and sometimes dangerous childbirth, illnesses, unexpected symptoms and complications—these are characteristic of the human female." Does it mean, then, that woman is biologically handicapped and hence cannot hope to achieve equality with man? No, says Mlle. de Beauvoir. Woman's biology does not condemn her to remain forever subordinate, because humans are not static but "forever in a state of change, forever becoming." Woman can resist and assert her individuality. Just how she can or should do so is not made quite clear. At any rate, it is the author's opinion that the reason woman has been relegated to the second sex does not lie in her biology.

I have dealt at some length with this aspect of Mlle. de Beauvoir's thesis because it seems to me basic to the entire argument. The rest of the book does not hold water unless the author can convince herself and the reader that the normal somatic and psychosomatic differences between men and women are not the main reasons for woman's position. Mlle. de Beauvoir does not evade the issue, and although her answers are somewhat tortured and neither conclusive nor convincing, she at least boldly assumes that the subjugation of woman is man-made, and if it is man-made, obviously it can be unmade.

The volume then flows in natural order. The author discusses the psychoanalytic and Marxian views on women and does not agree with either. She rejects "the sexual monism of Freud and the economic monism of Engels"—the psychoanalytic interpretation of woman's social claims as "masculine protest," and the Marxist economic interpretation of sexuality. She traces the history of women from the days of the nomads to the present, with special emphasis on the French scene. The latter fact is important, for much of what she says does not apply to social life or to the status of women in the U. S. today.

In a section called "Myths," Mlle. de Beauvoir gives a special chapter to "Myths of Woman in Five Authors." Although not especially relevant to the major theme, it is nevertheless one of the most charming chapters. Mlle. de Beauvoir is at her best in the area of *belles-lettres*.

The remaining chapters of the volume are devoted to a discussion of "Woman's Life Today." They trace her situation

from the formative period of childhood and adolescence to old age. The final chapter is called "Toward Liberation."

Because of my professional concern with the problems of marriage and family life, I found the chapters dealing with "The Married Woman" and "The Mother" of special interest. Like all the other parts of the book, these chapters are written with charm and eloquence, with astute observation and keen insight. Yet they exhibit a one-sidedness and distortion which is not merely provocative but often provoking.

Marriage and family life, according to the author, are only a burden to woman. A girl has to marry because this is the sole way she can become integrated into the community; otherwise she is viewed socially as so much "wastage." While a man *gets* married or *takes* a wife, a girl is *given* in marriage. In marriage she loses her identity: she takes her husband's name, joins his church, his class, his circle, his family—becomes his other "half." The husband is the productive worker. He "incarnates transcendence" (even, one supposes, if he merely tightens bolts or rivets steel girders all day), while the woman is "doomed" to immanence, to "continuation of the species and the care of the home."

One wonders where, and how long ago, this snapshot of the "doomed" woman chained to the stove and the crib was taken. Does it truly represent present-day French society? It certainly does not apply to marriage and family life among young people in the U. S. Here the tendency, if anything, is for the man to become more immanent and the wife more transcendent. He participates increasingly in the duties of keeping house and the care of the children, while she takes greater part in outside work and political and social life. According to recent figures, somewhere between 40 per cent and 55 per cent of married women today contribute partially or in full to the earnings of the family—clear evidence of woman's increasing participation in outside work and a sign of woman's growing "transcendence"—if that is so desirable.

Sexually as well as socially, according to Mlle. de Beauvoir, the married woman finds little satisfaction. "Since the sexual act is regarded as a *service* assigned to women, it is logical to ignore her personal preferences." Women are sexually frustrated, and this "has been truly accepted by men." Many men, in fact, enjoy "feminine misery," and males "have had no scruples at all in denying their mates sexual happiness." Marriage, society's calculated effort to regularize sexual life, "kills feminine eroticism."

Mlle. de Beauvoir argues that affection and passion cannot both be obtained in marriage. "Marriage," she says, "is obscene in principle insofar as it transforms into rights and duties those mutual relations which should be founded on a spontaneous urge. . . . Physical love should play in any human life an episodic and independent role; and, above all, it must be free." Conjugal love is anathema to Mlle. de Beauvoir. It is a "complex mixture of affection and resentment, hate, constraint, resignation, dullness and hypocrisy." Marital happiness is merely "a gilded mediocrity lacking ambition and passion, aimless duties indefinitely repeated, life that slips away towards death without questioning its purpose." No wonder, then, that in the author's opinion marriage is today merely "a surviving relic of dead ways of life." It should, in fact, be prohibited "as a career for women."

If I read it all correctly, Mlle. de Beauvoir's book merely gives a new expression, eloquent and persuasive though it may be, to the rather old idea of "free love." If neither sexual fulfillment nor liberty of the individual can be obtained within marriage, then marriage and family life must be replaced by some new form of male and female relationship. What this new form would be like, or should be like, Mlle. de Beauvoir does not make clear.

Nor does she have a high opinion of motherhood. "Ensnared by nature, the pregnant woman is plant and animal, a stockpile of colloids, an incubator, an egg; she scares children proud of their young straight bodies and makes young people titter contemptuously . . . she is a human being . . . who has become life's passive instrument." Not a pretty picture, but is it perhaps a little too surrealistic? How closely does it represent the picture of a woman who voluntarily and deliberately plans a baby and takes joy and pride in her maternity? There are millions of such mothers everywhere today.

The unhappiness of the mother, according to the author, reflects itself on her child. "The great danger which threatens the infant in our culture lies in the fact that the mother, to whom it is confided in all its helplessness, is almost always a discontented woman: sexually she is frigid or unsatisfied; socially she feels herself inferior to man; she has no independent grasp on the world or on the future. . . . One is frightened at the thought that defenseless infants are abandoned to her care." Under whose care, then, should the infant be placed? Would a caretaker in a state nursery necessarily be a "transcendent woman" —without frustrations and hostilities, better able to look after a brood of children than a mother would after her own? What about the generation of women in the U. S. who have been brought up on Arnold Gesell and Benjamin Spock? Would they accept this sorry estimate of themselves?

In support of her argument the author makes frequent reference to case histories cited by the psychoanalysts Wilhelm Stekel and Helene Deutsch. These two authors are in fact, the most frequently quoted in the volume. But both of them have dealt mainly with pathology—with the neurotic, the psychotic, the disturbed personality. The case histories they relate can hardly be taken to represent the normal pattern of human emotions and behavior.

I confess my own prejudice. I am prejudiced against an attempt to eliminate family life from human relationships. The greatest human satisfactions and the deepest emotional gratifications are still to be found within the circle of the family. Ralph Linton, the anthropologist, ended a chapter in *The Natural History of the Family* with the following statement: "The ancient trinity of father, mother and child has survived more vicissitudes than any other human relationship. . . . In the *Götterdämmerung* which over-wise science and over-foolish statesmanship are preparing for us, the last man will spend his last hours searching for his wife and child."

Mlle. de Beauvoir's book will be read, as it should be read, by a host of literate men and women. It will be praised, as it should be, for its wealth of material, its high literary qualities, its stimulating and challenging ideas and viewpoints. But it will also be criticized for its slanted outlook and sometimes distorted views. In her introduction Mlle. de Beauvoir quotes approvingly the statement of a French feminist: "All that has been written about women by men should be suspect, for the men are at once judge and party to the lawsuit." The same strictures would presumably apply to one who reviews a book about women. Nevertheless, this reviewer ventures to predict that most of the criticism will come not from members of the "first" but of the "second" sex.

Short Reviews

ANTOINE LAVOISIER, by Douglas McKie. Henry Schuman ($6.00). On May 8, 1794, a month after Danton's execution and at the peak of the Great Terror, Antoine Lavoisier perished on the guillotine. "Only a moment to cut off that head," said Lagrange to Delambre next day, "and a hundred years may not give us another like it." Lavoisier, a founder of modern chemistry, also distinguished himself in physiological research and as a geologist and cartographer. He wrote extensively on the economic and fiscal problems of France, exerted himself as a social reformer and agriculturist, served as director of the Academy of Sciences and was an indefatigable planner, organizer and adviser to government commissions. Mr. McKie has written a painstaking biography which unhappily makes a marble statue of the man. The merit of the book is its scrupulous account of Lavoisier's manifold activities; its weakness is the lifeless, uncritical delineation of what was evidently an extraordinary, though not necessarily sympathetic, figure.

Man the Chemical Machine, by Ernst Borek. Columbia University Press ($3.00). Dr. Borek's book is a popular explanation of the principal ideas of biochemistry and of the experiments, brilliant conjectures and lucky accidents which led to the amazing growth of this rich branch of science. The topics include enzymes, vitamins, sugars, isotopes, amino acids and proteins, immunology, virus research, and the chemical basis of genetics. His story moves at an easy gait. It is not only enlivened by anecdotes and dramatic incidents but reflects the author's awareness of the social implications and responsibilities of science.

Ballistics in the Seventeenth Century, by A. R. Hall. Cambridge University Press ($4.00). It has been suggested that the impetus to scientific research during the 17th century came largely from practical needs—war, manufactures, navigation and the like. Hall argues that this judgment is a misreading of the growth of scientific thought—certainly so far as ballistics is concerned. "Men were led to discoveries in mechanics less by their practical usefulness than by the logic of historical development and the relative ease of success in that part of science at that stage in its evolution." Without belittling the influence of society on the fashions and the emphasis of research, Hall maintains that the theory of projectiles was pursued more because it offered a useful and familiar mathematical approach to long-standing problems of mechanics than because the military required artillery data. He points out that the art of gunmaking was much too crude at the time to make use of a highly refined theory; a century later soldiers were still required to hold their fire until the whites of the enemies' eyes came into view. Hall's essay also emphasizes the timelag—greater in the 17th century than today—between theoretical advance and practical application, and "the vast changes in society which have not been sought, but have resulted accidentally as a by-product of increasing scientific knowledge." His book is a thoughtful and illuminating contribution to the history of science. Not the least of its merits is that it will spur further inquiries and promote debate.

The History of Astronomy, by Giorgio Abetti. Henry Schuman ($6.00). Until recently the only history of astronomy available to English-speaking students was Arthur Berry's *Short History of Astronomy*, an excellent work but published in 1898 and obviously out of date. In 1951 Peter Doig, editor of the *Journal of the British Astronomical Association*, published an able, concise work. Now we are offered in translation a second authoritative survey. Mr. Abetti, the director of the Astrophysical Observatory of Arcetri in Florence, covers the subject from the Chaldeans to Palomar. Besides describing the main features of astronomical progress and the work of modern observatories, his book provides an agreeable accompaniment of historical and biographical detail. He emphasizes—or as he puts it, "lingers on"—the contribution of Italian astronomers, but that is all to the good. Without distorting the record, Abetti's treatment supplies information which makes possible a sounder appreciation of the development of this most ancient and lively branch of physical knowledge. The general reader will enjoy the book, as will the student and the astronomer. Illustrated.

Stars in the Making, by Cecilia Payne-Gaposchkin. Harvard University Press ($4.25). Mrs. Payne-Gaposchkin, Phillips Astronomer at Harvard University, gives a most attractive account of present-day knowledge of the skies. She describes the heavens' heterogeneous population of sedate and rampageous stars, of twins and families, of interstellar dust, gas and atoms; the structure, traffic, size, age and life expectancy of the universe and its members; how it evolved and what various imaginative theorists think is going to happen to it. The ending, it is thought, will not be happy, but there is the admitted possibility that present forecasts may be wrong, and in any case everyone agrees that the last day—for the universe, that is—is pretty far off. This is the best all-around popularization of astronomy since the days of Jeans and Eddington. Excellent illustrations.

The Earth: Its Origin, History and Physical Constitution, by Harold Jeffreys. Cambridge University Press ($13.50). This third edition of a standard work by one of the leaders of British scientific thought has been almost entirely rewritten. The author has dropped chapters on the origin of the solar system and has added material on recent developments in geophysics, including information on the elastic properties of the Earth, the distribution of its density and its probable composition, the strength of the Earth's outer parts, its age, thermal history and the origin of its surface features. Jeffreys is an uncommonly literate scientist, and his book, despite its specialized and mathematical approach, will delight any reader who enjoys good writing and the high adventure of scientific speculation. As a piece of bookmaking and typography, the new edition is a superlative achievement.

Understanding the Weather, by T. Morris Longstreth. The Macmillan Company ($2.50). In this book of 100 pages, a thorough revision of a work first published 10 years ago, the author gives a simple account of the ways of wind, fog, rain and snow, the natural history of clouds, the causes and behavior of thunderstorms, hurricanes and tornadoes, the chancy business of forecasting and the meaning of the common technical terms of meteorology. The average reader will get more from this unpretentious, gracefully written little essay than from other meteorological primers three or four times its size.

British Scientists of the Twentieth Century, by J. G. Crowther. Routledge and Kegan Paul, Ltd. ($5.50). Mr. Crowther, the scientific correspondent of the Manchester *Guardian*, is especially interested in the social relations of science. This book consists of careful, detailed biographical essays on J. J. Thomson, Lord Rutherford, Sir James Jeans, Sir Arthur Stanley Eddington, Frederick Gowland Hopkins and William Bateson. Crowther writes in a flat, unpretentious, frequently jerky style, yet manages to convey a clear picture of these men and of their work in astronomy, experimental and mathematical physics, biochemistry and genetics. No writer on science makes difficult subjects more lucid than Crowther does. His essays are marred, however, by his insistence on judging scientists and their works according to his strongly-held social theories and, one must add, prejudices. These require him to drag in all sorts of irrelevant considerations and comparisons, to say of Thomson or Eddington that, brilliant though they were as innovators, they would have achieved much more if they had lived in a society guided by Marxist principles and had developed a mature sense of social responsibility. In other words, Crowther builds up his men only to bash them over the head. His book is well worth reading, but one must be as circumspect in going through it as one would be in traveling across Sherlock Holmes's "great Grimpen Mire."

What Is Science?, by Norman Campbell. Dover Publications, Inc. ($1.25 paperbound, $2.50 clothbound). Campbell, who died in 1949 at the age of 69, was a British physicist and philosopher of science highly regarded by specialists in these subjects but not well known to the general public. This popular study, based on lectures to adult education groups at Leeds, appeared in England in 1921 but has only now been published in the U. S. It deals with such fundamental concepts as numbers, measurement, the meaning and discovery of scientific laws and the general principles of the applications of science. It is a first-rate primer and deserves a wide audience. Campbell enjoyed to a conspicuous degree the true philosopher's ability to make men think anew about matters they have long taken for granted but never fully understood.

MATHEMATICAL MODELS, by H. Martyn Cundy and A. P. Rollett. Oxford University Press ($4.25). In this unusually attractive book the authors furnish clear and detailed instructions for making models to illustrate figures of plane geometry, the five regular Platonic solids, the four beautiful Kepler-Poinsot polyhedra, Möbius strips, Klein bottles, sphere-packs, linkages, statistical and mechanical models, machines for drawing curves and various other interesting mathematical objects. The book was "born in the classroom" of an English public school. Its authors are endowed not only with imagination and practical skill but with an acute understanding of how model-building can contribute to mathematical education. It is a pleasure to follow their work, and the publishers have enhanced the reader's satisfaction by an exemplary piece of printing, diagram-making and design.

THE MEANING OF DREAMS, by Calvin S. Hall. Harper & Brothers ($3.00). For this unpretentious interpretation Dr. Hall has collected a great many dreams from "normal" people. Since most of the literature on dreams comes from neurotics or psychotics, his book is an addition to the literature on the subject. Although he diverges from Freud in some ways, the author has been led by his data to conclusions that closely parallel Freud's theory of the unconscious and the function of dreams. Like Freud, he sees men as creatures of conflict between impulse and cultural acceptability. Their dream-lives play with unending variety on the theme of this conflict. Hall believes that although one dream will tell something about a person, it is only through a series of dreams that a man's real feelings and attitudes can be understood. The clues in a single dream may be interpreted in many ways, but a series of dreams is a mosaic in which the pattern of fears, conflicts and methods of solution can be laid bare. Hall describes the dream in terms of setting, plot, characters and the feelings engendered. He points out the differences between male and female dreams. His discussion relates dream symbols to the common mutually exclusive goals of human beings: to be free but to be secure; to be gratified but morally acceptable; to be both woman and man; to survive but to be at peace; to hate but not be hated; most of all, to hide anxiety in cloaks of many shapes and colors. The book is directed to the lay reader; it is straightforward but not condescending.

PROBLEMS OF CONSCIOUSNESS, edited by Harold A. Abramson. Josiah Macy, Jr., Foundation ($3.25). The merits and defects of round-table discussion are plainly visible in this transcript of the third Josiah Macy, Jr., Foundation conference on consciousness. One of the merits is information; a good deal of liveliness and spontaneity is introduced into what easily could have become a ponderous academic potpourri. On the other hand, the discussion is often undisciplined and incoherent. Seymour Kety's ideas on the relationship between the metabolism of the brain and various psychological states sets off the best part of the discussion. Also included are sections on hypnotic phenomena and experimental work on sleep. Despite their discursiveness and inability to arrive at a common definition of consciousness, the participants are worth listening to because they get beyond the superficial stage of paying lip service to the "organism as a whole."

Notes

INDUSTRIAL AND MANUFACTURING CHEMISTRY (Part I, Organic), by Geoffrey Martin, revised by Edward I. Cooke. The Technical Press, Ltd. ($21.00). This is the seventh edition, substantially rewritten and brought up to date, with a new section on the plastics industry.

STATISTICAL THERMODYNAMICS, by Erwin Schrödinger. Cambridge University Press ($1.75). A reprint to which has been added an appendix setting forth the author's new treatment of quantum mechanical energy levels.

HEREDITARY GENIUS, by Francis Galton. Horizon Press ($3.75). A reprint of a landmark in modern science. The book still makes good reading for laymen and experts.

LECTURES ON CAUCHY'S PROBLEM IN LINEAR PARTIAL DIFFERENTIAL EQUATIONS, by Jacques Hadamard. Dover Publications ($1.70 paperbound, $3.50 clothbound). Reissue of the 1923 edition, moderately priced for student use.

ANNUAL REVIEW OF NUCLEAR SCIENCE, Volume 2, 1953, edited by James G. Beckerley. Annual Reviews, Inc. ($6.00). Sixteen papers on various topics, including the origin and abundance distribution of the elements, subnuclear particles, recent progress in accelerators, isotopes, the production and distribution of radiocarbon, high-energy fission and the origin and propagation of cosmic rays.

ADVANCES IN GEOPHYSICS, edited by H. E. Landsberg. Academic Press, Inc. ($7.80). First volume of a new series of monographic treatises summarizing recent advances in geophysics. Among the eight papers are studies of exploration of the upper atmosphere by meteoritic techniques, the earth's gravitational field and its exploitation, aeromagnetic surveying, high-atmosphere physics and the general circulation of the atmosphere.

THE AMATEUR SCIENTIST

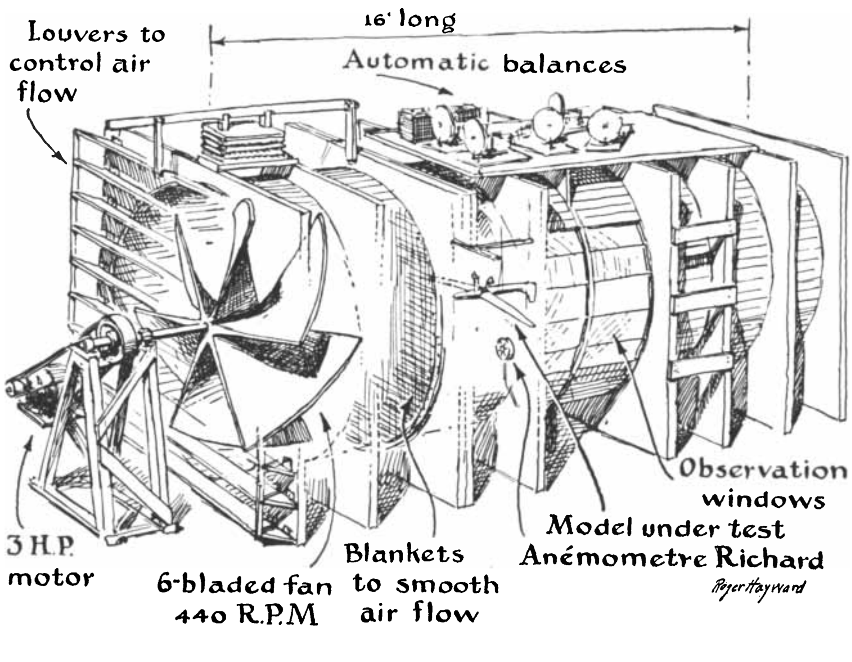
About a small wind tunnel, cloud chambers and "primitive" techniques of measurement

Conducted by Albert G. Ingalls

IF THE POPULARITY of a scientific avocation can be judged by the number of its followers, there can be no doubt about which one stands at the bottom of the list. Amateur aerodynamics wins without challenge. This is rather surprising, considering how intimately aerodynamics is related to everyday experience and how wide open one phase of the subject is to amateurs. That phase is the slow-speed flow of air. While the professionals give plenty of attention to high-speed air flow, almost nothing is known precisely about the forces generated by slow air currents. Yet not one amateur, so far as this department can learn, is investigating this fascinating subject. Nor is a single low-speed wind tunnel, professional or amateur, in operation anywhere in the U. S. If anyone knows where such work is going on, we would like to hear about it.

One does not need to look far for examples of low-speed aerodynamics. It enters into the physics of space-heating and of air-conditioning and ventilating systems generally. The design of several meteorological instruments involves the micro-ounce forces set up by movable surfaces that comprise their sensing elements. All of these mechanisms have been fashioned largely by cut-and-try methods rather than on scientific principles. Perhaps the professional neglect of this basic science can be explained in terms of dollars and cents: it may be felt that the small results would not be worth the time spent.

But this explanation can scarcely apply to amateurs. Time is the amateur's greatest stock in trade. Many boys (aged 8 to 80) spend endless hours building and flying kites. Still, with few exceptions the kites they fly are aerodynamically no improvement over those flown 3,000 years ago. Even the Navy continues to use the classical and grossly inefficient box kite to haul aloft the radio antennas of its emergency life rafts. It is true that some of these are fancy affairs with aluminum tubing and fabric substituted for sticks and paper. But aerodynamically the Navy's 1953 box kites are a thousand years old. Even more surprising is the lack of active interest in low-speed aerodynamics by the multimillion-dollar model-airplane industry. A significant percentage of its estimated 100,000 enthusiasts are gifted laymen, professional pilots and others who hold degrees in science and engineering. Each year these energetic hobbyists build and fly tens of thousands of model aircraft. Yet the miniature wings they construct are inappropriately patterned on large-scale airfoils designed for speeds above 50 miles per hour or on models put together by cut-and-try methods.



Partial cutaway of a low-speed wind tunnel

Some of the curious effects caused by the motion of air can be demonstrated with simple household objects. Suspend two apples by strings, like a pair of pendulums, and hold them close together. When you blow between them, they will move toward each other, instead of flying apart as might be expected. Take a piece of paper an inch or so square, stick a pin through it and drop it on the end of a spool with the pin in the spool opening. You will find it difficult to dislodge the paper by blowing through the other end of the spool. Set an electric fan on the floor and let its air stream blow toward the ceiling. If you drop an inflated rubber balloon into the air stream, it will not be blown away but will stay in the air stream and hover over the fan, even when the fan is tilted at a considerable angle.

All these effects are accounted for by a common property of moving air—one which explains why airplanes fly and how it is possible for a good baseball pitcher to throw a slight curve. Less pressure is exerted on a surface by air in motion than by air at rest. Airplane wings are shaped so that air flows faster over the upper surface than the lower one; this reduces the pressure above the wing and produces a lifting force. The effect was first described in precise terms by Daniel Bernoulli, of the celebrated family of Swiss mathematicians, in 1737.

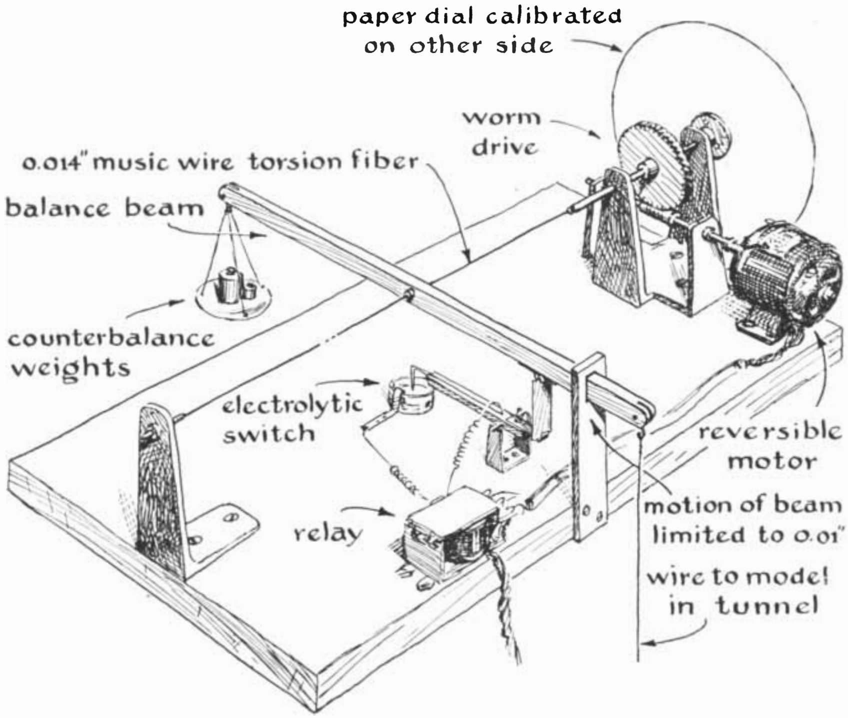
Another interesting property of air is its stickiness. It clings to objects, "wets" them and thus tends to retard their motion through it. In general these drag forces, as well as those of lift, increase with increasing velocity. At speeds from about 50 to 400 miles per hour, the thin film of air that clings to the surface influences the forces in significant ways. At higher speeds the forces change: at the speed of sound, for example, moving objects literally rip the air apart, compressing that in front and creating a vacuum in the wake. The professionals today are largely occupied by the effects that lie beyond the so-called sonic barrier.

But no one appears to be in the least concerned with the equally interesting effects in what may be called the region of the gentle breeze. Only once, at least during recent years, has anyone ventured into that region. Just before the beginning of World War II a group of amateurs in Boston, headed by Captain W. C. Brown of the Army Air Force, decided to explore the behavior of aerodynamic forces set up by velocities under 10 feet per second. Several members of the group were majoring in aerodynamics at the Massachusetts Institute of Technology. The group spent many months building a precision wind tunnel for low-speed investigations. Unfortunately the tunnel was in operation for only a brief period before the war started, and the group completed only two studies. They plotted the characteristics of a family of airfoils worked out mathematically for indoor airplane models, and investigated the effect of streamlining the structural elements associated with these profiles. After Pearl Harbor most of the group went into military aviation, and that ended the project. But the few prized scraps of information that emerged from it continue after more than a decade to be published all over the world.

Captain Brown, who is now with the U. S. Office of Education, writes of the historic Boston tunnel as follows:

"One of the failures of the past 35 years of aviation has been the inability of man to conquer the low-speed field. The slow autogiro and helicopter represent two of the few successful innovations in conventional design since aviation became a fact. Who can predict what other discoveries in this field may revolutionize present design?

"Before the war several attempts were made with various types of equipment to gather data in the low-speed aeronautical field. One notable project was a tunnel of about three feet diameter with the air stream driven by an ordinary fan. The famous B-7 airfoil came out of this work. Another project, more ambitious, was a tunnel in the Midwest which produced some interesting tests, although numerous corrections had to be made. But the Boston instrument continues to hold the record as the largest and most accurate low-speed wind tunnel ever constructed, and it could serve as a model for further work in this field today.



One of the five balances for the wind tunnel

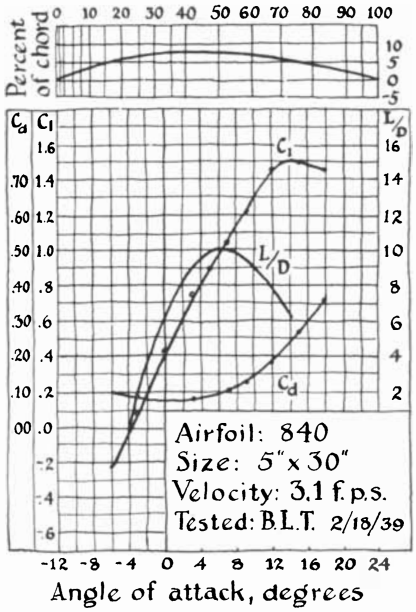
"John P. Glass, in those years a student at M.I.T., started it all, and to him goes much credit for the tunnel's design. Glass's design was executed by members of the Jordan Marsh Aviation League. William H. Phillips, also a former M.I.T. student, now with the National Advisory Committee for Aeronautics at Langley Field, Va., started designing the balances about a year after work was begun on the tunnel proper.

"The Boston tunnel was 18 feet long with a standard diameter of five feet at all points. The air was forced through the tunnel, instead of being sucked as in most high-speed tunnels. (Roger Hayward's drawing at the left shows the general arrangement.) This method was dictated largely by economic considerations. A tunnel of the conventional sucking type would have required an entrance cone about 18 feet in diameter and a length of 60 feet to get a smooth air flow. Even so, air flow at the low speeds contemplated by the designers would doubtless have been disturbed by eddies originating outside the tunnel. By compressing the air at the propeller end of the instrument and permitting it to seep through blanketing layers of fabric into the test chamber, the tunnel achieved a smooth air flow with a structure of reasonable size. The pressure drop through the blanket, about three pounds per square foot, overcame any irregular pressures arising from turbulence created by the propeller and kept out of the test chamber eddies caused by persons moving about in the room.

"The tunnel was driven by a propeller five feet in diameter with six overlapping blades connected through a belt to a direct-current motor of 440 revolutions per minute and three horsepower. The velocity of the air stream could be varied between 2 and 12 feet per second by means of a shutter placed between the propeller and the blanket. This system of control offered a distinct advantage over regulating the speed of the motor, because it tended to offset slight velocity changes caused by variations in power line voltage, belt slippage and related factors.

"Air speed through the tunnel was measured by two gauges: a calibrated pendulum vane and an anemometer of the Richard type. Pressure in the tunnel during the calibration period was measured by a manometer arrangement, built by Phillips, which utilized a pair of milk bottles. It was extremely accurate but was abandoned after it was found too sensitive to temperature changes for prolonged use.

"The test models were suspended from an airfoil balance. The first balances, intended for use with outdoor models, could weigh a force up to four ounces and were sensitive to three hundredths of an ounce. They were of the automatic spring type. It was found that a different type would be required for work with indoor models, because the forces to be measured were so infinitesimal. This problem was by far the most



Results of experiment were plotted

difficult encountered during the tunnel's design and construction. A successful design was developed after much work by Phillips [*see drawing on preceding page*]. The new balance, of the automatic torsion type, was sensitive to one thousandth of an ounce and had a capacity of one tenth of an ounce. It achieved its extreme sensitivity by using an electromechanical amplifier, incorporating the feedback principle, whose main features were derived from an instrument used at M.I.T. for measuring the surface tension of liquids. Any force tending to disturb the equilibrium of the balance's master beam was, in effect, counteracted by an equal force derived from a reversible electric motor actuated by a set of contacts carried by a secondary beam.

"The Boston tunnel employed five of these balances. One measured the vertical force, or lift, acting on the airfoil under test, and two others measured the drag forces. The two remaining balances measured pitching, rolling and yawing."

The test objects investigated by the Boston group consisted of a series of rectangular airfoils 30 inches long by five inches wide. They were not true wing sections, like those of an aircraft, but merely thin sheets, bowed like a wind-filled sail. The curve was stiffened by a set of lateral ribs. Starting with the arc of a circle as the curve of the basic airfoil, the experimenters derived mathematically a family of related curves in which the peak of the curve was progressively shifted aft from the leading edge. The curves are described by the N.A.C.A. system, in which the diameter of the airfoil, or "chord," is taken as unity and the remaining dimensions are expressed as a percentage of this length. Five numerals define the curve: the first digit gives the highest point reached above the chord; the second and third give the distance of this maximum height from the leading edge, and the last two specify thickness.

The experimeters found that the most successful airfoil aerodynamically was the one in which the peak of the curve (8 per cent) was located 40 per cent aft of the leading edge [*see top of chart at the left*]. Because this airfoil has no thickness (being formed of a single sheet of material), it is designated 84000. (For convenience the last two zeroes are frequently omitted.) A two-surface airfoil of the same shape with a thickness of 15 per cent is designated 84015.

The basic objective of these investigations is to measure two characteristics of a given airfoil: how variations in the speed of the air stream and the angle at which the airfoil meets the stream affect its lift and drag. The airfoil, or if desired a complete model of the airplane, is suspended in the test section of the tunnel from a T-shaped structure which in turn is coupled with the balances. After a series of readings at a predetermined range of air-stream velocities, the tunnel is shut down and the angle of attack is increased. A second set of forces is then recorded. The procedure is repeated through any range of attack angles desired.

The forces so observed are recorded in thousandths of an ounce. The observations are transformed by simple equations into coefficients of lift and of drag (usually designated C_l and C_d) and plotted as a set of curves, one showing the lift coefficients, another the drag coefficients and the third the "L/D" ratio of the two through a range of angles of attack. The main chart at the upper left shows a set of these curves derived for the 84000 airfoil.

The Boston tunnel of course can investigate the aerodynamic behavior of test objects of any shape. The instrument also opens boundless opportunities for the exploration of jet effects at low speed and of the drag effects of various surface textures.

THE ARTICLE on diffusion cloud chambers published in this department last September has brought forth hundreds of letters from amateurs, who made chambers of everything from whiskey glasses to fish tanks. The tricks they devised for getting around Murphy's law would fill a book.

Major Reuben B. Moody, an officer on duty at Wright-Patterson Air Force Base in Ohio, wrote:

"My brother Jerry, a graduate chemistry student at Ohio State University, and I have spent many enjoyable hours in the construction of cloud chambers of assorted shapes and sizes—some of which worked.

"Our first chamber was constructed according to the instructions in your article. For the chamber itself we used a wide-mouthed pickle jar with a metallic screw-top. A synthetic sponge was secured to the bottom of the jar by means of expansion clamps (manufactured from coat hangers), and the sponge was then thoroughly soaked with rubbing alcohol. Across the mouth of the jar we stretched a black cloth over which we screwed the metal lid. The jar was upended on a cake of dry ice. The cloth remaining outside the jar was spread out to cover the ice, thus providing a contrasting background and preventing the dry ice 'smoke' from interfering with our vision.

"We detected a miniature rainfall almost immediately, and within five minutes we could perceive the threadlike vapor trails. (My wife, who is not overly enthusiastic regarding scientific matters, was disappointed because no lightning flashes were detected during our miniature rain storm.)

"Our first cloud chamber remained active for as long as the dry ice lasted—about seven hours. Although we were fascinated and elated with the results of our first endeavor, we began to think of ways to improve our results and to reduce the eyestrain attendant on observing them. In our pickle-jar chamber the sensitive region never exceeded a depth of about one inch. Also, the eyestrain was terrible, due to the ghostlike and short-lived appearance of the tracks and because of light reflections from the glass sides of the jar.

"Since metal is a better heat conductor than glass, we conceived the idea that the all-important temperature difference could be improved by constructing a metal cloud chamber. Accordingly, from the kitchen we obtained a coffee can about six inches deep and six inches in diameter. After painting the interior of the tin can with blackboard slating, we cut three horizontal window slits in the can, one above the other. These windows, designed for observation and lighting purposes, were about one inch high and three inches wide. Over the windows we glued strips of cellophane (we found that scotch tape could not withstand the extreme cold without shrinking and without losing its adhesive properties). To ensure air-tightness we secured the edges of the cellophane windows with strips of plastic tape. On the bottom of the can we placed a cut-to-size disk of velveteen fabric, and to the lid of the coffee tin we glued the synthetic sponge [*see drawing at right*].

"With the coffee-can chamber we obtained much better results. The eyestrain was eliminated; the sensitive region increased in depth to about 2.5 inches, and we were able to observe from 30 to 50 tracks per minute. Again the chamber remained active for as long as the dry ice lasted—this time about 18 hours with a cake of ice about two inches thick.

"As fascinating as our primitive apparatus proved to be, even more fascinating is the mystery surrounding the cosmic rays whose paths we were able to see. How do these rays obtain their tremendous energies, and where do the rays themselves originate? Perhaps these questions will some day be answered by such a device as the cloud chamber."

A number of British amateurs also built successful chambers. R. P. Randall, a telescope-maker of South Harrow, Middlesex, England, reports:

"My chamber was a tall glass jar 18 by 5 inches. I carried out the whole experiment as a lecture to our scientific society. 'Rain' fell from a height of about five inches, and it was not until I had been watching for a few minutes that I realized that most of the rain was due to faint cosmic ray tracks about five inches from the bottom. The tracks could only be due to cosmic rays, as I had no active material available to produce them. The sensitive region was four to five inches deep, and I wonder if this was not due to using a tall cylinder and ethyl alcohol."

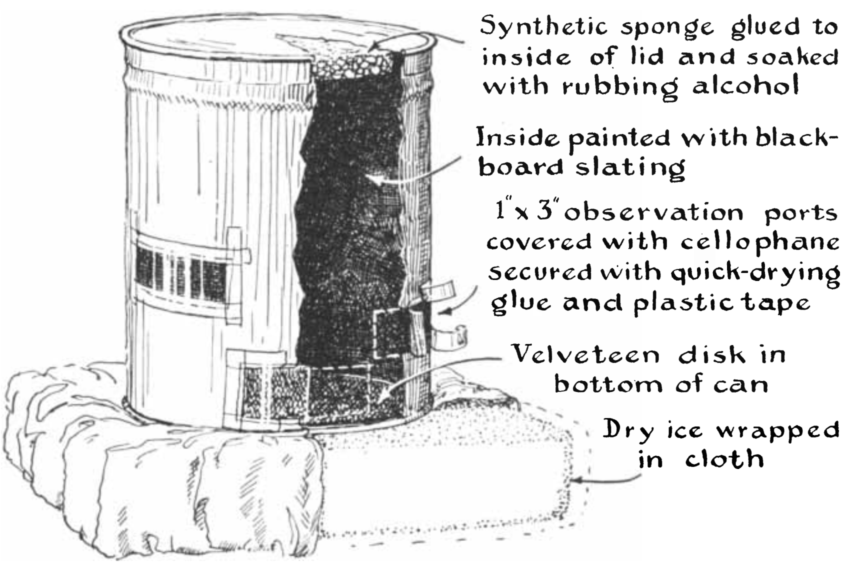
RECENTLY the Johns Hopkins University experimental physicist John Strong, in the course of designing his highly refined machine for ruling diffraction gratings [Scientific American, June, 1952, *et seq.*], was led to delve into the origins and history of modern high precision in the mechanical arts. He wrote in an article: "I find that the construction methods of greatest precision are all primitive methods." Just what he meant by primitive has been the subject of lively arguments among those who heard the term for the first time.

The literal meaning of primitive is first. In the sense in which Strong used the word, the dictionary defines primitive as "having something else of the same kind derived from it but not in itself derived from anything of the same kind." In other words, a primitive method of construction is distinguished from a derived method.

Let us consider a concrete example. Strong discusses the dividing of a circle into equal parts such as degrees. If it is done with a dividing engine, the accuracy obtained is derived from the master circle on the engine. Therefore this is not a primitive method of construction. If we put the circle in a lathe and divide it by rotating the lathe spindle by equal increments, this again is a secondary method. The increments are determined by the gears in the lathe, and their own precision, such as it is, was originally derived from a master circle.

In contrast consider this purely primitive method. Draw a circle on paper and cut it out with scissors, as shown in the drawings on the next page. Drive a spike through its center and into a mahogany table. Make a first mark anywhere on the circle's periphery and continue the mark on the table, as in the left-hand drawing. Estimate the 180-degree point opposite, mark the circle there and extend the mark to the table. Now rotate the circle as in the right-hand drawing, placing the trial 180-degree mark on the paper at the first mark on the table. The true 180-degree point lies between extension of the trial 180-degree mark on the table and the first mark on the paper. A second approximation by the same principle brings us much closer to precision, which, however, we can never quite reach.

In the experimental physicist's encyclopedia edited by Sir Richard Glazebrook, entitled *A Dictionary of Applied Physics*, E. O. Henrici and G. W. Watts describe the procedure, at once primitive and modern, used in placing the degree and finer marks on the large circle for a precise dividing engine. They used the cut-and-try principle just described, with micrometer microscopes for locat-



An improved version of the continuous cloud chamber ing the marks. After placing the 180-degree marks, they filled in the 90-degree, 45-degree and 22½-degree marks, and then the marks for all the 4,320 five-minute divisions, each within one half-second of arc, the whole task requiring six months of tedious application.

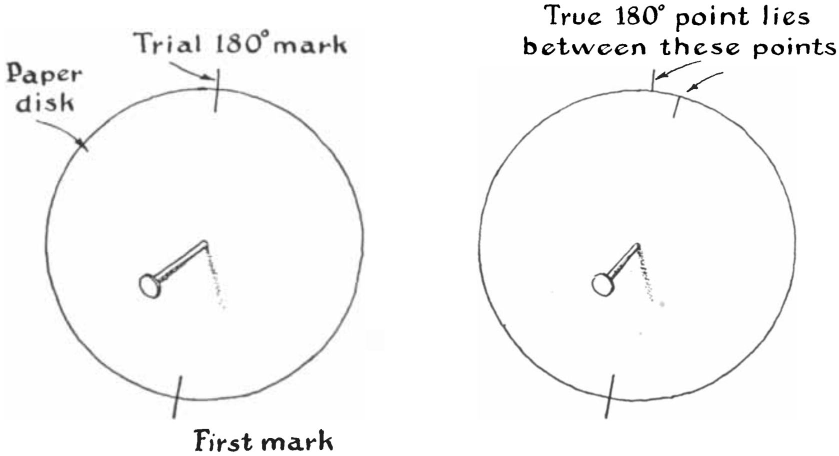
This was a truly primitive method because precision was not derived but created, as it were, "from the blue." The unfortunate fact that the word primitive is often used in a secondary or derived sense (for many words have their own primitive and derived meanings) to denote "antiquated," or "out-of-date," has misled many. Some supposed that Strong had said in effect that the construction methods of greatest precision were the outmoded, crude or clumsy ones. Not at all; he was simply separating primary methods of construction from those "derived from other things of the same kind." As a matter of fact, there is still no better method for dividing a circle than by a series of approximations made by cut-and-try.

To the list of primitive methods could be added the generation of an accurate sphere by smoothing a rough ball on the end of a tube—a method by which the Chinese have made crystal balls for centuries and amateur telescope-makers have made Coddington lenses ["The Amateur Astronomer"; SCIENTIFIC AMERICAN, August, 1948]. The same method can be used in reverse to generate concave spherical surfaces [*Amateur Telescope Making—Advanced*, page 247].

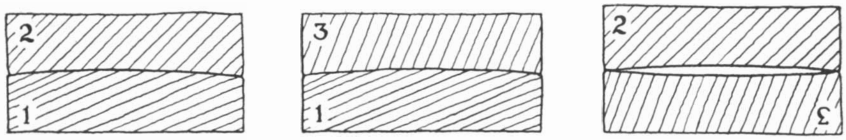
Those who enjoy philosophical contemplation of the primitive methods often speak of them as "elegant," in the sense of refined. It is fun to imagine oneself a Robinson Crusoe and to speculate on how many of the amenities of science and technology one could re-create on an island without modern technical resources. Perhaps "Robinson Crusoe methods" most clearly defines the primitive principles.

Optical flats are ground by a primitive method. If three equal disks of glass or metal are ground together in pairs with abrasive grains between them—the first against the second, the second against the third, and the third against the first—they will approach ever closer to true plane surfaces. In his list of primitive methods Strong describes this as "the generation of flat surfaces, three at a time, by Whitworth's method of lapping." Mechanical engineers use the term "Whitworth's method" for the method of making the flats they call "surface plates." The term is less familiar to optical workers.

Sir Joseph Whitworth was described by Joseph Wickham Roe of Yale, in his classic *English and American Tool Builders*, as "the most influential machine-tool builder of the 19th century." He standardized the screw thread, and his tools became the standard of the world. Though Whitworth's name is attached to the three-disk method, James Weir French says, in his article on the working of optical parts in *A Dictionary of Applied Physics*, that the method appears to have been known to earlier opticians. They did not, however, describe it clearly; they were secretive. James Nasmyth, another 19th-century English machine-tool builder (whose hobby was astronomy), says the three-disk method was in use early in that century in the shop of Henry Maudslay, the greatest of the old English tool builders. Whitworth had worked in Maudslay's shop. The three disks were then ground with emery grains. Noting that this usually resulted in "bell-mouth form," or what is now called "turned-down edge," Whitworth substituted local scraping of the metal with a hand tool. Though Whitworth contributed only the scraping (and improved on Maudslay's surface plates) his name has been attached to the whole three-disk principle. This is no more than just, after all, because he made the method public for the use of all instead of keeping it secret. He described it in 1840 before the British As-



The "primitive" way to divide a circle



The classical Whitworth method of making flat surfaces

sociation for the Advancement of Science in lucid language:

"Let one of the plates now be selected as the model, and the others be surfaced to it with the aid of coloring matter. For distinctness they may be called Nos. 1, 2 and 3 [*see drawing above*]. When Nos. 2 and 3 have been brought up to [made as nearly flat as] No. 1, compare them together. It is evident that if No. 1 be in any degree out of truth, Nos. 2 and 3 will be alike, and the nature of their error will become sensible on comparing them together by the intervention of color. To bring them to a true plane, equal quantities must be taken in both from corresponding places. When this has been done with all the skill the mechanic may possess, and Nos. 2 and 3 are found to agree, the next step is to get up No. 1 to both, applying it to them in immediate succession, so as to compare the impressions. The art here lies in getting No. 1 between the two, which is the probable direction of the true plane. It is to be presumed that No. 1 is now nearer truth than either of the others, and it is therefore to be again taken as the model, and the operation repeated."

Whitworth accomplished far more than to tell the world how to make a better flat. In an age that was still advancing from the mechanical crudity of the 18th century, when millwrights' wooden rules were graduated only to eighths of an inch and the best of the workmen could go only to "32nds bare" and "32nds full," and when the principal tools of the machinist were a hammer and cold chisel, he set forth the underlying significance of the surface plate or flat in controlling practically everything manufactured. Thanks to this control the parts of lathes and planers could now be made much more nearly plane; other machines built on these primary tools could for the first time be precise, and everything made on these in turn could be precise.

Today the optical flat makes possible the interchangeability of parts and thus controls mass production in all the mechanical industries, including the optical. This has come about in four decades, since industry adopted the gauge block for use with optical flats to test the tools that measure mechanical parts with high precision using light waves.

Anyone who has tried to make even a six-inch optical flat knows that it is much more difficult to make a flat to standard optical tolerance (one 500,000th of an inch) than to make a paraboloidal mirror of equal diameter, also that the difficulty increases with increasing diameter more than in mirror making. A dozen years ago Fred B. Ferson of Biloxi, Miss., was an advanced amateur telescope-maker, teaching himself how to make roof prisms. Each facet of a prism is a small optical flat, but the facets are not made singly: groups of them are attached to a single rigid metal backing and the whole is figured as a single flat of about 10-inch diameter. While making thousands of these 10-inch flats in wartime, Ferson also taught the advanced amateurs in this magazine's wartime roof-prism program how to make them.

Ferson remained in optical work. Recently he and his chief optician, Peter Lenart, Jr., made a flat of 10⅝ inches diameter that was flat within one five-millionth of an inch. This has been acquired by the National Bureau of Standards as the standard for testing flats that are submitted to it for calibration. Most of them are submitted by industries that use flats to control the accuracy of gauge blocks, which in turn control the accuracy of shop tools.

There is a common impression that expert flat figurers use occult methods, generally behind doubly barred doors. Actually their methods are essentially no different from those available to beginners. Their "secret" is working with the best possible conditions. First, they use disks of fused quartz, to minimize differential expansion from changing temperature. Second, they work with thick disks (2½ inches for a 10-inch), to minimize flexure. Third, they use correct methods of reading the interference fringes that measure the flatness, and of dealing with the residue of flexure. This factor, which the worker must understand before he can achieve accuracy of better than one millionth of an inch, has been reduced from an art to a science in an eminent new paper by Walter B. Emerson of the National Bureau of Standards titled "Determination of Planeness and Bending of Optical Flats" (N.B.S. Research Paper 2359, Superintendent of Documents, Washington 25, D.C., 10 cents). The key problem is to ascertain the true shape of the flat—the shape if it did not bend. Emerson accomplishes this by supporting the flat first at the edge, then at the center, pairing it with a flat of different thickness and working out equations. After studying his paper one wonders how many determinations of flatness previously made with master flats were correct, and what are the true contours of flats so measured.

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