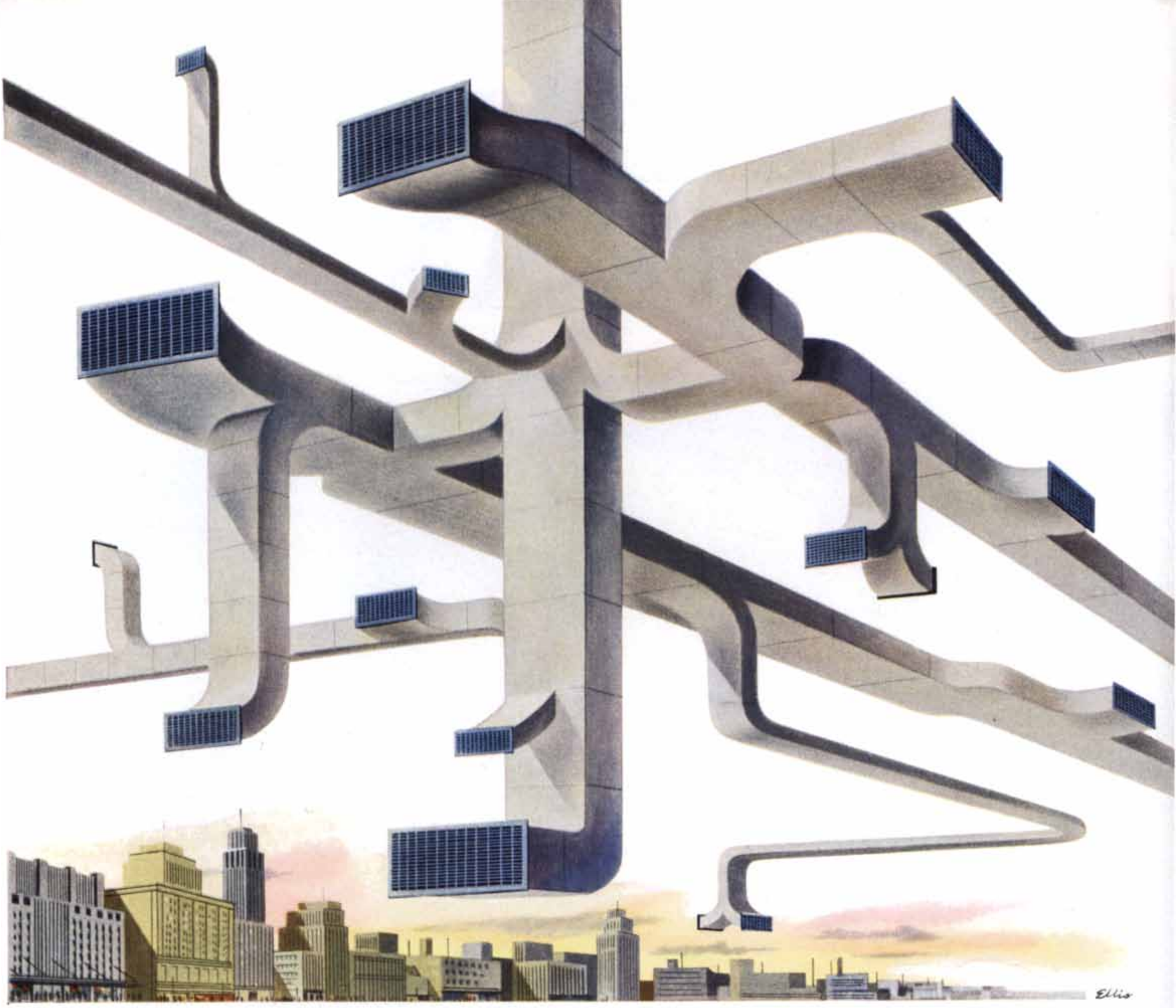
SCIENTIFIC AMERICAN

BIRD FLIGHT

FIFTY CENTS
75 CENTS OUTSIDE THE AMERICAS

April 1952



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It is generally recognized that Fiberglas* Duct Insulations do this double job with exceptional efficiency. But, oddly enough, that is not the principal reason why they're so widely used!

The main reason is that they go on faster, easier, cost less installed . . . a money-saving characteristic of Fiberglas insulating materials.

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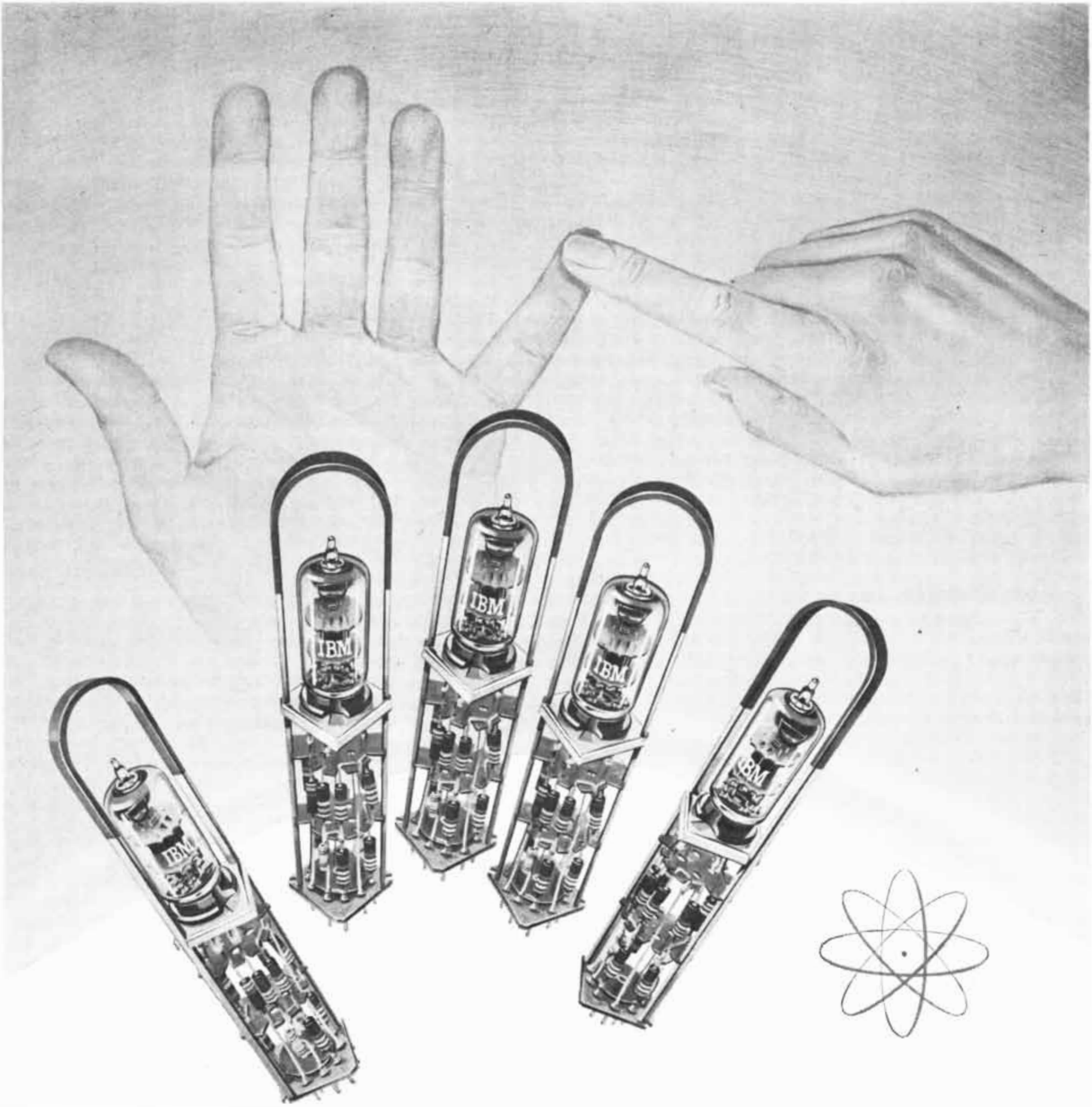
*Fiberglas is the trade-mark (Reg. U. S. Pat. Off.) of the Owens-Corning Fiberglas Corporation for a variety of products made of or with fibers of glass.



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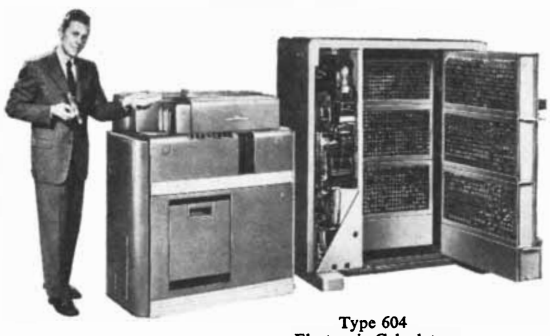
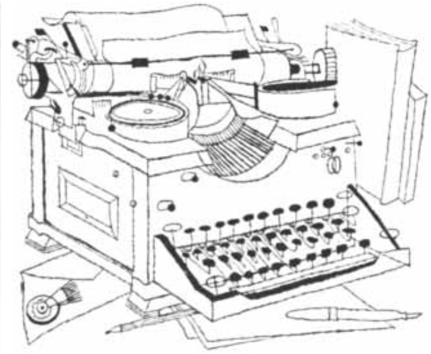


Type 604
Electronic Calculator

IBM Electronic Business Machines

LETTERS



Sirs:

As a practicing electronics engineer I found Louis Ridenour's article on the transistor in your issue of August, 1951, and the letters by Lee deForest and Dr. Ridenour which appeared in your January issue, to be of considerable interest. With respect particularly to the letters, the thought occurred to me that whatever controversy they reflect is wholly a matter of relative emphasis. To me Dr. deForest's great contribution was the triode—the 3-element electronic amplifying device. At the time he first made that contribution the only practical form it could take was that in which the electrons moved in a vacuum. That this was indeed a practical form is certainly demonstrated by the many billions of vacuum tubes which have been made.

Much later our knowledge of the detailed nature of the solid state of matter reached a point which permitted the electron flow of Dr. deForest's triode to take place in a solid. Perhaps in the end solid triodes will largely supersede vacuum triodes; no one yet knows. But the important point is that they are still triodes.

A. V. LOUGHREN

Director of Research
Hazeltine Corporation
Little Neck, N. Y.

Sirs:

Before too many readers' brows rise over sharp eyes, I should like to correct two slips in my article, "Radiocarbon Dating" in the February issue.

The first concerns the half-life of uranium 238, which almost everybody knows is 4.56 billion years. My figure of 7.6 billion came from a hasty reading of F. E. Zeuner's book "Dating the Past." Actually the relation given by Zeuner is a rough approximation that takes no account of the existence of uranium 235 and its end-product of radioactive decay, lead 207, and at best is satisfactory only for comparatively young rocks.

The second mistake was not mine originally, but arose when the editors fused two of my illustrations, and the vertical scale of the diagram showing pollen percentages came out in "thousands of years" instead of "depth in meters." Evidence so far is altogether inadequate for dating a complete post-glacial sequence of mud layers containing pollen. As it happens, the depth figures on the pollen diagram correspond rather well to the guesses we can now make at their ages; the bottom part of the oak-hemlock pollen zone of warm, moist climate, lying between eight and nine meters depth in this boring, has given radiocarbon ages between 8,000 and 9,000 years. At two higher levels in the same lake the radiocarbon ages in thousands of years agree with the depths by 1,000 years or less. But nature can hardly be expected to imitate art so successfully on all occasions, and in various details, especially in the narrowness of the "warm, dry" (pine pollen) layer, the diagram is inaccurate, or at least atypical.

EDWARD S. DEEVEY, JR.

Geochronometric Laboratory
Yale University
New Haven, Conn.

Sirs:

The January article by Robert E. Marshak entitled "The Multiplicity of Particles" is an excellent up-to-date account of how we stand in this confusing business. It may be of interest to you and to your readers to know what Albert Einstein remarked to me a summer or two ago when I visited with him.

I put the question: "What can we say

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about these elemental particles? We now have 14 and there appears to be no end."

To which Einstein replied: "The question is: what is elemental?"

It is sensibly safe to say that Nature is not this complex. The ultimate answer, like other ultimate answers, may never be within our understanding!

JULIUS SUMNER MILLER

Dillard University
New Orleans, La.

Sirs:

I have read H. M. Thorne's very informative paper concerning the recovery of petroleum products from shale in the February issue of SCIENTIFIC AMERICAN with considerable interest, and was pleased to learn of the optimistic outlook both as to supply of shale and cost of retorting and refining.

However, in Dr. Thorne's discussion of the recovery of chemicals by means of high-temperature retorting, there is an obvious error in material balance which I should like to bring to your attention. Dr. Thorne discusses a unit processing 20,000 tons of shale per day; operating 365 days per year, this would be 7.3 million tons of shale per year (or .876 million tons of oil per year, based on his estimate of 12 per cent by weight of shale). Then he lists the annual production of chemicals as 14 million tons of benzene, 5.3 million tons of toluene, etc., totaling some 50 million tons of hydrocarbon material, representing about 7 times the weight of shale (or 57 times the weight of oil) retorted! Since this is clearly impossible, there must be some error in the figures.

I would like very much to know the correct figures, and the correction, if any, to be applied to the economics also included in Dr. Thorne's discussion of retorting for chemicals production.

ROBERT V. JELINEK

Standard Oil Development Co.
Linden, N. J.

Sirs:

The error noted by Mr. Jelinek occurred when a table presenting the estimated yield of aromatic chemicals in terms of gallons was eliminated and the values written into the text of the article. During this procedure a slip in transcription changed gallons to tons.

The discussion of the economics of retorting for chemical production is correct as it is based upon yields in terms of gallons rather than tons.

H. M. THORNE

Bureau of Mines
Laramie, Wyo.

Measure film and oscillograph data
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with this *New* Team in Automatic Data Analysis

1. The Universal Telereader measures film and paper records of any width, ranging from 16 and 35 mm film to 12″ oscillograph records

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Types of records—handles translucent or opaque records; continuous roll records up to 100 feet in length or single sheet records up to 12″ in width

Speed—up to 50 measurements per minute

Optical system—three interchangeable lenses give magnification of 2X, 4X and 14X

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Measuring method—the rapid motion of X and Y crosswires is electronically converted into digital form.

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electronically counts, stores and records the measurements of the Telereader in decimal form, prints them on the typewriter for preliminary analysis.

It also can transmit the data to an IBM Summary Punch for simultaneous card punching.

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- Strip Charts
- Multiple Manometer Data
- Mass spectrometer data
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*Tests show the Universal Telereader and Telecordex measure and record 20 times faster than is possible in manual operation on an average. It is impossible to achieve the Telereader's accuracy through manual measurements.

When an IBM Summary Punch is connected to the Telecordex and cards are punched simultaneously as measurements are made, the speed over manual operation increases greatly—because manual punching of IBM cards is eliminated.

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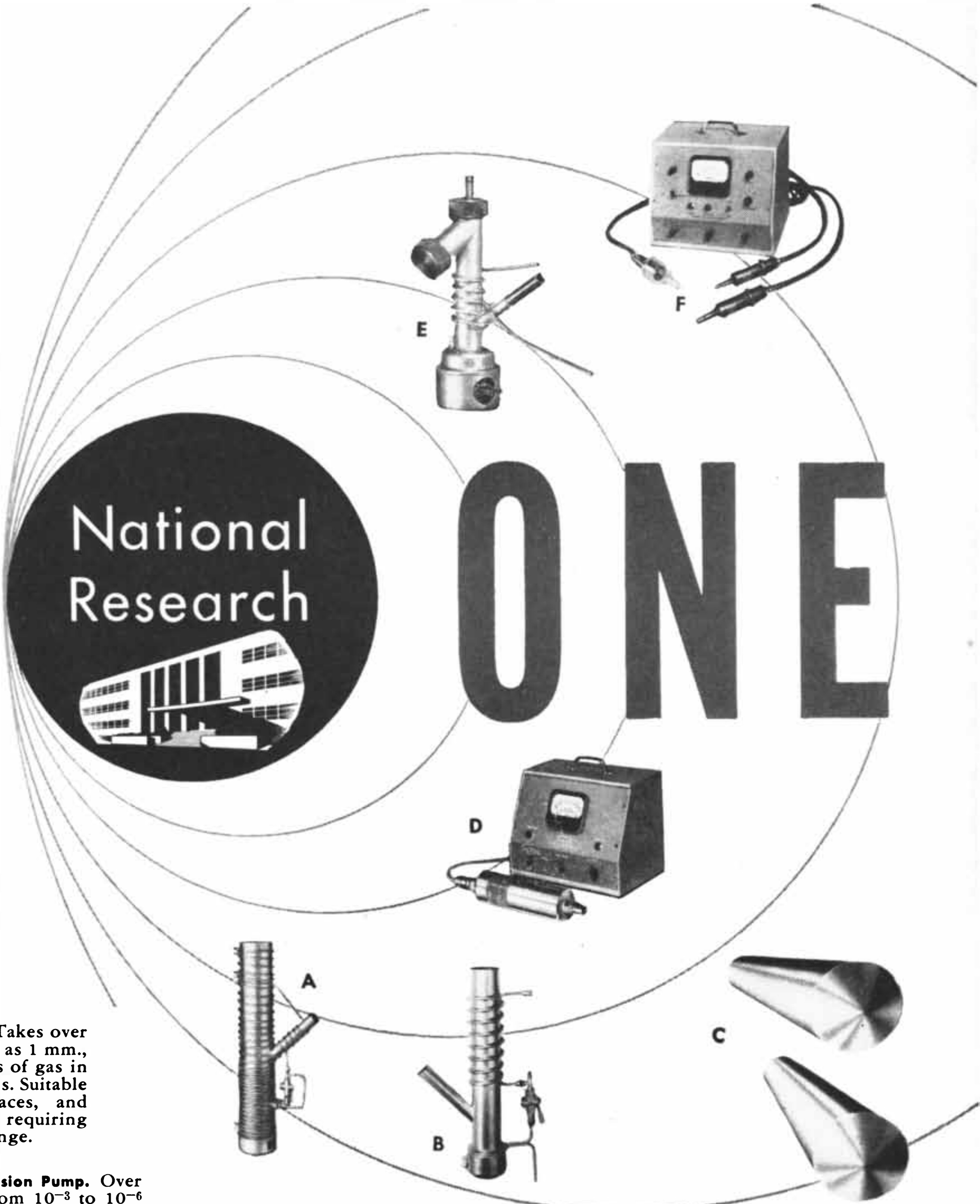

(A) B-4 Booster Pump. Takes over at forepressures as high as 1 mm., handling large amounts of gas in range of 1 — 30 microns. Suitable for evaporators, furnaces, and other vacuum systems requiring high capacity in this range.

(B) H-2-P Purifying Diffusion Pump. Over 50 liters per second from 10^{-3} to 10^{-6} mm. range. Operates against forepressures as high as 0.300 mm. Blank-off 2×10^{-7} mm.

(C) Gas Free High Purity Metals. Copper, nickel, cobalt and iron. Special melts on request. Ingot weights up to 600 pounds.

(D) Alphatron* Vacuum Gauge. Accurate gauging from 10 mm. to 1 micron. A rugged metal ionization type instrument which can be adapted for recording, controlling, gas filling, and leak detection.

(E) B-1 Booster Pump. A small pump designed for rotary exhaust equipment used in miniature and subminiature tube production. Useful where a small pump is required to quickly obtain pressures in the region of one micron.

(F) Type 710 Thermocouple-Ionization Gauge Control. One instrument for scientific and industrial vacuum gauging. Incorporates two thermocouple gauges (1 — 1000 microns) and one ionization gauge (10^{-3} mm. to 10^{-8} mm. Hg. range) in one control. Automatic input regulation and protective circuit.

(G) Standard Vacuum Furnace. A versatile packaged unit to melt, pour, heat treat, degas, sinter, and anneal under high vacuum or controlled atmospheres. Temperatures up to 2000° C.

(H) Vacuum Seals. For introducing motion, power, or connecting gauges.

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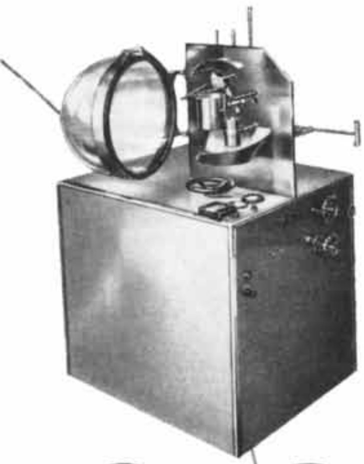
(J) Vacuum Fusion Gas Analyzer. Analyzes metals and alloys, including titanium, for combined or dissolved oxygen, nitrogen, and hydrogen.

(K) Type 701 Thermocouple Gauge Control. A light, portable instrument for vacuum testing in range 1 — 1000 microns. Compact and rugged.



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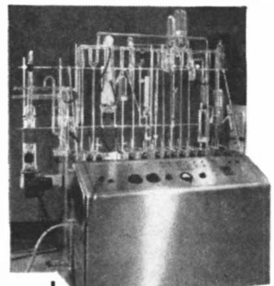

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(L) H-16-P Purifying Diffusion Pump. Over 10,000 CFM in 10^{-5} range. Suitable for cyclotrons, commercial coating units, and other equipment demanding high pumping speed.

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*Reg. U. S. Pat. Off.

50 AND 100 YEARS AGO

APRIL 1902. "William Flinders Petrie, the distinguished Egyptologist, in an address to the supporters of the Egypt Exploration Fund, said that they had completed the most important historical work that had yet come into their hands, settling, in a manner which had hitherto seemed beyond hope, the very foundations of Egyptian history. No such complete materialization of history had been obtained by one stroke in any other country or age. He detailed the discoveries of twenty engraved tablets and dozens of fragments of tablets, and 100 inscriptions on vases, giving more information of dynasties ruling 6,600 years ago than is known regarding half the Saxon Kings of England."

"Peter Lebedev has succeeded in demonstrating both qualitatively and quantitatively the pressure exercised by light, which is postulated by Maxwell's theory. To facilitate a rapid equalization of heat in the radiometer vanes, he made them of very thin aluminium foil, suspended torsionally by a glass thread. The light used was that of an arc lamp. The results agree with the theoretical values of Maxwell and Bartoli within 10 per cent. The pressure is directly proportional to the energy of the incident light, and is independent of its color."

"Prof. Charles Wilson has announced to the Royal Society a new determination of the temperature of the sun. His figures are 6,200 degrees C. (11,192 degrees F.). It is stated that the absorption of the sun's atmosphere probably makes this temperature equivalent to 6,600 degrees C. at the surface."

"That the Marconi system is apparently on the road to commercial success would seem to be indicated by the formation of a huge company for the purpose of exploiting the invention. The Marconi Wireless Telegraphy Company of America, according to Marconi, was recently founded and capitalized at $6,150,000."

"To-day the Census Office presents the appearance and busy hum of a vast machine shop rather than that of a great countinghouse. The Hollerith system of mechanical punching and tabulation had its inception in the preceding census. The system, however, has been greatly improved and extended to meet the larger needs of the present time. The two main features of the system are, first, a punched card, and, secondly, means for transferring its legend mechanically to registers which classify it into groups or categories and add the units to form sum totals for the groups."

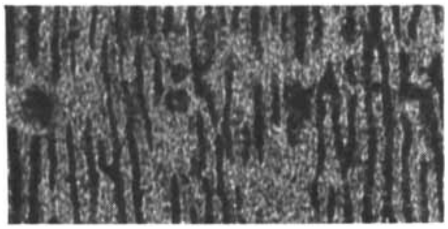
APRIL 1852. "Telegraphy has reached that point, by its great stretch of wires and great facilities for transmission of communications, to almost rival the mail in the quantity of matter sent over it. It has become indispensable to many business transactions, and an interruption of the communication between cities is severely felt by the business community. Nearly 700 messages, exclusive of those for the press, were sent on Thursday last, over the Morse Albany Line."

"The astronomer hath constructed his telescope six feet in diameter, and with it he seeth clearly 500 times farther than he can with his naked eye; with it he hath made many discoveries in the starry heavens, for he can tell the height of the mountains and the depths of terrific craters in the moon; he hath counted other systems beside our own solar corner of the universe; but these things only impress more strongly upon his mind the simple fact, 'he is but a babe in knowledge.' Plagues and fearful diseases are carried on the wings of the wind, but no chemist, by the most refined analysis, has been able to detect the subtle destroyer. His weights and measures are yet far too coarse to weigh an atom or circumscribe its dimensions; and here may lie some of those secrets which, for want of a better term, chemists give the name of 'isomeric compounds.' In the organic cell of the loftiest and lowliest known existences, there is a world beyond the search of the most powerful microscope that has yet been constructed."

"In the University of Turin is given, by one of its learned Professors, a course of chemical lectures specially intended for students of architecture. It is called chemistry applied to the art of the builder. How eminently serviceable might not such a course be in our country! Had even so much only of the laws of chemistry as relates to the temperature at which wood is liable to take fire been understood or attended to by the build-

Electrons probe the future

1 Electron micrograph of an alloy of aluminum, nickel, cobalt and iron. Magnification 20,000 diameters.



2 Cooled from high temperature in a magnetic field, the alloy becomes a powerful, permanent magnet. Note changed structure. Black bars reveal formation of precipitate parallel to the applied field. Each bar is a permanent magnet.

3 A Bell scientist adjusts electron diffraction camera. Electrons are projected on the specimen at glancing angles. They rebound in patterns which tell the arrangement of the atoms . . . help show how telephone materials can be improved.

IN 1927, Bell Laboratories physicists demonstrated that moving electrons behave like light waves, and thus launched the new science of electron optics.

Now, through the electron beams of the electron microscope and electron diffraction camera, scientists learn crucial details about the properties of metals far beyond the reach of optical microscopes or chemical analysis.

At the Laboratories, electron beams have revealed the minute formations which produce the vigor of the permanent magnets used in telephone ringers and magnetron tubes for radar. The same techniques help show what makes an alloy hard, a cathode emit more electrons and how germanium must be processed to make good Transistors.

This is the kind of research which digs deep *inside* materials to discover how they can be made better for your telephone system . . . and for the many devices which the Laboratories are now developing for national defense.

4 Diffraction pattern of polished germanium reveals minute impurities which would degrade the performance of a Transistor.

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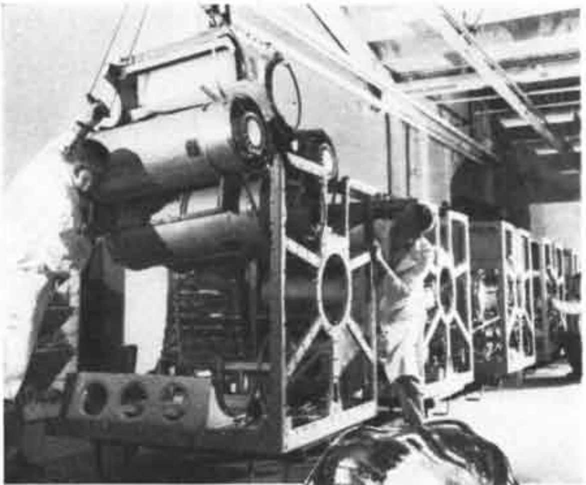
ers of our national capitol, we might probably have been spared the deplorable and discreditable loss of our great Congressional Library. And had something been known of the causes of decay and disintegration of building materials, our public edifices at the seat of government would not have so often required the mantle of charity to be spread over their multitude of sins, in the shape of coats of paint, daubings of putty, and patches of plaster."

"Prof. A. Henessy has brought the higher mathematics to bear upon various questions connected with the changes in a globe cooling from fusion. In the course of his paper, the author shows that the solidification of the earth must have gone on from the surface, adding successive layers of cooled rocks. He infers that the least possible thickness of the crust is 18 miles, and the greatest possible thickness 600 miles. He infers also that a considerable amount of friction and pressure must exist between the shell and fluid nucleus."

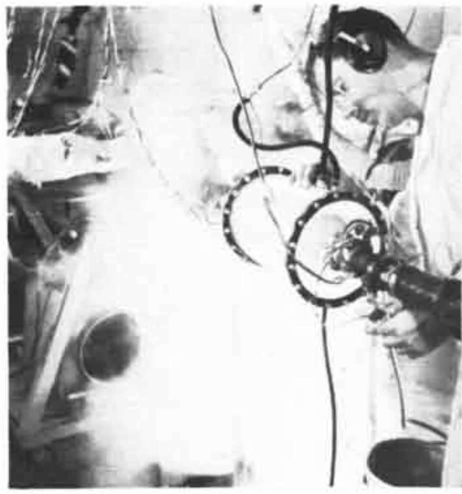
"We cannot indulge in vituperous language towards conductors and engineers, as some papers do, every time an accident takes place on a railroad. It is a great wonder to us that there are not more railroad accidents, for when we consider how our tracks are all open, so many of them single, so many poor bridges, and besides all this, many of our railroads were built with curves and laid with rail for engines one-half lighter than those now used, and to run at one-half the present general speed, we say the conductors and engineers (taking the mass) deserve great credit for their vigilance and ability. Our railroad system is bad, and neither the conductors nor engineers should be blamed for this."

"At a meeting of the American Geographical Society held at the University, this city, Mr. Leavitt read a very interesting paper from the Rev. Mr. David Livingstone, a missionary in South Africa. The people here are strongly developed, but peaceful. The Baloc tribes melt large quantities of iron, and are very good smiths. The people are all aware of the existence of a God, and seem to be informed in regard to future life, and rewards and punishments. The Portuguese slave traders begin to penetrate there. About two years ago some traders came into the Chobe region, but the people were not inclined to the business. The price of a boy was about eight or nine yards of calico or baize cloth. Mr. Livingstone proposes to send his family home and go himself as a missionary to reside in the heart of the country."

"Patent granted, for improvement in sewing machines, to Isaac M. Singer, of New York City."



MANUFACTURING
Among the more than 700 products manufactured at AiResearch is a portable gas turbine ground heater. Most powerful heater for its size ever developed, it was designed to heat up Air Force planes and equipment in the Arctic. One unit produces 4,000,000 btu's per hour at −65 degrees F.



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DESIGNER

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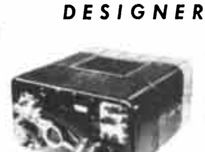
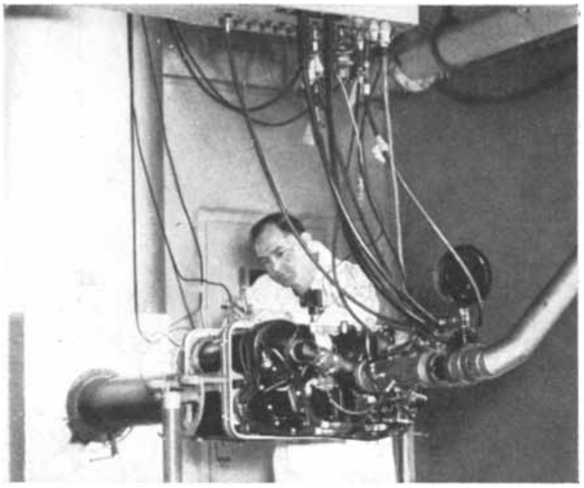


Gas Turbines

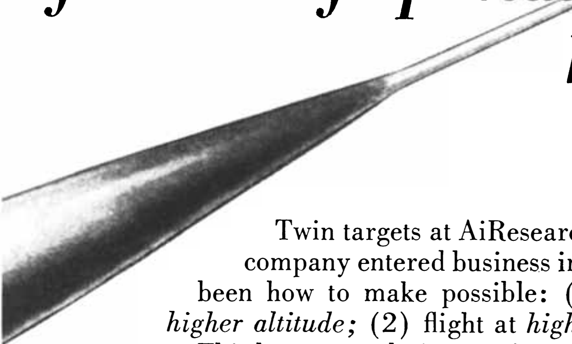
RESEARCH *Long range research policies have made the AiResearch Manufacturing Company a recognized industrial leader in many fields. Current lab facilities include 12 major research divisions, equipped to perform countless tests. Pictured at left under test is a moisture control unit for cabin air conditioning.*



QUALITY *Complete production testing facilities, combined with years of experience in proving equipment before delivery, have built the AiResearch reputation for quality. Shown here is a small gas turbine engine in the 100 hp class, one of the many "firsts" pioneered by AiResearch engineers and craftsmen.*

arch to achieve "the impossible"

ufacture of specialized aircraft accessories has made this company a world leader!



Twin targets at AiResearch, since this company entered business in 1939, have been how to make possible: (1) flight at *higher altitude;* (2) flight at *higher speed.*

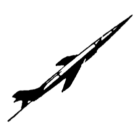
This has meant design, testing and manufacturing in unexplored fields. The major effort has been to control and utilize patterns of air flow, air density, air pressure and air temperature as they affect high altitude, high speed flight.

The company now employs more than 4500 engineers, technicians and skilled craftsmen in modern plants in Los Angeles and Phoenix.

These plants are equipped with complete up-to-date manufacturing facilities. In them are being produced over 700 different accessory products. All were developed and proven in the company's research laboratories, the most complete of their kind in existence.

Today every type of high speed, high altitude airplane of U. S. design is equipped with AiResearch products. Only AiResearch can supply all the integrated system components for cabin pressurization and air conditioning and lightweight pneumatic power for aircraft.

TODAY *AiResearch concentrates on helping to make America's commercial transports and military fighting planes the best in the world.*



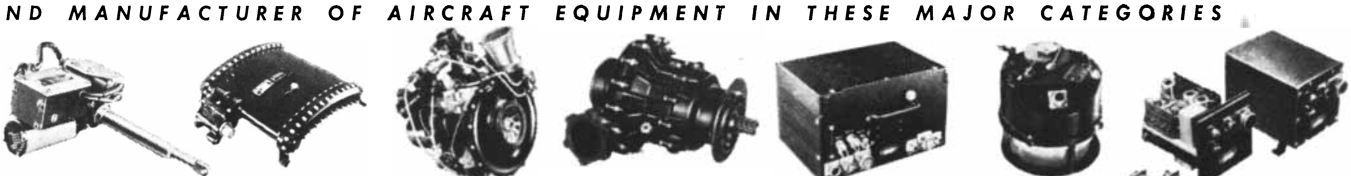
TOMORROW *this proven ability will be available to meet new problems in the advance of aeronautics and in other fields of industrial enterprise.*

AiResearch Manufacturing Company

A DIVISION OF THE GARRETT CORPORATION

LOS ANGELES 45, CALIFORNIA

AND MANUFACTURER OF AIRCRAFT EQUIPMENT IN THESE MAJOR CATEGORIES



Electric Actuators | Heat Transfer Equipment | Cabin Superchargers | Pneumatic Power Units | Electronic Controls | Cabin Pressure Controls | Temperature Controls

THE COVER

The painting on the cover depicts the wings of a pigeon and some of the features that make them effective aerodynamic devices (*see page 24*). All but the larger feathers have been removed from the lower of the two wings. The feathers of the outer half of the wing are primarily adapted to control and propulsion; the feathers of the inner half, to lift. Projecting from the leading edge of the wing is a small group of feathers called the alula; these can be moved to change the flight characteristics of the wing. The upper of the two wings retains all of its feathers, the smaller of which, as can be seen from the cross section of the wing, combine with the larger to form an airfoil like that of an airplane. The lone feather fluttering to earth at the right is one of those which impart a smooth curve to the leading edge of the wing. The wings in the painting were prepared by Frank Nocera of New York's American Museum of Natural History.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
20	Official U. S. Navy Photographs
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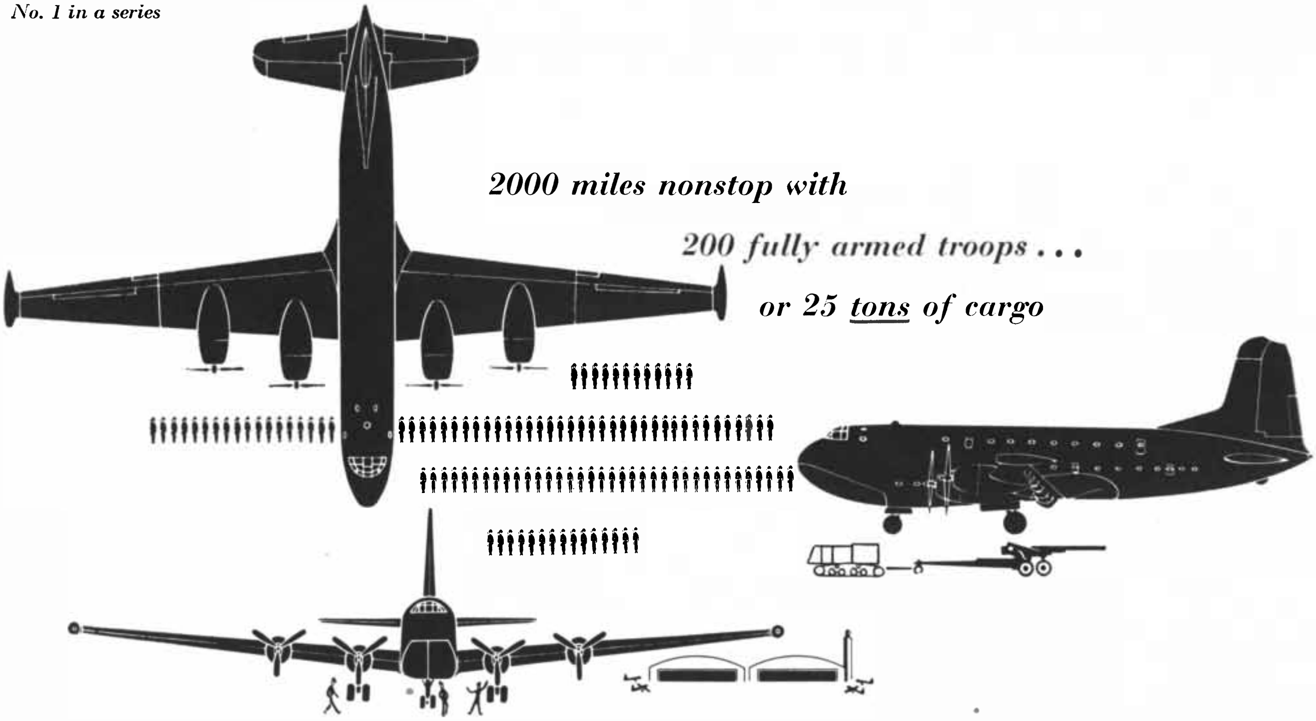

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SCIENTIFIC AMERICAN

Established 1845

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ARTICLES

DEPARTMENTS

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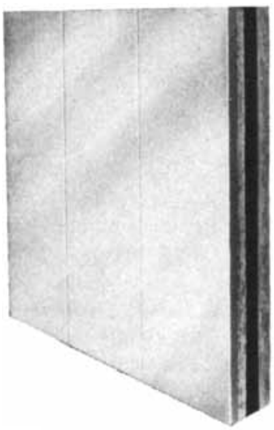
What's Happening at CRUCIBLE

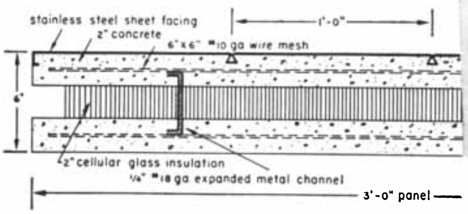
about stainless curtain walls

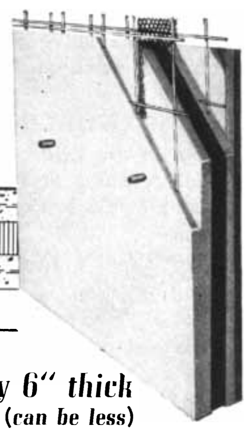
Modern construction methods have changed walls from the self-supporting type to a mere covering which does not support its own weight for more than one or two stories. Hence the definition of "curtain wall":—the facing or enclosure of the structural steel frame. This frame supports the entire weight of modern buildings.

The need has existed for a covering that would not only clothe the building, but be lightweight, economical and space saving. Because these requirements are more than adequately met with stainless steel curtain wall construction, this method is becoming increasingly popular with cost and space conscious owners, builders and architects.



the CRUCIBLE "sandwich"





the CRUCIBLE "sandwich"—only 6" thick (can be less)

Crucible stainless steel curtain wall panels are in the form of 6-inch thick "sandwiches". The facing consists of flanged, light-gauge stainless steel sheets with a factory, or site-fabricated, sandwich consisting of cellular glass insulation between two layers of concrete with connecting reinforcing. Crucible 18-8 stainless as the outside face offers excellent resistance to weather and fire while providing eternal beauty with a minimum of maintenance; the inside face can be finished or painted to suit the requirements of modern building interiors. Since 18-8 is restricted in use, a good substitute material, type 430 stainless, now government decontrolled, offers the same benefits as 18-8 stainless.

moisture penetration

The unique characteristics of the cellular glass insulation stop moisture vapor migration from one face of the panel to the other. The cellular insulation properly designed and installed assures that condensation will not take place *anywhere* within the sandwich.

insulation

Although less than half as thick as the usual wall construction, this Crucible stainless steel panel construction has more than twice the insulating value. The "U" value (overall thermal conductivity) is approximately 0.15 BTU Hr./Sq.Ft./°F.

fire resistance

The Crucible sandwich met the requirements of a standard 4-hour fire test conducted in the testing laboratories of the National Bureau of Standards. This meets all old building codes and is double, or better, the requirements of modern enlightened building codes.

erection and fabrication

Since a building frame is not precision built, the attachment of the panel walls to the frame is done with fastening devices that provide necessary 3-dimensional adjustment. Panels can be made at the building site, and a 24-hour casting-to-fastening cycle is possible.

technical service available

Though the use of some stainless steel is now restricted, Crucible metallurgists and development personnel are continuing to investigate improved methods of curtain wall and other construction so that better buildings can be built when stainless is more freely available. For more information write: CRUCIBLE STEEL COMPANY OF AMERICA, General Sales and Operating Offices, Oliver Building, Pittsburgh, Penna.

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APRIL 1952

SCIENTIFIC AMERICAN

VOL. 186, NO. 4

The Pacific Floor

Modern methods of undersea exploration have pieced together a dramatic picture of this rugged landscape. A description of it in terms of an imaginary voyage in a supersubmarine

by Robert S. Dietz

THREE great diverse surfaces—interfaces between the different states of matter—cover our planet: the land surface, the sea surface and the interface between sea and land at the bottom of the oceans. With the first two areas we are well acquainted; the interface where land and air meet is man's natural habitat, and he has made himself almost equally at home on the surface of the seven seas. But the third interface, the sea floor, is still a vast unexplored frontier. This immense area, covering 71 per cent of the surface of the globe, has not yet been penetrated by man except at its shallow fringes along the ocean shores. We actually know much less about the topography of the Pacific Ocean floor, for example, than we do about the face of the moon.

The vast lands beneath the sea must forever remain hidden from any large-scale visual exploration, for even in the clearest water and with the most powerful light we can see no farther than 180 feet. Nor can a "seeing" aid such as radar help us; the oceans are almost opaque to all electromagnetic radiation. But man's inventiveness has at last produced an instrument with which we can begin the exploration of the sea bottom, which has fascinated science and the imagination for centuries. The instrument is sonar: a "searchlight" that uses sound waves. As the atmosphere is the realm of light and other electromagnetic radiation, so the sea is the realm of sound. Sea water is an excellent transmitter of sound waves: a two-pound charge of TNT exploded in deep water off Hawaii can be heard by submerged hydrophones more than 2,300 miles away off the California coast. (If a shot is ever actually "heard 'round the world," it will be fired under water.) Under the sponsorship of the U. S. Navy the science of underwater sound is growing vigorously, and many types of sonar devices have been developed. For the oceanographic explorer the most useful is the echo sounder, which bounces sound pulses off the sea floor and paints a picture of its profile on a screen.

Thanks to the echo sounder we now have a partial map of the Pacific floor. Let us survey some of these discoveries by taking an imaginary cruise along an explored route on the ocean bottom. We must imagine that we are making the voyage in a submarine for which only Jules Verne, as yet, holds the patent—a true submarine that will carry its own source of oxygen and will have a hull strong enough to stand the great pressure of the deep sea. We must further suppose that we are equipped with advanced sonars of the future which will give us a clear view of the seascape as we proceed on our voyage.

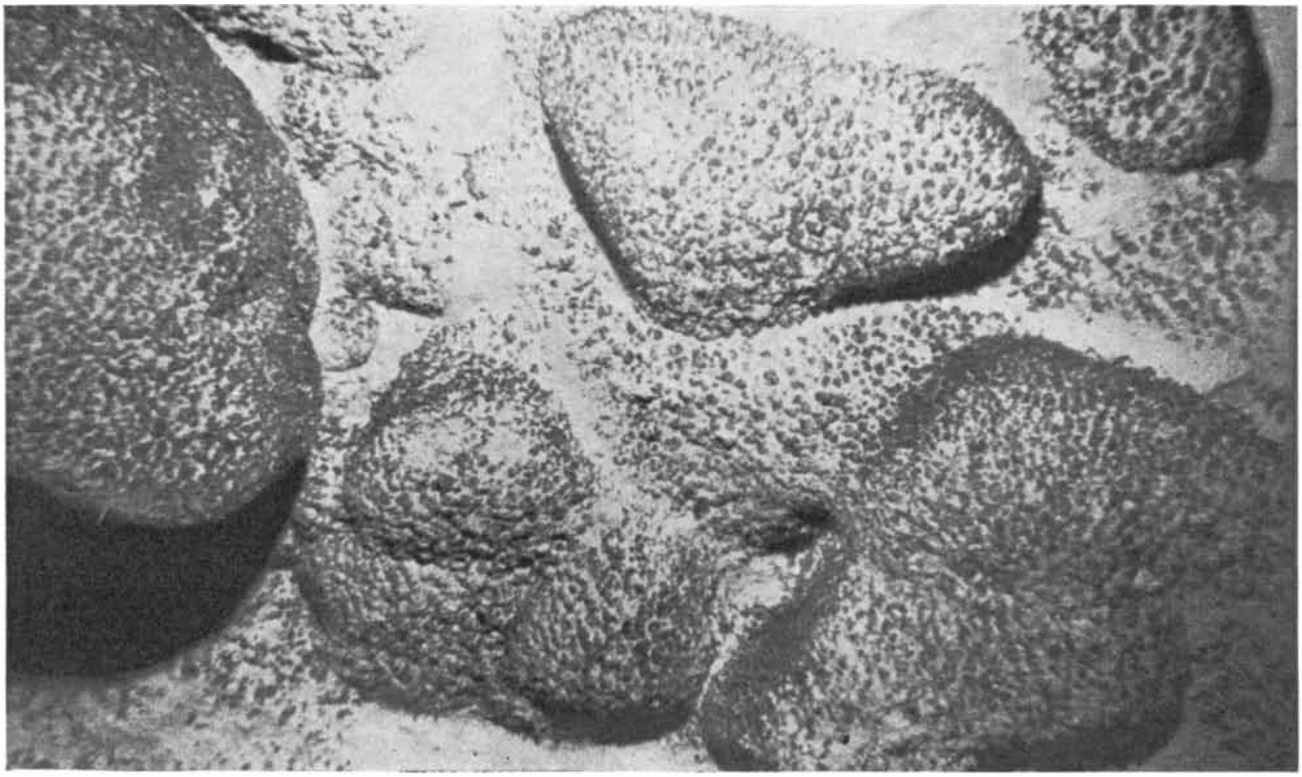
We start from San Diego. Diving to the bottom and heading straight out to sea, we travel for the first 10 miles across a shallow, gently sloping plain—the continental shelf. We have to grope our way slowly here, because the green water is clouded with stirred-up sediment, organic pigments and millions of diatoms, and the teeming marine life produces echoes on our sonar that obscure

K. CHESTER

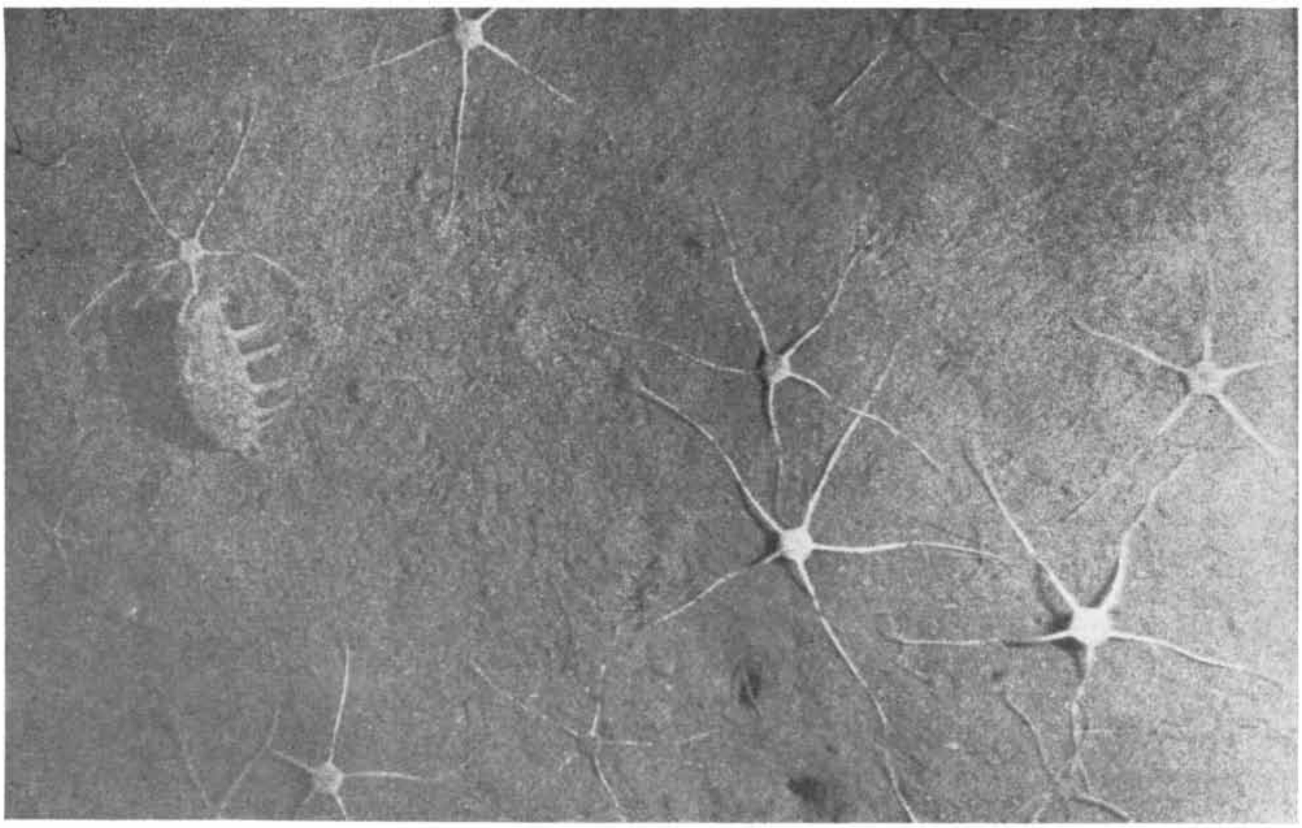
As this issue of SCIENTIFIC AMERICAN went to press its art director, K. Chester, died of cancer. His age was 33.

Chester had been responsible for the format, illustration and production of this magazine since its reorganization in 1948. He was a gentle and versatile man. He began his career as a scholar and teacher of art; later he became a successful photographer for *Life* and other magazines. During World War II he was a photographic officer at the Supreme Headquarters of the Allied Expeditionary Forces. At the end of the war he organized the photographic coverage of the Nuremberg trials.

But Chester's first loves were science and art. He felt that these two expressions of the creative imagination, which once were more closely associated than they are today, had much to contribute to each other. He was successful in persuading many fine artists to lend their talents to scientific illustration for the first time. The journalism of science has lost a gifted and original worker.



ROCKS on the flat top of a mountain 4,500 feet below the surface of the Central Pacific were photographed by means of a special camera. The rocks are coated with a layer of manganese dioxide. Because this substance forms very slowly, it is a measure of the time that has passed since the mountain sank beneath the surface.



CREATURES on the mud bottom of the San Diego Trough 3,600 feet below the surface are a species called the brittle star, and a sea cucumber (*left*). The brittle star bears its name because its arms may easily be broken off. These animals live on the biological refuse that settles out of the waters nearer the surface.

the bottom. The smooth, shallow continental shelf slopes down to only about 330 feet below sea level at its deepest. Extending completely around North and South America, it is believed to have been alternately under and above water as the sea rose and fell in geological time, and its edge is supposed to mark the lowest sea level, *i.e.*, the farthest coastline, of the Ice Age, when the water piled up in glaciers on the land.

TEN MILES OUT the shelf ends abruptly, and we find ourselves at the edge of a scarp, or cliff, that plunges steeply into the deeper ocean. We dive down its face to a depth of more than 1,000 feet, where our sonar view will not be obscured by interfering echoes from surface organisms or from the deep floating layer of small animal life that shows up on the echo sounder as a phantom bottom ("The Deep-Sea Layer of Life," by Lionel A. Walford; SCIENTIFIC AMERICAN, August, 1951).

The scarp is a convenient feature to follow as a navigation guide, so we turn north and travel along its face. Twenty miles north of San Diego we come to a great gash 1,500 feet deep: the La Jolla Submarine Canyon. Looking remarkably like some of the famous river canyons in the Sierra Nevadas, this huge steep-walled valley plunges down into the deep undersea trough off San Diego. There it becomes a leveed channel that winds across the flat bottom of the trough. The levees remind us of the natural levees built by the Mississippi River on its delta at New Orleans, but these are much larger. They must be produced by mud-charged currents that shoot down the canyon, flow across the trough, spill over the narrow channel and leave deposits of mud that build up the levees. Perhaps the huge canyon itself has been cut in the continental shelf by such currents through eons of time.

From the submarine canyon we swing west toward the deeper ocean. On the way to the abyssal Pacific Basin, we cross a rough badlands of banks and depressions—a continental borderland which is unique to this particular part of the world. Its seascapes are everywhere green; oozy green muds carpet the basins, and patches of the sandstone known as greensand coat the rocky banks. Its shallower basins are the realm of organisms that live on the rain of organic matter which constantly falls from the surface waters above. The bottoms are populated by countless millions of serpent starfish, in company with mud-groveling sea cucumbers and sea spiders. Some of the deeper basins, however, support little or no life, because their semi-stagnant water lacks oxygen. The organic matter that rains into them is gradually buried and will eventually form pools of petroleum.

When we turn our special optical searchlight on the banks that rise over the basins, we find them covered with extensive beds of shiny, brown, grotesquely shaped lumps of rock rich in phosphorus. These nodules have grown as crystals grow, by the slow addition of material to their nuclei. In this case they are built up of colloidal particles of tricalcium phosphate from animal shells. In the ancient heart of some of these long-growing nodules we find fossils 15 million years old. On the same banks, scattered among the nodules, are phosphatized whales' ear bones, sharks' teeth and other bones of fish and sea mammals. Someday no doubt these great undersea beds of rock and bone will be mined for their phosphates and rich content of radioactive trace elements.

We cruise on westward for 140 miles across the continental slope and arrive at length at the brink where it drops off to the Pacific Basin itself. Like Pizarro standing on the Andes, we face a breathtaking outlook. Below us falls away a gigantic escarpment as sheer as the east face of the Sierra Nevada and almost twice as high. Here we have reached the real edge of the continent, where the granitic continental rock gives way to the world-girdling foundation of denser basic rock on which the continents float.

THE FLOOR of the Pacific Basin, lying three miles below us, is unlike anything else on earth. It is studded with immense volcanic cones and calderas, vastly larger than any on the continents, and is split by huge fault blocks and scarps. Along the base of the continental cliff stand several great sea mountains. But most striking is the fresh, youthful look of the topography. It looks as if it was created only yesterday. The volcanic cones have the classically simple forms of textbook diagrams of volcanoes, and the fault scarps rise like the straight sheer faces of blocks several thousand feet high. This pristine simplicity is not, however, a sign of youth; it is the result of excellent preservation, due to the protection of the seascape from weathering. Unlike mountains on the land, the seamounts have been free from the erosion of wind, rain, streams or ice. Largely untouched by erosive forces, they are physiographic museum pieces still standing as they were when formed eons ago.

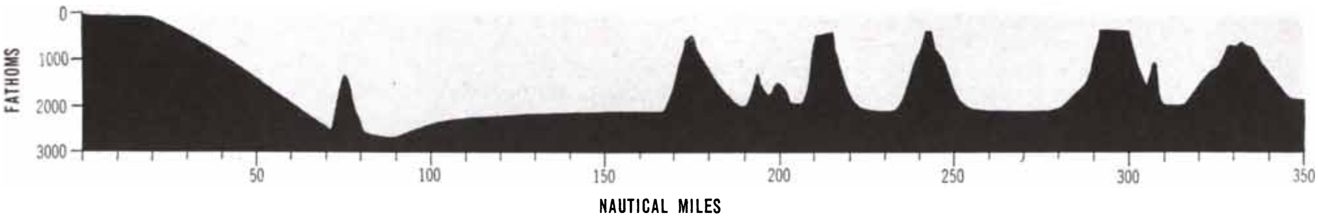
Before we go on with the journey, let us take a little time to inspect the sea floor closely. In the hollows and basins between the mountains and knolls are ponded deposits of a soft, fine-grained red clay such as has never been seen on the continents. Its red color indicates an oxidized state, which in turn shows that very little organic matter is deposited here. For one thing, the surface waters of the deep Pacific are relatively poor in nutrients, so they grow only about one per cent as much organic matter as the richer waters inshore. For another, the solvent power of the cold water masses, rich in carbon dioxide, that flow in from the Antarctic prevents permanent deposition of any of the organic material that may fall here from the surface.

We now turn our submarine to follow the steep continental escarpment northward. Cruising at 2,400 feet below sea level to avoid bucking the strong south-setting California Current near the surface, we explore the rugged face of the great scarp, broken by deep gullies, landslides and enormous mudflows. Off Monterey Bay, California, we pass one of the great submarine canyons of the world. Fifty miles long and more than 7,000 feet deep, it compares in grandeur with the Grand Canyon. Farther north, off Cape Mendocino, we run into a two-mile-high escarpment that branches from the main north-south scarp and heads out almost at right angles toward the west. We could follow this winding cliff for 1,000 miles and still not find the end of it. It evidently marks a major boundary in the earth's crust, because to the north of it the sea floor is about a half-mile higher, indicating that its rock is lighter—intermediate in density between the continental and the oceanic rock types.

Soon we are cruising along the floor of the Gulf of Alaska, a smooth plain that slopes toward the southwest. The floor is covered with a gray, felt-textured ooze composed of the shells of countless millions of diatoms that have settled down from the surface waters. Here and there seamounts projecting through this sea of ooze rise up 5,000 to 8,000 feet, to within a mile or less of the sea surface. Most of them have broad flat tops.

THESE table mounts, called guyots, look like decapitated volcanoes, and that is exactly what they are. Their tops must have been cut off by some knife-edged erosive process. In the realm of the sea there is only one way that such a clean job of decapitation could have been accomplished: by the action of surf. In other words, their tops once stood above the water as islands and were sliced off by breakers cutting into them. This conclusion is confirmed by the fact that their flat tops are fringed by a narrow border of rounded cobblestones—the remains of their ancient cobble beaches.

These ancient islands are now deeply drowned below the surface of the sea. What caused them to fall so far below the sea level? Our echo sounder provides a clue. Several of the table mounts are surrounded by depressions, or moats, around their bases; they look like a coffee cup turned upside down in a saucer. It is tempting to conclude that they sank because the mountain mass bent down



CROSS SECTION of a part of the Gulf of Alaska shows the continental shelf (*left*), the Aleutian Trench (*at the bottom of the shelf*) and a chain of nine seamounts. The tallest of the mounts rises 11,214 feet from the bottom of the Gulf. The top of the mount that stands in the Trench is 7,000 feet below the surface.

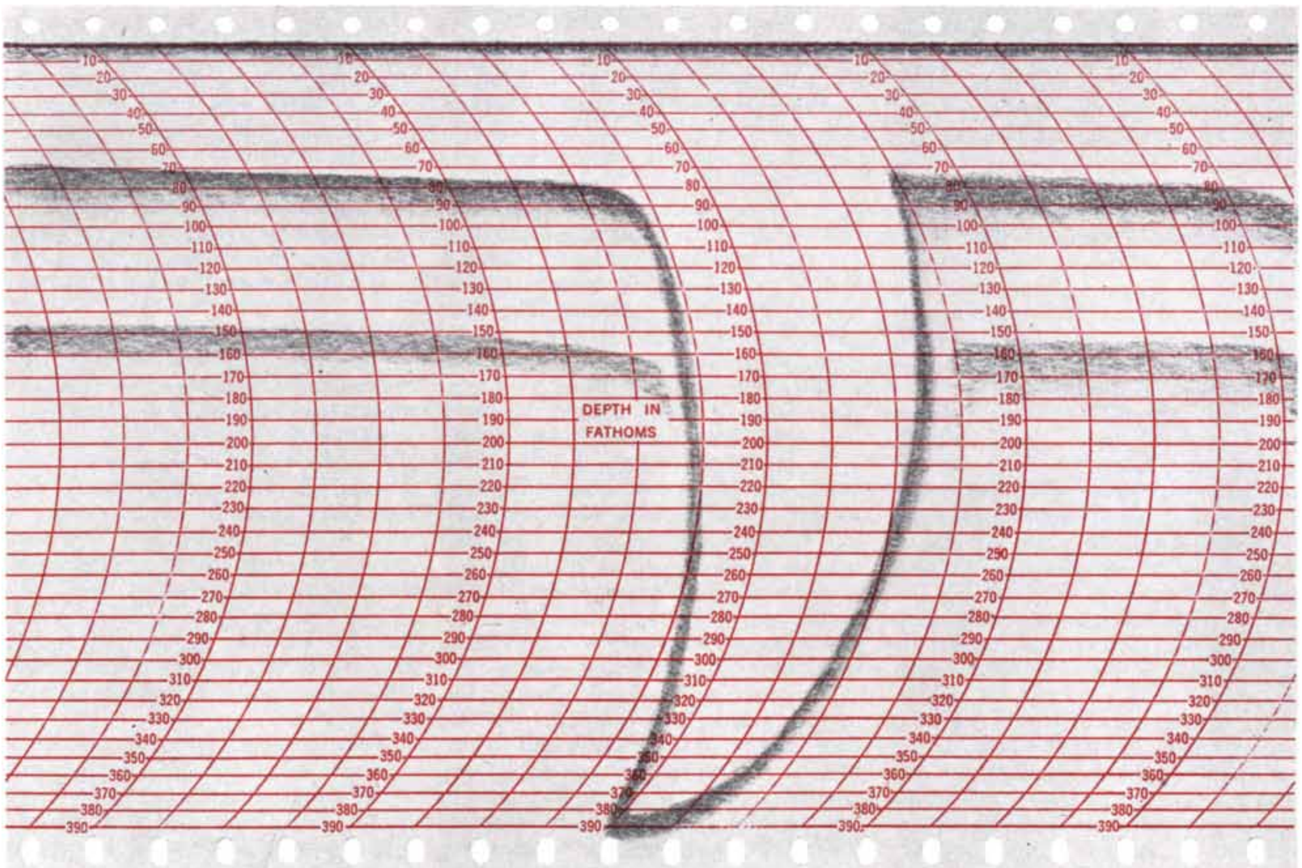
the earth's crust, much as a small boy standing on thin ice bends down the ice over a large saucer-shaped area.

But movement and buckling of the crust itself has also contributed to the drowning of some of the guyots. As we drive north into the great undersea valley known as the Aleutian Trench, we can see evidences of this. On the south flank of the Trench is a table mount whose top is tilted in toward the Trench; evidently it was first decapitated and then tilted over when the Trench was formed by downbuckling of the crust. There is another guyot standing on the bottom of the Trench, and its flat top is 7,000 feet below the sea surface—the most deeply drowned guyot we have seen. In all likelihood the formation of the trough is responsible for its deep sinking. Geological evidence indicates that the Trench is at least 15 million years old, so the two guyots must be older than this. The sea mountains truly are long-lived; on land a similar mountain would be worn away by erosion in a few million years at most.

Strewn over the tops of some guyots we find occasional boulders of granite and other continental rocks. This is a startling discovery: How did they get out here in the deep ocean? Probably, a little reflection suggests, they were ferried out from the continent by icebergs of the Ice Age and dropped on the guyots when the ice melted.

FROM THE Aleutian Trench we turn south and, steering by our gyrocompass, head for the Hawaiian Islands. The islands themselves are only the occasional surface projections of a great 1,800-mile volcanic ridge that stretches almost continuously from the island of Hawaii to Midway Atoll. The ridge lies along the axis of a broad low swell of the sea floor dotted with numerous sea knolls and seamounts: the foothills of the mountain range. Here and there long straight fault scarps strike across the swell. Along the base of much of the ridge are deep moats and terraces, showing that the islands are sinking and the crust is being depressed by the great mass of the ridge. The subsidence is greatest toward the northwest end of the island chain.

This sinking would long ago have drowned the atolls were it not for the fact that they are constantly being built



FATHOGRAM, the record of an echo sounder, shows the cross section of Astoria Canyon at the mouth of the Columbia River. The sides of the canyon are curved by the convention of the record. The horizontal line at about 80 fathoms is the continental shelf; the second line at about 160 fathoms, the bottom of the shelf.

up by the skeletal remains of corals and coralline algae. These animals and plants, which thrive in the warm waters, maintain a coral reef at the sea surface as the foundation slowly subsides.

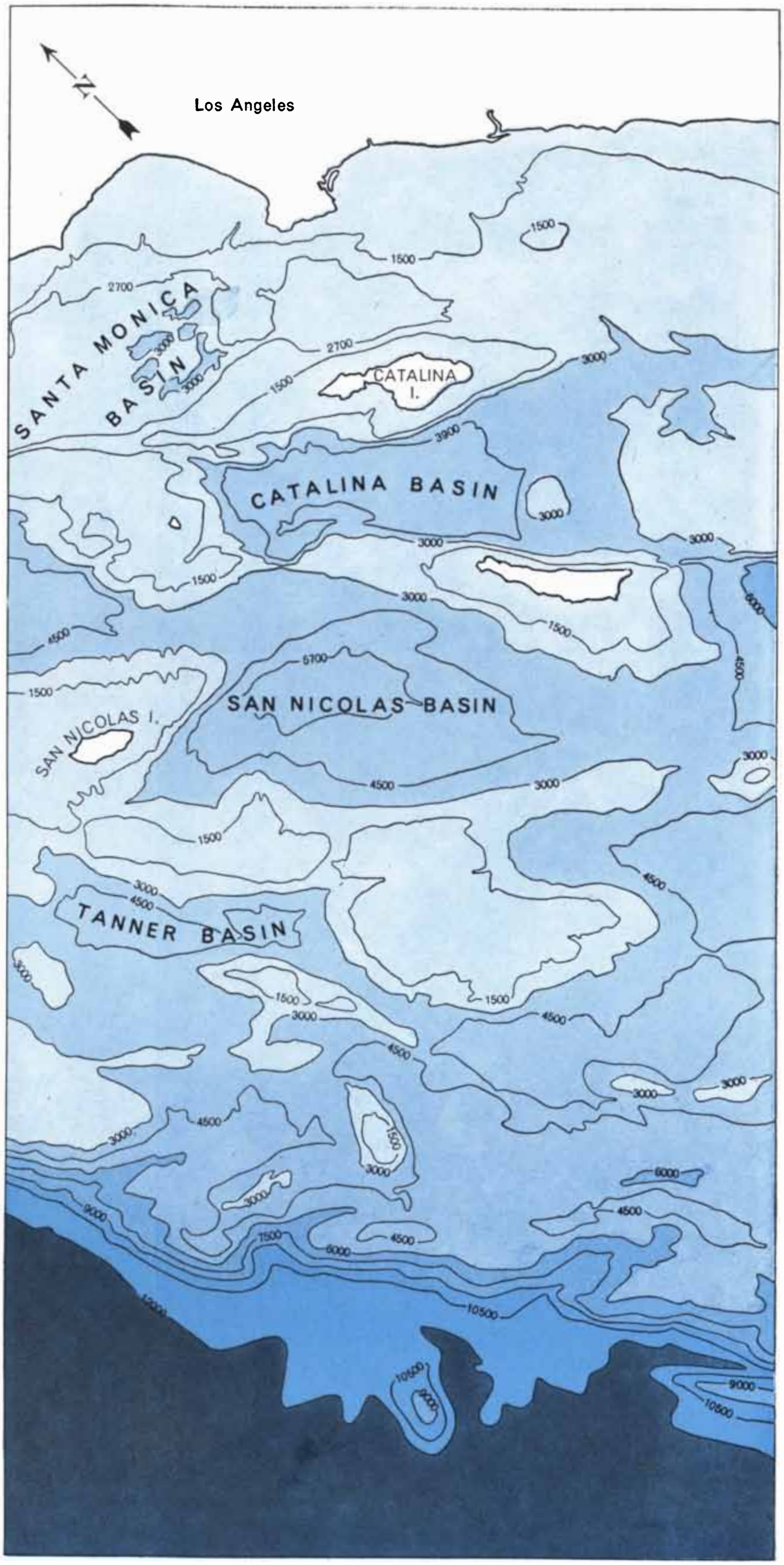
From the Hawaiian Islands we cruise west 300 miles to the Mid-Pacific Mountains. This mountain range lies completely submerged in the region between the Hawaiian Islands and Wake Atoll. From the top of the mountain mass rise a number of tall guyots, as the volcanoes Mount Hood and Mount Rainier project above the Cascade Mountains of the Rockies. Some of the guyots have dazzling white caps, like mountains on land, but the caps, of course, are not snow. They consist of a white ooze made of the remains of certain small protozoa (members of a family of floating foraminifera) which have shells of calcium carbonate. These animals live in profusion in the waters of the tropical Pacific, and their dead shells form extensive deposits in the shoaler parts of the Pacific.

Coral reefs fringe the tops of some of the mile-deep guyots, but these deeply drowned formations are dead: corals do not grow at depths below about 180 feet. The dead animals composing these reefs are ancient, extinct types, some of them about 100 million years old. These fossils give us positive proof that the guyots are indeed truncated ancient islands of the Pacific. We can only speculate as to why the building of these reefs failed to keep pace with the sinking of the guyots, as it did elsewhere. A period of cold may have killed off the corals, or the guyots may have sunk too rapidly for the reproduction of the animals to maintain the atoll at sea level.

The evidence of the coral fossils shows that the Pacific Ocean must have been at least two miles deep 100 million years ago, when the coral was growing on these guyot tops, because the sinking guyots still stand two miles above the surrounding Pacific sea floor.

Romanticists may be tempted to imagine that these guyots were once peopled by a race of human beings who were wiped out by a catastrophic rise of the sea—a kind of Pacific counterpart of the lost continent of Atlantis. But man did not arrive on the earth until a million years ago at the earliest, and the guyots had disappeared into the ocean long before that. It is possible, however, that geological history will repeat itself: that the Hawaiian Islands, a present-day counterpart of the Mid-Pacific Mountains, will eventually be cut to shallow banks and, like them, slowly sink beneath the sea.

Robert S. Dietz is an oceanographer at the U. S. Naval Electronics Laboratory in San Diego, Calif.



SUBMARINE TOPOGRAPHY off the coast of Southern California consists of a rugged system of swells and depressions. The contour intervals are given in feet. This map was prepared by the American Geographical Society.

RING-BILLED GULL has a long, narrow wing characteristic of birds that do much gliding over water. The anatomy of the wing is shown at the top of page 28. Birds that do little gliding have shorter and broader wings.

BROWN PELICAN is another gliding bird. The feathers at the tip of its left wing are turned up by a current of air. When the wing beats down during active flight, this same effect occurs and pushes the bird forward.

BIRD AERODYNAMICS

It is even more like that of the airplane than is generally assumed. A bird does not fly through the air as a man swims through the water; it employs the airfoil and the propeller

by John H. Storer

THE flight of birds has always excited man's envy and wonder. At first sight the process looks simple enough: a bird seems to lift and drive itself forward by beating its wings against the air in much the same way as a swimmer propels himself through water by flapping his arms. When men first tried to fly, they built their flying machines ("ornithopters") on this principle, with mechanical wings that flapped. But the machines never got off the ground.

For this is not at all the way birds fly. Paradoxically it was the development of the modern propeller plane that finally taught us how birds fly—not the other way around. A bird is actually a living airplane. It flies by the same aerodynamical principles as a plane and uses much of the same mechanical equipment—wings, propellers, steering gear, even slots and flaps for help in taking off and landing.

The slow-motion camera shows that a bird does not push itself along by beating its wings back against the air. On the downstroke the wings move forward, not backward. And when the bird lifts its wings for the next stroke, it does not lose altitude, as might be expected, but sails on steadily on a level course. The easiest way to understand its flight is to consider first how an airplane flies.

The air, like any fluid, has weight, and it presses against every surface of anything submerged in it—downward from above, upward from below and inward from all sides. At sea level the air presses on all surfaces with a force of 14.7 pounds per square inch. The air therefore will supply the force to support flight, provided the flying object can somehow reduce the pressure on its upper surface to less than the lifting pressure, and decrease the pressure against its front surface or increase that from behind. Birds and airplanes do this by means of properly shaped wings and propellers which they manipulate to drive themselves forward at a certain required angle and speed.

We can study the aerodynamical problems involved by blowing a stream of smoke, which makes the air currents visible, against an obstruction in a wind tunnel. When the smoke stream hits the obstruction, it does not flow smoothly around the surface and close up again immediately behind it. Instead, it breaks up and is deflected away from the obstruction so that the air no longer presses against the object's sides with the same force. Moreover, the air stream does not close up again until it has moved some distance past the obstruction, so the pressure on the rear surface of the obstacle also is reduced. There remains a disproportionate pressure on the front surface of the obstacle: what would be known as "drag" if the object instead of the air stream were moving.

Now suppose we place in the air stream an object so shaped that it fills in the spaces that were left vacant when the air was deflected by the first obstruction. The air flows smoothly around this new object, and the pressure is more nearly even on all sides. Drag is reduced. We have "streamlined" the obstacle. By altering this shape just a little, we can change the relative pressures on its different surfaces. Let us flatten the bottom surface slightly, reducing the downward deflection of the air stream. Now the upward pressure of air against the bottom surface is more nearly normal, while the downward pressure on the top surface remains subnormal as before. Presto! We have more pressure from below than from above. If the streamlined model is light enough, the moving air will lift it. We have the beginning of a wing.

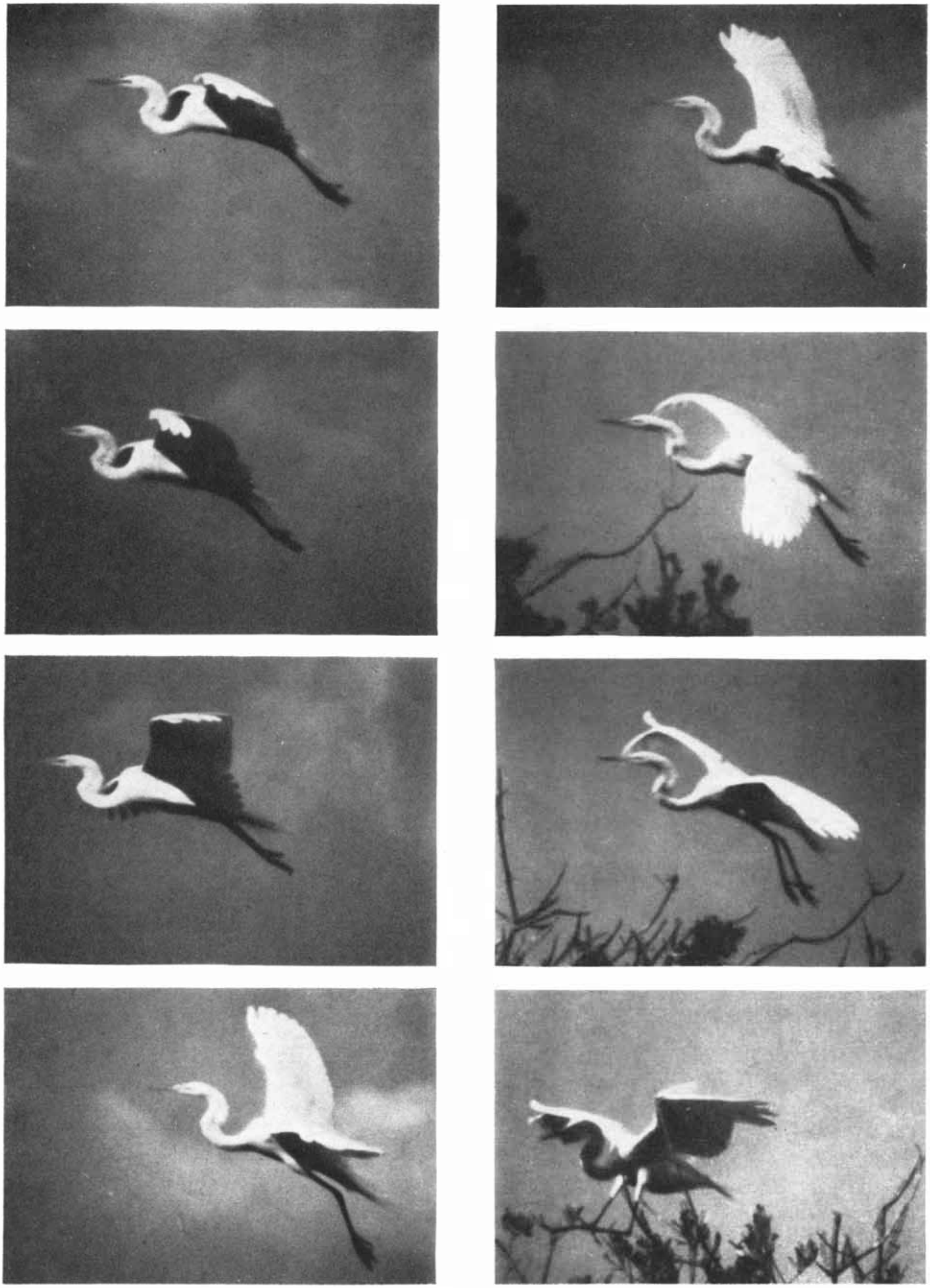
If the front edge of this embryo wing is tilted upward just a little so that the air strikes the bottom surface more directly, the lifting force on the wing is increased. The more the wing is tilted, the more lift it will give—up to a certain point. As the angle of tilt approaches the vertical, the pressure against the bottom surface begins to push the wing backward rather than upward. Eventually, if a plane's wing is tilted too much, the lifting force vanishes, the drag is so great that it stops the plane, and we have what is known as a "stall." The plane must regain the proper angle and speed or it will crash.

In the air a pilot controls the lifting power of his plane both by tilt and by speed: the more speed, the more lift. In taking off or landing, however, he must rely mainly on tilt: to get enough lifting force he must hold his wing at the greatest possible angle against the air, up to the point of stalling. The angle to which he can tilt the wing without stalling can be increased by placing a very small auxiliary wing in front of or behind the main wing. The "slot" formed between the main wing and the small auxiliary airfoil increases the speed of the air flow over the wing and so maintains its lifting power, even after it has passed the normal stalling point.

Once we have a streamlined wing, the next step necessary for flying is to move it through the air fast enough to generate lift. This we accomplish by equipping the machine with propellers, which are actually another set of wings, whose "lift" is exerted forward rather than upward. For mechanical reasons the blades of a propeller function better with a shape and angle slightly different from those of the wings, but the principle on which they work is just the same.

So we have, basically, a single mechanism which, placed in one position, holds an airplane up, and in another, drives it forward. Now we can look at a bird's anatomy and find exactly the same mechanism used in just the same two ways.

THE WING of a bird consists of two parts, which have two very different functions. It is divided into an inner half, operated from the shoulder joint, and an outer half, which is moved separately by a "wrist" midway along the wing. The inner half of the wing is devoted almost exclusively to giving lift. It is held rather rigidly at a slight angle, sloping like the wing of a plane. It also



LANDING American egret demonstrates the use of feathers in its alulas and wing tips to maintain balance and control. The alula is a small bunch of feathers on the leading edge of the wing. By opening slots with these feathers and those of the wing tips, the bird can control its lift while losing flying speed.

has the streamlined shape of a plane's wing: its upper feathers are arched to make a curved surface.

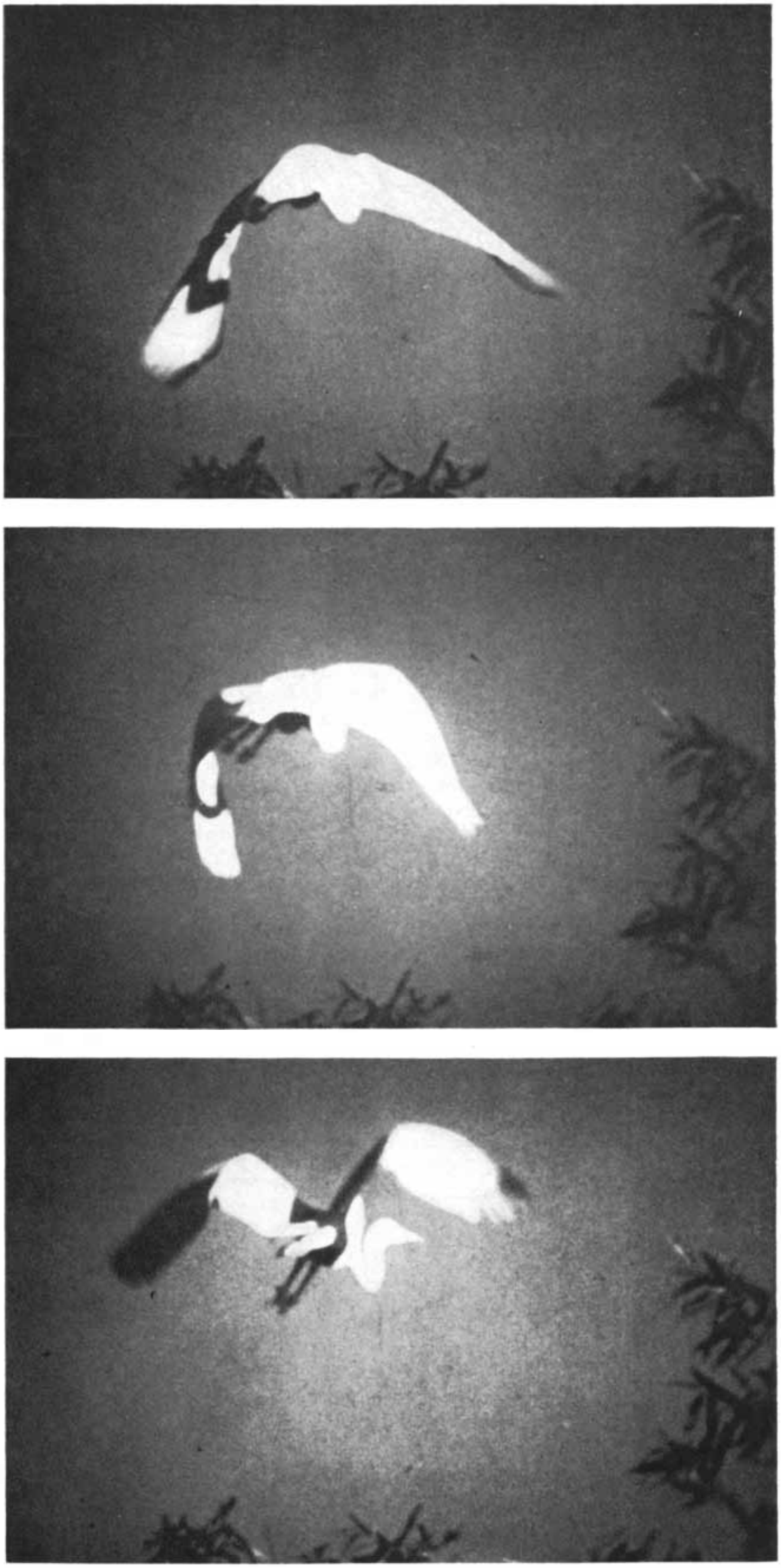
At the front edge of the wrist, where the inner and outer wings join, is a small group of feathers called the alula. This is the bird's auxiliary airfoil for help in taking off and landing. The bird can raise the alula to form a slot between that structure and the main wing. Without the alula a bird cannot take off or land successfully.

But where is the propeller? Astonishing as it may seem, every bird has a pair of them, though where they might be is certainly far from obvious. They can be seen in action best in a slow-motion picture of a bird in flight. During the downward beat of the wings the primary feathers at the wing tips stand out almost at right angles to the rest of the wing and to the line of flight. These feathers are the propellers. They take on this twisted form for only a split second during each wing beat. But this ability to change their shape and position is the key to bird flight. Throughout the entire wing beat they are constantly changing their shape, adjusting automatically to air pressure and the changing requirements of the wing as it moves up and down.

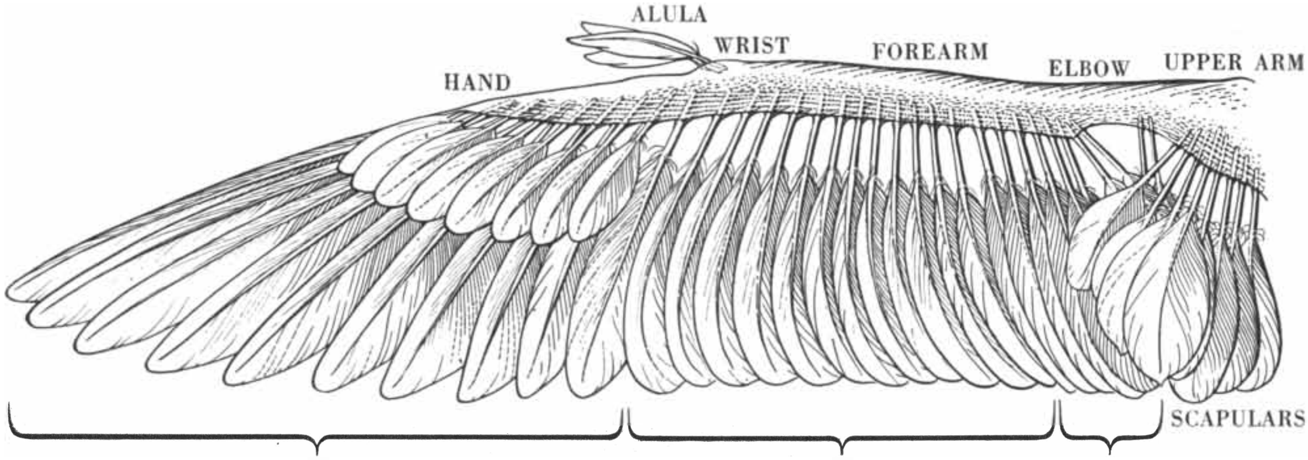
This automatic adjustment is made possible by special features of the feather design. The front vane of a wing-tip feather (on the forward side of the quill) is much narrower than the rear vane. Out of this difference comes the force that twists the feather into the shape of a propeller. As the wing beats downward against the air, the greater pressure against the wide rear vane of each of these feathers twists that vane upward until the feather takes on the proper shape and angle to function as a propeller. The degree and shape of its twist is controlled largely by the design of the quill, which is rigid at its base but flattened and flexible toward the end.

With their specialized design the primary feathers are beautifully adapted to meet the varied demands of bird flight. An airplane's propeller rotates around a pivot in one direction; the bird's propeller, in contrast, oscillates rapidly down and up, and it must automatically adapt its shape, position, angle and speed to the changing requirements of the moment. The feathers are not fastened immovably to the bone of the wing but are held by a broad flexible membrane, which allows considerable freedom of movement to each feather. While the bird is flying easily, only the tips of the feathers twist to become propellers. But if the bird is in a hurry and beats its wings more strongly against the air, the whole outer section of the wing, from the wrist out, may be twisted by the greater pressure into one big propeller.

The path of the propeller on the



FLYING egret shows the different functions of the inner and outer halves of a bird wing. In the first two pictures the wings are moving downward. In the third the inner half rises ahead of the outer to maintain lift.



ANATOMY of a herring gull's wing reflects the different functions of its inner and outer halves. The inner half of the wing, from the shoulder to the wrist, is adapted primarily to lift; the outer half, from the wrist to the wing tip, to control and propulsion. Only the principal feathers of the wing are shown in this drawing. The smaller feathers are arranged to give the wing the cross section of an airfoil (*see painting on the cover*).

downstroke is downward and forward; on the upstroke, upward and backward. The amount of forward and backward motion varies with the bird's wingbeat. When the bird beats its wings fast, as in taking off, the increased pressure drives the wing tips forward on a more nearly horizontal path; in leisurely flight the movement is more nearly vertical. The inner wing, by maintaining the proper angle, supports the bird's weight through the entire wing beat. This angle is constantly adjusted to maintain a steady lifting force.

In free flight the bird's powerful breast muscles sweep the whole wing up and down from the shoulder. The inner wing does not actually need to move, but it acts as a handle to move the propeller and gives the latter greater speed and power. I have a slow-motion movie of a low-flying white heron skimming some bushes so closely that it did not have room to make a full downward wing beat. The bird held the inner half of each wing extended horizontally and beat the outer half up and down from the wrist. To move the propeller fast enough without the help of the breast muscles must have required great effort. But this flight demonstrated perfectly the true function of each half of the wing. The inner half was the wing of a living airplane, lifting the bird. The outer half was the propeller, driving it forward.

Like an airplane, a bird has special equipment for steering and balancing. It steers by turning its tail, up, down or sidewise. (It can also spread the tail wide to give added lifting surface when needed.) The bird balances itself by means of its wings; if it tips to one side, it can restore itself to an even keel by increasing the lift of that wing, either by beating more strongly with it or by changing its angle.

	MILES PER HOUR
Great Blue Heron *[cruising]*	18-29
Great Blue Heron *[pressed]*	36
Canada Goose *[easy flight]*	20
Canada Goose *[pressed by plane]*	45-60
Mallard *[pressed by plane]*	55-60
Duck Hawk *[pressed by plane]*	175-180
Pheasant *[average top speed]*	60
Woodcock	5-13
Ruby-throated Hummingbird *[easy flight]*	45-55
Barn Swallow	20-46
Crow	25-60
Sharp-shinned Hawk	16-60
Osprey	20-80

FLYING SPEEDS of 13 species of birds are listed in this table. The conditions under which the observations were made are in parentheses.

OF ALL the powers of birds in the air probably none has caused more wonder than their soaring ability. To see a bird rise in the air and sail on motionless wings into the distance until at last it disappears from sight gives one a sense of magic. We now know how it is done, but it is still difficult to realize what is happening as we watch it.

Actually the bird is coasting downhill in relation to the flow of air. It rises because it is riding a rising current of air which is ascending faster than the bird is sinking in the current.

Ascending air currents on which birds can soar or glide arise from two different kinds of situations. One is an obstruction, such as an ocean wave, a shore line or a hillside, which deflects the wind upward. It is common to see a pelican or albatross sailing over the water on motionless wings just above the crest of a moving wave, or a gull hanging motionless against a wind current that rises over a headland, or a hawk soaring on the air current that sweeps up a mountainside.

The second type of rising current is heated air, known as a thermal. A field warmed by the sun heats the air above it, causing it to expand and rise. If the field is surrounded by a cooler forest, the heated pocket of air may rise in the form of a great bubble or of a column. Everyone has seen birds soaring in wide circles over land; usually they are coasting around the periphery of a rising air column. Over the ocean, when the water warms colder air above it, the air rises in a whole group of columns, packed together like the cells of a honeycomb. If the wind then freshens, it may blow the columns over until they lie horizontally on the water. The flat-lying columns of air may rotate around their axes, each in the opposite direction from its neighbor. This has been demonstrated in the laboratory by blowing smoke-filled air over a warmed surface at increasing speed, corresponding to an increase in the wind over the ocean. If you put your two fists together and rotate them, the right clockwise and the left counterclockwise, you will see that the two inner faces of the fists rise together. Just so two adjoining air cells rotating in opposite directions will push up between them a ridge of rising air. Birds can glide in a straight line along such a ridge.

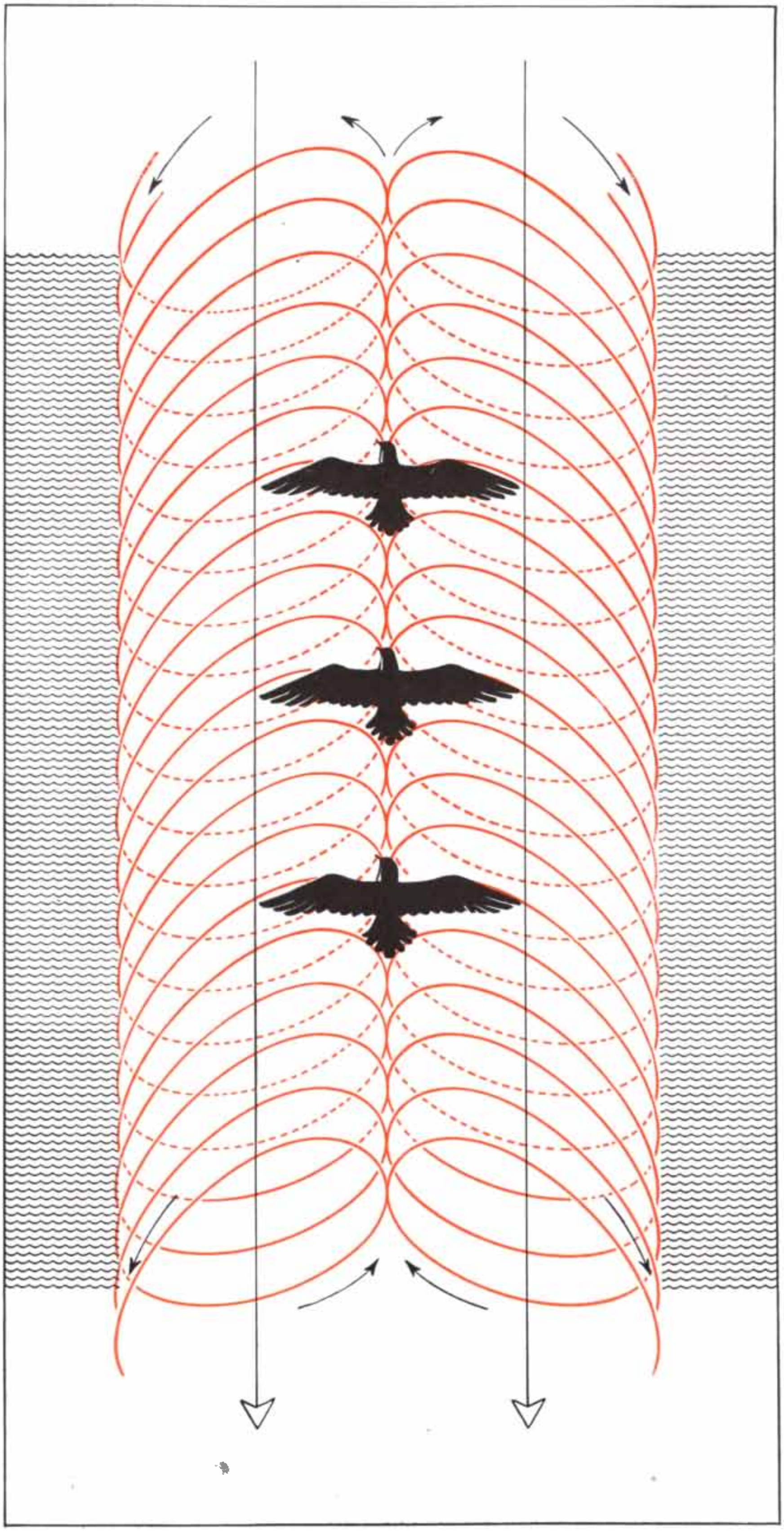
At the Woods Hole Oceanographic Institution Alfred H. Woodcock studied the soaring of sea gulls at different seasons. During the summer, when the air is warmer than the water, gulls seldom do any soaring. But they do a great deal of it in the fall, when the water is warmer than the air and produces many updrafts. The gull's movements may clearly mark the outlines of the rising air columns. When the wind is relatively light, under 16 miles an hour, the gulls soar in spirals, showing that the columns are standing upright. But as the wind freshens and tilts over the columns, the birds' soaring patterns begin to change; when the wind speed reaches 24 miles per hour, all the gulls soar in straight lines. The spectacle is all but incredible, with the birds sailing into the strong wind on motionless wings and gaining altitude as they go, until they disappear in the distance. I watched it once, and it is a never-to-be-forgotten sight.

How fast do birds fly? A great deal of nonsense has been uttered on this subject. The measurement of a bird's speed capabilities is a very uncertain and tricky thing. The wind, the angle of the bird's flight, whether it is being pressed—these factors and many others affect its speed.

The cruising and top speeds of some common birds are listed in the table at the bottom of the opposite page. Birds vary greatly, of course, in their speed requirements and possibilities. The pheasant and grouse, which have short wings adapted to maneuvering in underbrush, must fly with a rapid wing beat and considerable speed to stay in the air. The same is true of ducks, which do not need large wings because they have an easy landing field on the water. Herons, on the other hand, must be able to land slowly to protect their long, slender legs, which they use for wading to find food. Their big, cumbersome wings are suited for slow landing, but they produce so much friction and drag in the air that herons cannot fly very fast.

As the table shows, 60 miles an hour is fast for a bird, and the fastest known species, the duck hawk, does not exceed 175 to 180 miles per hour. These speeds, of course, are far slower than the speeds of modern planes. They involve very different problems in aerodynamics, and different streamline designs. But some of them do approach the speed of the early planes, and it is interesting to see how closely the designs produced by nature approach the best results of the human engineer.

John H. Storer is a student of the aerodynamics of birds. He is author of the book The Flight of Birds.



SEA BIRDS sometimes soar against a prevailing wind (*vertical arrows*) by riding an updraft between two counter-rotating cylinders of air. These cylinders result from the fact that when the sea is warmer than the air, many vertical columns of warm air rise from the surface of the water. If the wind freshens, the columns lie parallel to the surface. Birds are not drawn to scale.

PICTURE 1

SCHIZOPHRENIC ART: A CASE STUDY

The drawings and paintings of a child who lost both of her parents and developed schizophrenia show how she changed over three years of successful treatment

by Bruno Bettelheim

THE pictures on these pages are of simple things—houses, people and animals—and they were drawn and painted by a child. The girl who did them, like most children, loved to draw. But the girl was different from other children, and so the style and subject matter of her pictures, though they have all the familiar elements of children's art, are also startlingly different.

These pictures were all done by Mary, a schizophrenic girl, during a three-year period when she was a patient at the Sonia Shankman Orthogenic School of the University of Chicago, and they illustrate steps in her rehabilitation. Her pictures were unsolicited, motivated only by what went on within her and incidental to happenings around her. During her three years at the School she made hundreds, but she destroyed many of them immediately, and others she kept; those reproduced here are some of the few she gave us.

Mary was an orphan. Her father died so soon after her birth that she did not know him, though this did not prevent her from having elaborate fantasies about him. After his death Mary's mother became melancholic and lost interest in her child; this was only one aspect of her lack of interest in living. Mary was not only neglected but remained uneducated even in such matters as toilet training. Her mother provided barely enough care to keep her alive, and then died when she was three. From that time until she came to the School, Mary lived with various relatives, all of whom were appalled by her antisocial behavior and tried to make her conform to middle-class standards. To their pressure she reacted with violent tantrums, with homicidal attacks on other children and with attempts to run away. On these expeditions she stole and had a number of sex experiences. Her behavior grew worse and worse, and finally, at the age of nine, she was placed in our school.

At that time she saw herself as a murderer. Sex anxiety and confusion were very great. She said, "I always get the he's and she's mixed up." She believed that no one could like children, particularly her. Neither could she understand how any child could like an adult.

During her first months at the School Mary spent long periods in complete isolation, despite our efforts to keep her company at all times. She lay on her bed, not speaking, not moving, except during occasional outbursts when she screamed threats of wholesale murder.

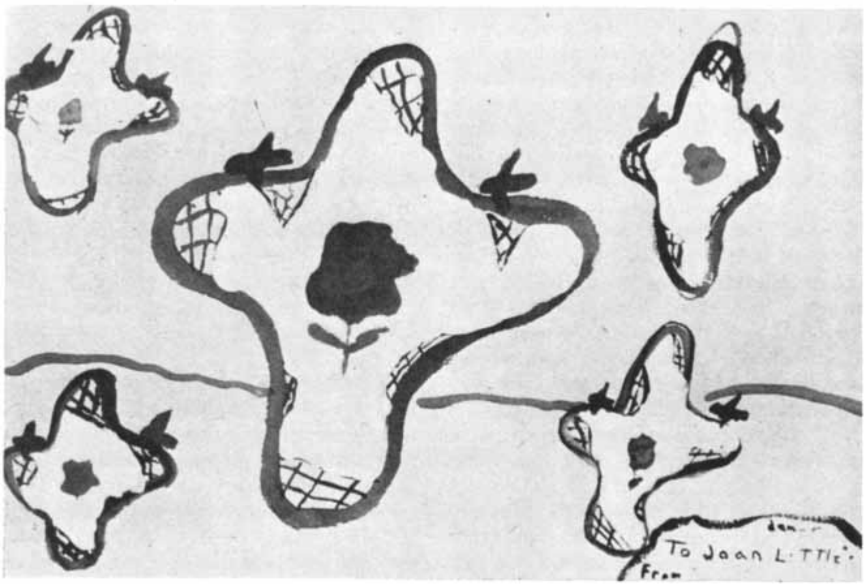
Though she herself sometimes screamed for hours, when she was quiet she insisted on complete silence around her. Eventually we understood that in this way she was trying to relive and master the life she had known with her melancholic mother, when her cries for food and care remained mostly unnoticed, when she was crying in the wilderness and no other sound was to be heard.

MARY approached paints with the great anxiety that was so characteristic of her. But messing around with paints and clay proved to be one of the first things she had ever enjoyed. While trying out colors in her first weeks with us, she painted as if by chance a self-portrait (picture 1). She said it was a picture of herself, but added immediately: "It's just any girl, a girl without

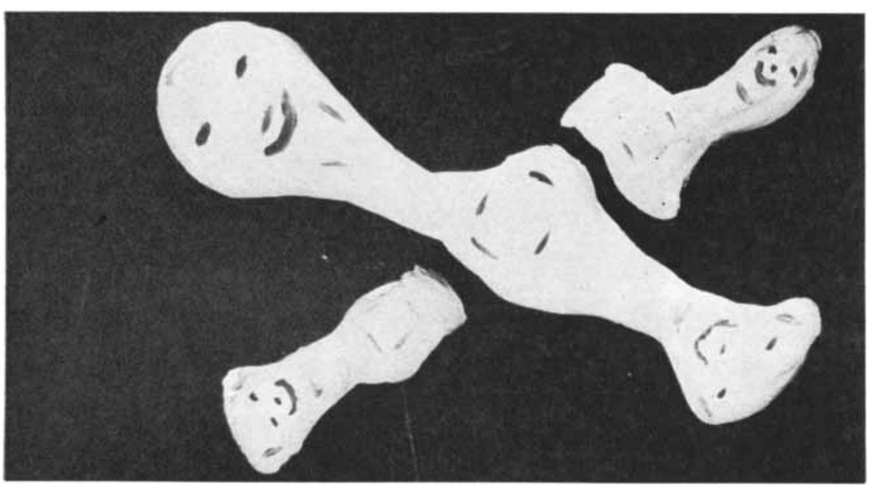
PICTURE 2

PICTURE 3

PICTURE 4



PICTURE 5



PICTURE 6

any name." As a matter of fact, when later in her rehabilitation she endeavored to change her ways (declaring, "Let's start the world all over again"), she wanted to get rid of her name and take a new one.

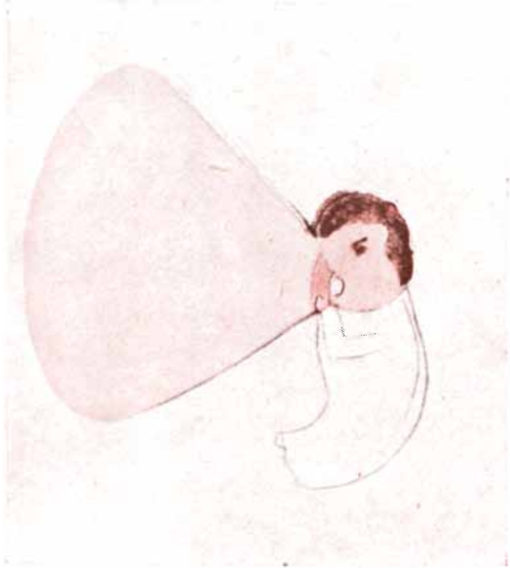
The loving care and therapeutic help she received at the School made her try to like this new world where people uncomplainingly endured her mistreatment and still tried to make life pleasant for her. By the end of the first year she wanted the faces she drew to have happy expressions. They continued to look sad, however, in spite of her efforts. Her self-portraits still showed the face of a terribly unhappy girl.

Up to this time Mary had had very little use for toys. She began now to cling to a few favored ones. She still could not like people because she did not like herself. But when she found a toy animal that had been neglected, mistreated and deserted (as she had been), she "rescued" it and preferred it to the new toys we gave her. Though she could not yet permit us to be good to her, or be good to herself, she could at least be good to these decrepit animals.

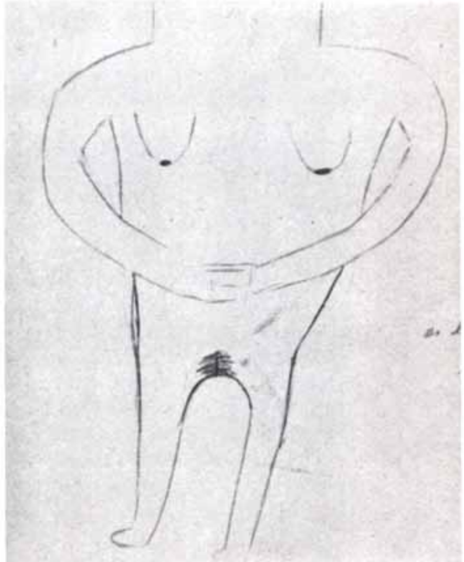
The first she really enjoyed was her stuffed panda. Her drawings of this battered toy show her identification with it and express her early experiences as well. As an infant she had had to look out for herself—to be mother and child at the same time. So she drew the panda twice, both as mother and baby (picture 2). She said the baby panda was three years old (her age when her mother died), and the picture shows Mary's greatest wish at that time: that her mother should take good care of her. Now that she felt better protected by us, she could face the thought of that wish and its frustration. Because of her early and deep privation, she felt food to be her greatest need, and she pictured the mother panda going to the store to buy candy, ice cream, cake and meat for the baby.

Food is one basic need and the other is shelter. Not until a person feels secure about these can he undertake the difficult task of integrating his personality. After a year at the School, this homeless child finally felt that she had acquired a home. Her drawings at that time were mostly of houses, representing the School. First she used gloomy colors and omitted people (picture 3). Later human beings appeared, but only as creatures to be repulsed. The first elaboration of her drawings of houses was a fence, "to keep everybody away." It was as if she were trying to insure that nobody should interfere with the security she had begun to feel. Still later a few sketchily drawn figures of children appeared at the windows. Finally she combined the two basic needs and her feelings about them in one drawing. She began by drawing a huge candy cone—

PICTURE 7



PICTURE 8



PICTURE 9

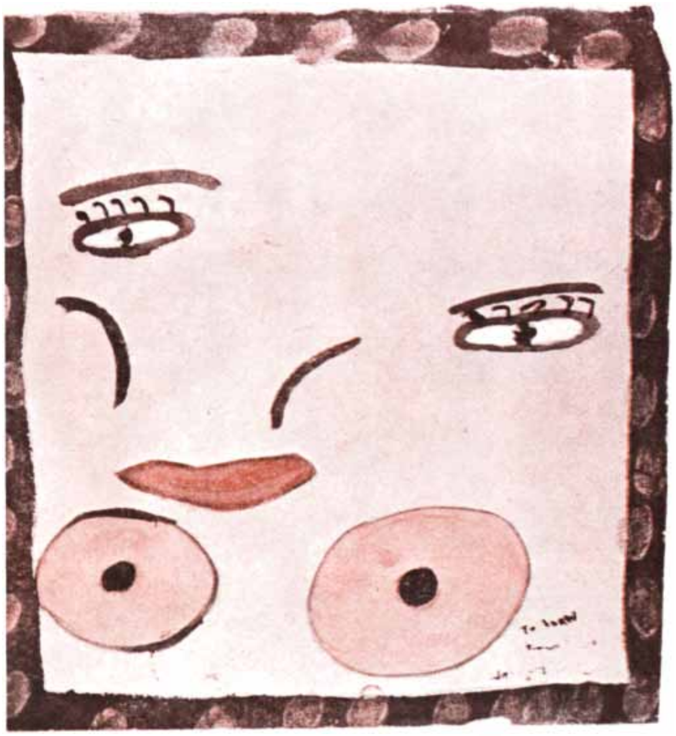
food still came first. Then she added the School and fence, making sure that the candy cone was inside the fence. Then she changed the candy cone into a tree and added the sun. During this phase she was trying in actual life to master the world by trimming it down to the size of the School, fencing out the world beyond.

In Mary's second year at the School, her self-portraits began to show greater freedom (picture 4). Her eyes were now wide open. Though in these portraits she still had an empty and unhappy stare, it was as if she wished to devour the world, rather than, as in her first self-portraits, not look at it. Her faces were all mouth and eyes; she never drew the full body.

AFTER TWO YEARS she began to try to master the trauma of her mother's death. Picture 5 reflects the stages she underwent in this effort. First she painted the center cross, the grave of her mother. Then she added four similar crosses, to make it a graveyard. Saying that it happened long ago, she painted cobwebs over the crosses. The picture now looked too gloomy. She painted the crosses white, but this failed to make the picture cheerful enough, so she added a red flower on each, indicating her desire to overcome her depression and the loss of her mother.

A short while later she tried to conquer her thoughts of death and destruction by means of humor (picture 6). She painted two bones; when they seemed too sad, she gave them faces. Now, she said, they were dancing bones, dancing a funny death dance. She was trying to deny her deep mourning for her mother by making fun of her feelings.

Only much later, in her last year at the School, did Mary finally come to grips with the central issue of her disturbance: her feeling that she was both



PICTURE 10

PICTURE 11

mother and baby at the same time. She succeeded in freeing herself from this dual feeling by giving birth to herself as a new person, an infant. This process was accompanied by a long series of drawings.

The first is that of a woman nursing a newborn baby in the maternity ward (picture 7). She labeled the picture to make clear that it was she, Mary, who was nursing herself, Mary, as a baby. Next she pictured herself as a baby devouring the mother while sucking at the breast (picture 8). Because she had destroyed her mother in this way, she feared to be destroyed in retaliation, or to "explode" because her small body could not safely contain the huge body of her mother. After reliving this incorporation of her mother, she was able to free herself and to view her mother independently from herself (picture 9). The neck is tremendous; there is no head. (Could she recall only her mother's body and not yet her face?) She began by drawing the big pendulous breasts, then put in two openings for the vagina and rectum, both in front. The rest of the body was drawn last. She drew over the body openings and the nipples again and again "to make them stand out more clearly." In picture 10, which she called "The Baby Drinking the Mother's Milk from the Breast," she seems to have recaptured her mother's face. This was a pictorial world that consisted only of the mother's breasts and, just above them, what the nursing infant sees—mouth and eyes. As if to emphasize the primitive sensations, she put fingerprints all around the border.

By this time she was able to say openly that she had always felt herself to be mother and child at the same time, and to explain why she had thought so. She had believed that while in the uterus she had been damaged by the father's penis during parental intercourse, and, moreover, that she had been made pregnant by the father at the same time.

After she separated herself as baby from herself as mother, it seemed as if Mary tried to begin her life afresh. She drew a series of pictures of her re-creation as a new person, beginning with life in the uterus and culminating in her rebirth. While she illustrated this process with her drawings, she lived out much of it in reality. For months her abdomen grew larger; her stance and walk became like those of a pregnant woman. Finally one day she threw herself on the ground and re-enacted labor pains, shouting that she felt the baby coming out of her.

THIS was Mary's final separation of herself from the mother role. When she gave up the baby with which she felt pregnant, she also abandoned the idea of having been made pregnant by her father. At once her life, and her paintings, changed dramatically. Within days her body returned to normal; she no longer looked like a pregnant woman but like a normal child of twelve. She had mastered her schizophrenic disturbance and become a relatively normal girl—and she saw herself that way. From having always thought of herself as an ugly duckling, she now switched to portraying herself as a pretty, carefree girl (picture 11) and considered becoming a ballet dancer. She drew happy children at play and other pleasant subjects. She titled one of her last drawings, made shortly before she left the School, "Fun on the Beach" (picture 12). Mary now could have fun as normal children do.

Bruno Bettelheim is principal of the Sonia Shankman Orthogenic School at the University of Chicago.

PICTURE 12

IDEA-PLASTICS

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The maker of this new, improved pipette, or dropper, had to have a plastic with a unique combination of properties. "Alathon" polythene resin was the answer. "Alathon" is strong, yet soft and flexible. It makes a shatter-proof pipette that can't scratch or cut delicate skin tissues. It's transparent enough to show the level of contents. Because "Alathon" repels liquid, drops don't cling to the tip but flow freely, are more uniform in size. And "Alathon" is inert—doesn't affect solutions, isn't affected by them.

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Technical bulletins on "Alathon" polythene resin and the plastics and chemicals used in your industry are available. Each product bulletin in the booklet presents physical and chemical properties, description, specifications, uses and possible applications, bibliography and other data. Write us on your business letterhead for your copy. We will gladly cooperate with you on any application for plastics or chemicals you would like to investigate.

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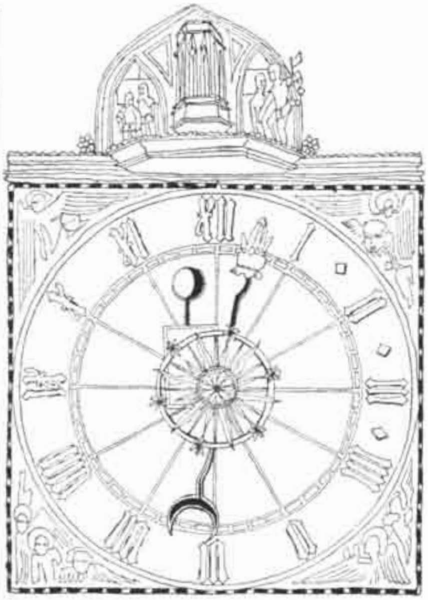


Chemistry and Farming

THE wide and increasing use of chemicals in agriculture has raised the specter of serious unemployment for U. S. farmers. So said a comprehensive report issued by a subcommittee of the U. S. Senate Committee on Labor and Public Welfare last month. The report, called "Manpower, Chemistry and Agriculture," finds that the application of chemicals is generating a new revolution in U. S. agriculture. It considers the effects on farm employment and makes some predictions and suggestions.

During the past hundred years the mechanization of farming has fabulously boosted output and steadily diminished the manpower need. According to the Senate report, the recent large-scale introduction of chemicals into farming (as fertilizers, pest-killers, weed-killers, defoliants, and so on) will greatly accelerate this trend. It predicts that chemicals will cut some 1.5 million farm workers out of jobs in the next 10 years and 3.3 million by 1970.

The report was prepared for the Committee by Francis Joseph Weiss of the U. S. Department of Agriculture. He pointed out that one innovation alone, chemical spraying to remove the leaves from ripened cotton plants, would result in a huge labor saving. It has at last made feasible the long-delayed use of machines for cotton picking. Similarly the development of potent chemicals that are effective in relatively small amounts has facilitated spraying by airplanes. A plane can spray 60 or 70 acres an hour, as compared with 100 acres a day by a tractor-drawn ground sprayer. About half the spraying on U. S. farms is now done by plane.

The 2,4-D produced by a worker in a chemical factory in one hour will kill as many weeds as 800 farm workers could hoe in the same length of time. Another big labor-saver is the new technique of sowing pellets containing seeds and various chemicals, which can combine the tasks of seeding, fertilizing, spraying and dusting in one operation. And to the chemical aids already available must be added probable further developments, such as new soil-conditioners and even the production of food from algae or by artificial photosynthesis.

The problems raised are not limited to technological unemployment. The report says: "Chemicals are very powerful weapons, and he who wields them, whether manufacturer, distributor or operator, could use them for monopolistic practices if not restrained by proper legislation. Furthermore, the strong competitive advantage that large contiguous areas planted with the same crop offer to big farmers, especially in chemical agriculture, will constitute a strong force toward undesirable agricultural concentration."

The main concern of the report and of the Committee, however, is the employment problem. What is to become of the farm workers who are displaced by chemicals? Some may be absorbed into industries serving the new agricultural needs: aircraft, transportation and handling of chemicals, servicing of farm machinery, and so on. But most of them will have to find other work. Stressing the need to keep as many people as possible on the land, the report suggests the encouragement of rural industries, such as chemurgic plants of moderate size and small factories producing articles of local handicraft.

The report concludes:

"We are at the threshold of a new era that promises plentiful food and fiber, but it is also fraught with the dangers of economic and social disruption, against which we have to prepare our nation."

Britain's Bomb

WHEN Prime Minister Churchill visited the U. S. in January, his advisers sounded out U. S. authorities again on the delicate and painful question of a resumption of U. S.-British cooperation in atomic research. They got nowhere, as the present Atomic Energy Act in the U. S. forbids exchange of atomic energy information with other countries. During the following month hints began to appear in the press that Britain was producing an atomic bomb of her own and was ahead of the U. S. in theoretical work on atomic artillery and guided missiles. Mr. Churchill finally capped the hints with a formal announcement that his Government would test a British-made "atomic weapon" in Australia sometime during 1952.

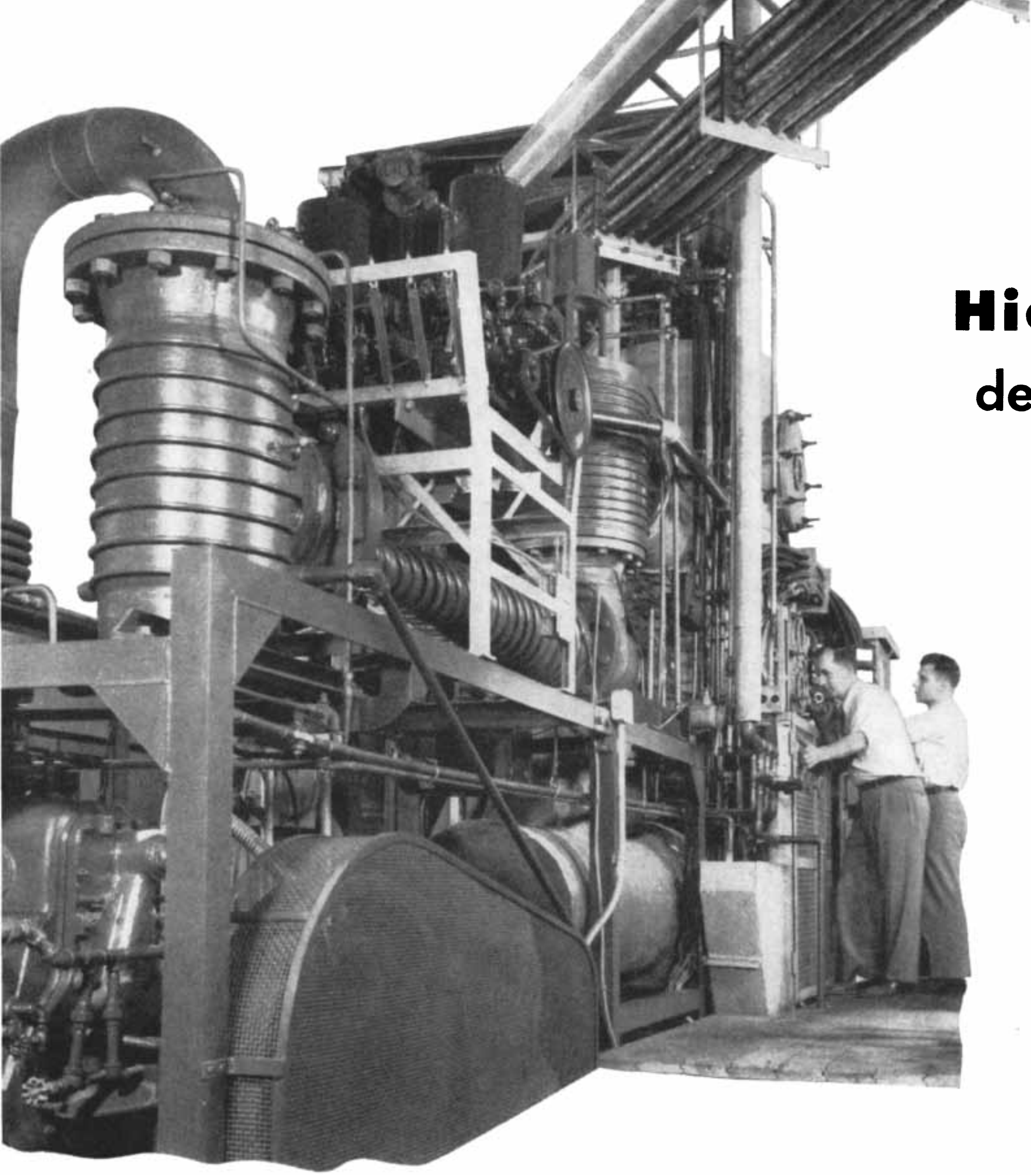
Mr. Churchill informed the House of Commons that the British bomb was produced some months ago, during the Labor administration. He said he was astonished to learn when he took office "that not only had the Socialist Government made the atomic bomb as a matter of research, but that they had created . . . important plant necessary for its regular production." He upbraided ex-Prime Minister Clement Attlee for having hidden Britain's light under a Socialist bushel. Mr. Attlee replied that the work was no secret within the Government and that Mr. Churchill's adviser, Lord Cherwell, should have kept the Conservative leader informed. He added that the U. S. Government had been "told about everything in order to get their cooperation."

In the U. S. officials were disappointed that Britain was making an independent test of its bomb in Australia. Senator Brien McMahon, chairman of the Joint Committee on Atomic Energy, remarked: "I might have wished that the British had seen fit to take advantage of our offer to make available a test site, subject to conditions which our law lays down."

The Beginning

THE National Science Foundation has announced its first batch of grants for the support of basic research. U. S. taxpayers will spend $50,000 during the next five years for an investigation of "Polygenic Variability," $41,400 for a 3-year study of "Cytotoxic Reactions Mediated by Antibody and Complement," $3,000 for an 18-month "Botanical Survey of the Tongan Islands"—a total of $410,000 for these and 25 other projects in the biological sciences. The fields represented by the 28 grants include biochemistry, enzyme chemistry, biophysics, systematic biology, microbiology, aquatic biology, experimental embryology, genetics and immunology.

These awards leave approximately $600,000 of the Foundation's first-year appropriation for basic research still to be spent. Most of it is likely to be awarded in the mathematical, physical and engineering sciences. The Foundation's third division, Medical Research, probably will get little this year. Director Alan Waterman pointed out to an American Medical Association congress that "those phases of medical research generally described as clinical research



High vacuum develops muscles for "moly"

Pure molybdenum is sensitive to oxygen at the temperature it takes to melt it . . . and "moly" with oxygen is not much use. Jet engines, rockets, and other equipment need the pure metal because it stands up under heat that melts the strongest steels, but if there's oxygen in it the advantage vanishes.

High vacuum solves the problem. Climax Molybdenum Company of Detroit, Michigan, hydraulically compresses pure molybdenum powder and sometimes molybdenum chips with a little carbon. This mass is sintered into a crude stick which serves as a consumable electrode in an arc. The molten metal is caught in a pool which serves as the other electrode while it builds up into a half-ton ingot of malleable, ductile molybdenum.

The molybdenum turns out malleable and ductile because *high vacuum* gets rid of the injurious oxygen.

Why, you may ask, don't they just use an inert gas? Bear in mind that at the high vacuum under which these operations are carried out (20 microns Hg) oxygen content is equivalent to about 0.0026% at atmospheric pressure. Inert gas pure enough and in sufficient quantity to dilute atmospheric oxygen to this level would be staggering in cost. A DPi oil ejector pump, uniquely economical to operate, creates the vacuum in the sizable space needed for the whole series of continuous operations and gets rid of the gases evolved.

In supplying equipment for high vacuum metallurgy, DPi pools its own diversified experience in high vacuum technology with the experience of leading manufacturers of metallurgical furnaces.

In many other fields, too, where high vacuum processing has earned a useful role, DPi stands ready to help you with the vital details that add up to efficient, profitable production. Write to ***Distillation Products Industries,*** Vacuum Equipment Department, 751 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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are already enjoying considerable support from the Federal Government and from other sources. We feel that the Foundation can make a more significant contribution by supporting certain fundamental studies in biology where much new knowledge is needed and for which funds are much less readily available."

The Foundation is processing 2,800 applications for fellowships, in the hope of selecting 500 fellows to enroll in the nation's graduate schools next fall. Unlike other fellowship programs, this one will favor first-year candidates over those already in graduate school, on the theory that its funds can be most effectively spent by encouraging the largest possible number of promising young scientists to enter graduate study.

Celebration

THE premature announcement by New York newspapers of a new drug for the treatment of tuberculosis has raised the hopes of many patients and the blood pressure of the medical profession.

At New York City's Sea View Hospital, the Cornell Medical Center and several other places, physicians in recent months have tested certain molecular variations of niacin, the anti-pellagra vitamin, on several hundred tuberculosis patients. The patients, all in very advanced stages of the disease, have responded remarkably. They lost their fever, regained their appetites and normal weight, and the disease seems to have been arrested. The three isomers tested appear to be powerful killers of the tubercle bacillus. The most effective of them is isonicotinic acid hydrazide, synthesized independently by scientists in the laboratories of E. R. Squibb & Sons and Hoffmann-LaRoche, Inc.

New York's newspapers, apparently tipped off to the new "miracle drugs" by relatives of the patients, broke the news on their front pages last month. It quickly developed into a journalistic celebration. Some of the "cured" patients danced in the hospital corridors for the benefit of newspaper photographers. Overnight, physicians all over the country found themselves besieged with demands from their t.b. patients for the cheap new cure.

The stunned doctors did what they could to restrain the enthusiasm. Five days after the first newspaper stories six eminent experts on tuberculosis appeared before the New York Academy of Medicine to explain some of the reasons for caution. They pointed out that what has been observed so far is only "symptomatic relief." The real test of a drug's curative ability is the healing of diseased tissue and the eradication of tubercle bacilli. On these two matters no conclusive evidence is yet available. Furthermore, the experts noted that tubercle bacilli have a tendency to develop resistance to drugs. And even if the new drug should prove capable of stopping tuberculous infections, it cannot repair the damage the bacilli may have caused to infected organs such as the lungs. Surgery may still be mandatory, as may hospitalization, rest and many other details of standard treatment. The experts emphasized that it will take time, perhaps years, to determine the value of the new drug, promising as it is.

Animals for Research

BOTH houses of New York's State Legislature have passed and Governor Dewey has signed the Metcalf-Hatch Bill, which provides that "unlicensed, unclaimed and unwanted" dogs and cats may be requisitioned from public-aided pounds for research laboratories.

Desalting the Ocean

SHIPWRECKED sailors are not the only people who have complained that the ocean offers "water, water everywhere, but not a drop to drink." Hydrologists concerned about the enormously increased demands on U. S. fresh water supplies have long looked thoughtfully at the salty oceans. The President's Water Resources Policy Commission suggested that the invention of an economical method of demineralizing sea water might rank with the development of atomic energy in importance to the nation's future.

Ionics, Inc., of Cambridge, Mass., an affiliate of the American Research and Development Corporation, now thinks it has found a way. It has worked out a method for desalting water by the ion-exchange process. Many communities in the U. S. now freshen brackish water by percolating it through beds of ion-exchange resins, but to remove all the minerals from sea water by this method would be too expensive. What the Cambridge group has developed is an ion-exchange membrane to replace the granular beds. Sea water would be passed over such membranes (plastic films containing ion-exchange materials) and would be demineralized with the aid of electrical energy. Where power can be bought cheaply, these membranes may permit the cost of sea-water purification to be brought down to between 10 and 20 cents per thousand gallons.

Vitamins from Sewage

FOR more than 25 years the City of Milwaukee has made a comfortable income from its sewage by converting it into an organic fertilizer named Milorganite. It is one of the richest fertilizers known, but it now develops that the stuff is even richer than the City realized.

Several years ago the Milwaukee Sew-

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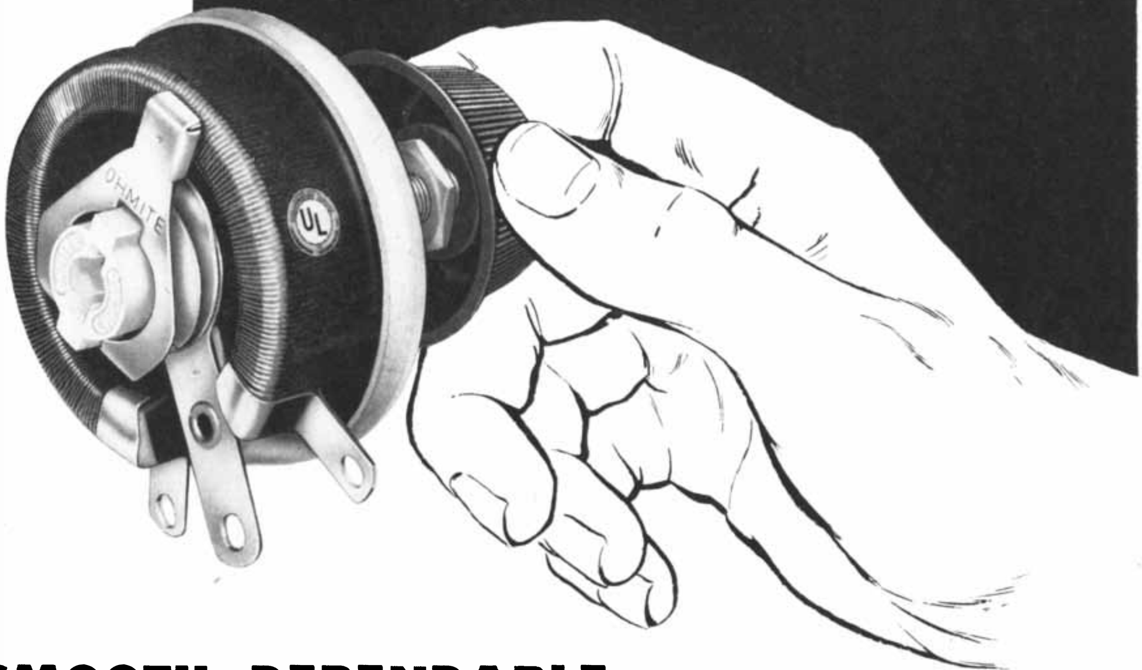

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first IN WIRE-WOUND RHEOSTATS AND RESISTORS erage Commission employed the Miner Laboratories in Chicago to analyze Milorganite for possible products that might be extracted from it. The chemists soon found a factor, still not identified, which speeds up fermentation and produces higher yields of alcohol from molasses or converted wood-grain mashes. The investigators thought this factor might be a vitamin. When vitamin B_{12} was discovered in brews of antibiotics (*see page 49*), they immediately wondered whether B_{12} might be found in Milorganite. They discovered that it might, indeed—one to four milligrams in each pound of the dried sludge. In pilot-plant operations, concentrates of about 10 times this potency have been prepared. The next step will be large-scale production of these concentrates for sale to companies that can extract the pure vitamin. It is hoped that Milwaukee's sewage will relieve the shortage of B_{12}; Milorganite is the richest source of the vitamin yet found.

Inanna's Temple

TWO years ago archaeologists working at the site of ancient Nippur in Iraq dug out of the desert sand a small clay tablet on which someone, 3,500 years ago, had inscribed all he knew about the science of agriculture ("Sumerian 'Farmer's Almanac,'" SCIENTIFIC AMERICAN, November, 1951). This earliest known treatise on farming leaned heavily on religion; for such difficult problems as insects and rodents and "the harshness of the evening and night" it could advise only prayer.

Further evidence of the important role of the gods in the early Sumerians' effort to turn their desert into a Garden of Eden has now been unearthed at the same site. Members of the University of Chicago and University of Pennsylvania joint expedition have discovered there a great temple for Inanna, fertility goddess and bride of the dying god, Tammuz. It was Inanna whom Sumerian farmers worshipped at the annual harvest festival, and Inanna who received their thanks when the crops were good.

In the scribes' room adjoining the temple hundreds of clay tablets were found, "stacked like books against the walls." They are all covered with cuneiform inscriptions. When they are deciphered, they may throw a flood of new light on the Sumerians and on many other phases of their science and religion. Altogether the new finds are described as a "monumental discovery."

The Location of Beowulf

BEFORE the discovery of the Sutton Hoo ship burial near the East Anglian Coast (SCIENTIFIC AMERICAN, April, 1951), historians had not known of any high cultural achievements in that part of England in the seventh and

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Faster and more accurate gas analysis by mass separation is now possible with new improved G-E Mass Spectrometers. The sample introduction system has been relocated. Ion source temperature is controlled to within a fraction of a degree. Range is increased to mass 500. See bulletin GEC-587*.

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New G-E Recording Spectroradiometer provides increased sensitivity for automatic measurement and recording of spectral energy in ultraviolet, and visible spectrum. Measures dyes, inks, paints, textiles, plastics, TV tubes, etc. See bulletin GEC-604A*.

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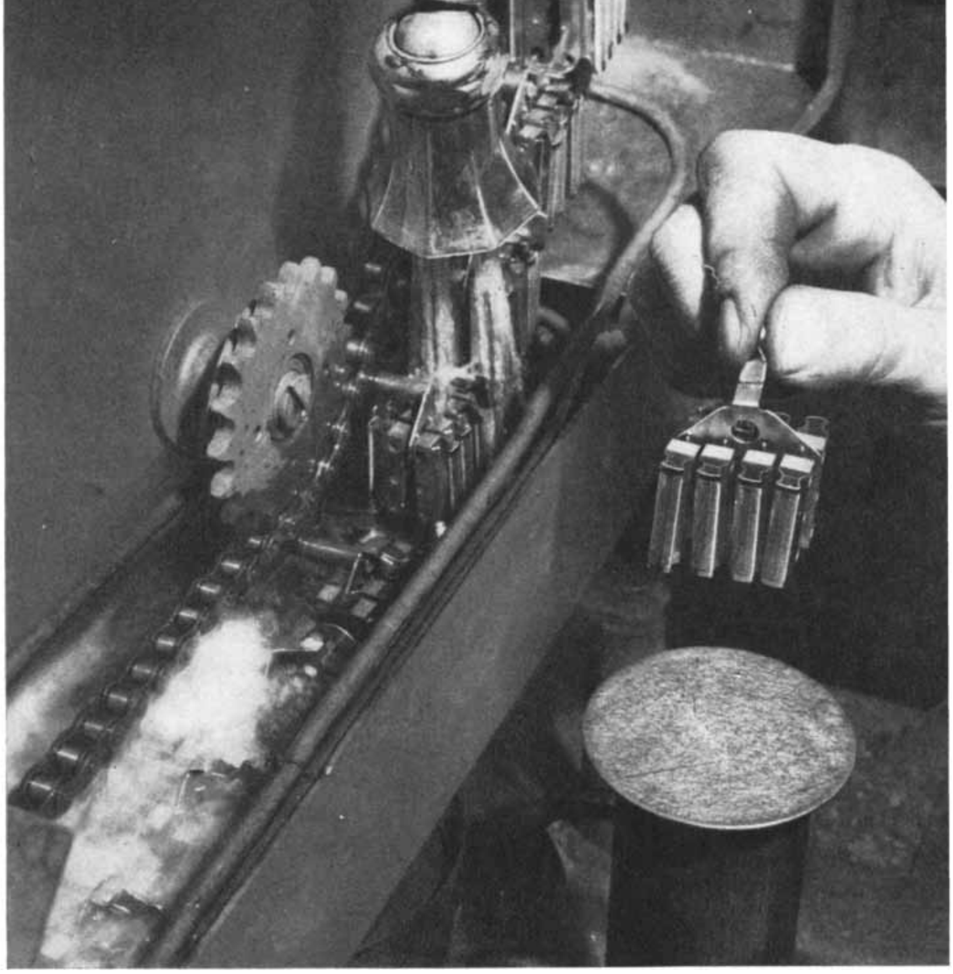


Shaver heads are cleaned (left) then rinsed at Schick, Inc., Stamford, Conn. The result . . .

CLEANING COSTS CUT 58% WITH ULTRASONIC VIBRATIONS

G. E. Develops New Technique For Cleaning Small Metal Parts

Research men at General Electric showed that high-frequency sound (300–1000 kc) increased the action of many standard cleaning solvents 10 to 100 times. Inaudible sound waves set up in the liquid accelerated the removal of oil, grease, tars, resins, metal chips, and machining and buffing compounds.

The ultrasonic cleaning unit developed by G.E. enabled Schick, Inc. to cut over-all cleaning costs 58%. This new technique has also been applied to ball bearings, watch gears, and precision instrument parts.

Here is an example of research put to work . . . a specialty at General Electric, where research and development are linked to provide more and better instruments and processes for modern industry.

Magnet shows metal chips removed from shaver heads by ultrasonics.

GENERAL ELECTRIC

687-98

eighth centuries. Interest focused on the region north of the Humber, where the existence of a great Anglo-Saxon culture was well known. Most literary scholars have assumed that this culture, which produced the Venerable Bede and Caedmon, the father of English poetry, was the source of the great poem *Beowulf*, written about 700 A.D. The author of the epic is unknown; we have only a single 11th-century manuscript with no positive information as to where it was originally composed.

But the Oxford University scholar J. L. N. O'Loughlin, who has just made a careful new study of this much-studied poem, concludes that *Beowulf* was written in East Anglia. In support of this thesis he finds "a far weightier body of evidence than has been offered for Northumbria or any other locality."

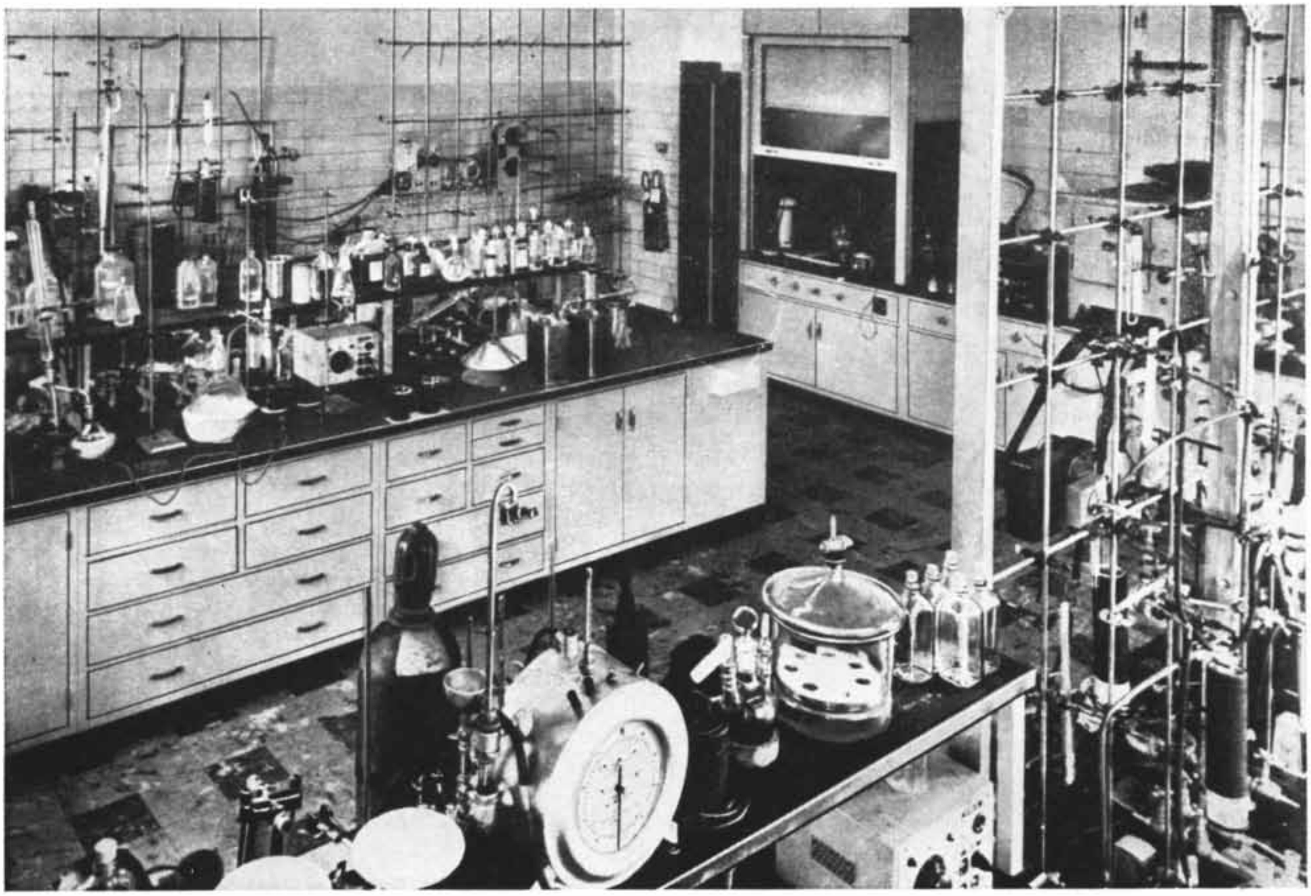
If O'Loughlin is right, and *Beowulf* and the archaeological riches of Sutton Hoo do belong to the same cultural center, historians will have to give East Anglia a much more prominent place in the origins of English civilization than they have done. It would mean that between the Fens and the North Sea Coast a remarkable civilization flowered in the seventh and eighth centuries, only to be blotted out by the Danish invasions. The Sutton Hoo mounds still to be excavated may tell more about this culture.

Hard Lines for Hedgehogs

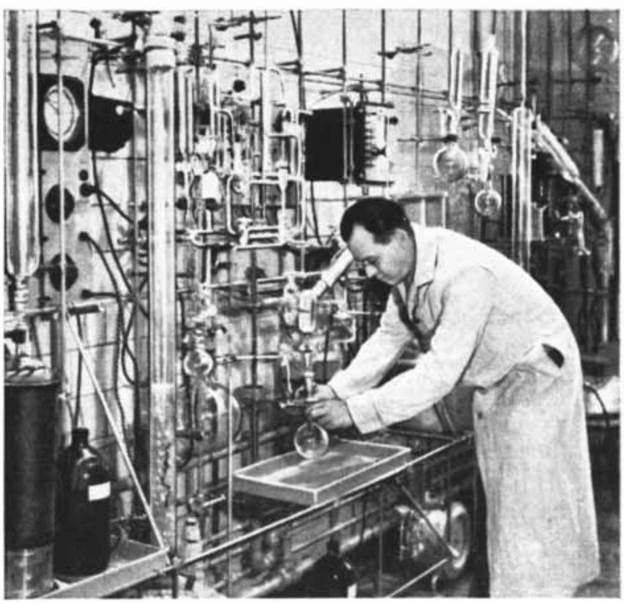
WHEN a hedgehog takes the path of least resistance in hunting birds' eggs, he does not get a very good meal. The hedgehog, whose taste in eggs is much like man's, finds most palatable those that are hardest to come by.

Seeking light on nature, the British zoologist Hugh Cott chose to make an extensive study of this particular predator's egg-eating habits. He tried hedgehogs out on eggs from 25 species of birds. Some the hedgehogs refused; some they ate without apparent relish; some they gobbled happily. Cott could find no consistent relation between the palatability of the egg and of the parent's flesh; for hedgehogs apparently, tasty birds do not necessarily lay tasty eggs. But there was a clear correlation between an egg's flavor and its accessibility. The eggs that suit the hedgehog's taste are apt to be hard to reach: they are laid either by big birds well able to defend the eggs, or in nesting colonies where the birds can team up to fight off the intruder, or in places that cost the hedgehog some effort to get at. On the other hand, the kinds of eggs that are laid by small and solitary birds in easily accessible nests generally have a flavor distasteful to hedgehogs. The defenseless eggs are further protected by bright colors or other identifying marks that warn the hedgehog it would be unprofitable to break them open.

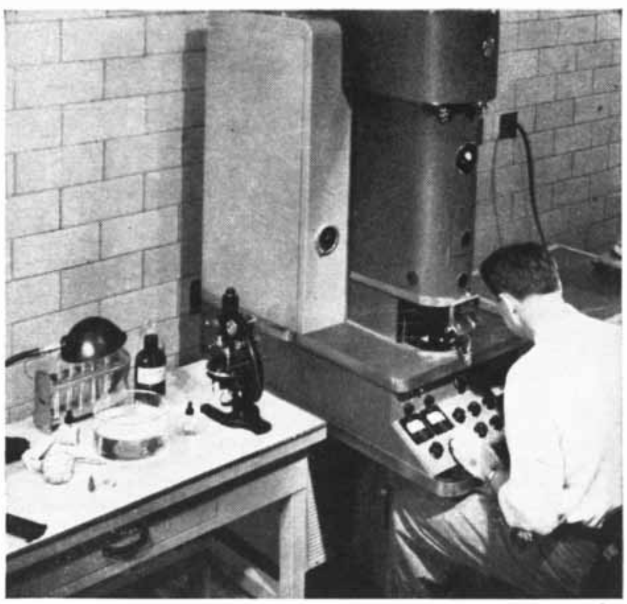
These Great Laboratory



PETROCHEMICALS offer independent inventors great opportunity for exploration and reward. Such synthetics as Nylon, Vinylite, Neolite are already indispensable to our expanding economy—and new ideas in this area are at a premium today.



UNDER THE SINCLAIR PLAN, chemistry laboratories like these are open for the first time to independent inventors.



ELECTRON MICROSCOPE, capable of magnifying 100,000 times, is typical of the expensive equipment now available.

THE PROGRESS OF ANTIBIOTICS

In the decade since the first patient was treated with penicillin, some 300 of these substances have been discovered. Only a few have come into wide clinical use, but they have revolutionized medicine

by Kenneth B. Raper

IT IS little more than a decade since the first patients were successfully treated with penicillin. In that decade what amounts to a revolution in medicine has taken place; we have entered an "antibiotic age." To penicillin there have been added four other antibiotic drugs of major importance. Some of the most deadly infections of mankind have been mastered, and countless lives saved. From the new drugs have come new methods of animal feeding that produce more meat at lower cost. The antibiotics have become a multimillion-dollar industry.

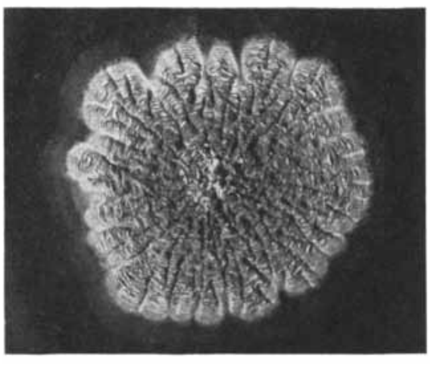
The purpose of this article is to attempt to survey the large-scale impact of the antibiotics on scientific research, on our national health and on our economy. Let us begin by considering the present state of the various antibiotic drugs.

After 10 years penicillin still remains the least toxic and the most generally useful of all the antibiotic drugs. Last year some 350 trillion units of penicillin were produced in the U. S. It continues to be the drug of choice for combatting pneumococci, streptococci, staphylococci, gonococci, anthrax bacillus and the spirochetes of syphilis and yaws. In conjunction with antiserums it is used to treat diphtheria, gas gangrene and tetanus. The methods of administering it have steadily been improved. At the beginning penicillin had to be injected every three or four hours; with the present form of the drug, in which it is combined with procaine to enable the body to hold it longer, most infections can be handled by a single daily injection of 300,000 to 500,000 units. Intramuscular injection is still the chief means of giving the drug, but it is increasingly being administered by mouth, though this requires much larger amounts. It is also used as an inhalant and in ointments and salves.

Only about two to five per cent of the patients who receive the drug become sensitized to it. Because of its low toxicity, there has been a constant tendency to increase the doses given. This may account for the fact that resistance to the drug by bacteria has been slow to develop. In some places the emergence of resistant strains of staphylococci and streptococci has become a serious problem, but on the whole penicillin still holds the upper hand over most of the infections it is designed to combat.

The second important antibiotic drug, streptomycin, also has a fairly wide spectrum of effectiveness: it is generally considered the drug of choice for treating tularemia; it is valuable against certain secondary bacterial infections that accompany influenza and pneumonia; it is used to combat various bacteria that resist sulfa drugs and penicillin, and it is given in combination with penicillin to treat mixed bacterial infections of the urinary and upper respiratory tracts. But streptomycin's chief use, of course, is against tuberculosis. Upwards of 70 per cent of the present production of this drug goes to t.b. patients.

Although streptomycin is the most effective known chemical treatment for tuberculosis, it falls far short of being an ideal drug. When used for extended periods, it may damage the eighth nerve (to the ear) and sometimes cause deafness. A second weakness of streptomycin is that when substantial amounts of the drug are given regularly for a matter of months, it is prone to produce resistant strains of the tubercle bacillus, some of which actually thrive on streptomycin. These defects have been somewhat mitigated by the development of a less toxic variety of the drug, called dihydrostreptomycin, and by a combined treatment of daily doses of para-aminosalicylic acid and weekly or twice-weekly administrations of dihydrostreptomycin. This substantially reduces the toxic effects on the nervous system and the development of resistant bacilli.



STREPTOMYCES RIMOSUS is a soil mold that produces terramycin.

The Broad-Spectrum Drugs

The three other major antibiotics, all discovered since 1947, are chloromycetin, aureomycin and terramycin. They are known as the broad-spectrum drugs, because each of them attacks a wide range of infections. All three are produced by species of the *Streptomyces* earth molds. All three are effective against gram-negative and gram-positive bacteria and against rickettsiae, the tiny microbes intermediate between the bacteria and true viruses. Each was discovered independently, and each seems to be finding some field of special application, though for some diseases any one of the three may be used effectively.

Chloromycetin is the drug of choice for the treatment of typhoid fever. It is effective against Q-fever, Rocky Mountain spotted fever, typhus, scrub typhus and other rickettsial infections, combats whooping cough and is useful for treating mixed infections after surgery and various gram-negative infections of the gastrointestinal and urinary tracts. Chloromycetin is the only antibiotic drug for which a practical method of chemical synthesis has been worked out, and about half of the supply is now produced by this method.

Aureomycin has two important special qualities: very low toxicity and great penetrating power. It is absorbed into the central nervous system, bone joints and other relatively inaccessible places more readily than most other microbial drugs. For this reason it often finds application where the specific infection might otherwise indicate penicillin or some other antibiotic. Aureomycin is especially valuable in the treatment of various rickettsial diseases, infections caused by the psittacosis-lymphogranuloma-venereum group and many infections by cocci, micrococci and spirochetes that are resistant to penicillin. It is widely used to combat mixed infections of the gastrointestinal and urinary tracts. In combination with dihydrostreptomycin it affords a promising treatment for brucellosis. It is effective in the treatment of amoebic dysentery, possibly exerting its effect by killing off the bacteria upon which the amoebae feed. For the same reason it is also a good drug to use before operations on the alimentary tract to prevent infection.

Terramycin also is a comparatively nontoxic drug; its side effects, as in the cases of aureomycin and chloromycetin, are generally limited to gastrointestinal disturbances. Unlike aureomycin, terramycin does not diffuse readily into the cerebrospinal area. In general, however, its range approximates that of aureomycin and chloromycetin. It has given especially favorable responses in the treatment of amoebiasis and brucellosis. It has also produced striking cures of syphilis and yaws infections that resisted penicillin, has shown promise against some rheumatic diseases, has successfully controlled pinworm infections and is the first choice of some physicians for treating mixed bacterial infections of the gastrointestinal and urinary tracts. When given in combination with streptomycin to tuberculous patients, terramycin appears to delay the emergence of streptomycin-resistant bacilli.

The broad-spectrum antibiotics generally are given by mouth. Though this has obvious advantages, it also has an important disadvantage: a drug taken into the alimentary tract may destroy useful intestinal bacteria and upset the healthy balance of nature there. Patients subjected to extended treatment with drugs by the oral route may develop diarrhea. Their stools show a heavy growth of the disease-producing fungus *Candida albicans*. Occasional deaths from such infections have been reported.

In the laboratory it has been found that some bacteria develop resistance to the broad-spectrum drugs if they are grown in increasing concentrations of the drugs. Fortunately, however, resistant strains have seldom appeared so far in clinical practice.

Drugs from Bacteria

The antibiotics we have been considering so far are all produced by molds. There are also some that are made by bacteria. The most important are tyrothricin, bacitracin and polymyxin.

Tyrothricin was one of the first antibiotics; it was discovered by René J. Dubos of the Rockefeller Institute for Medical Research in 1939. It is produced by a soil bacillus. Tyrothricin is used as an antiseptic in medicated bandages and surgical dressings and in certain preparations for the treatment of upper respiratory tract infections, but it is too toxic to be taken for systemic infections.

Bacitracin, first described in 1945 by B. A. Johnson, H. S. Anker and F. L. Meleney of the Columbia University College of Physicians and Surgeons, also is obtained from a bacillus. Physicians employ it for localized treatment of wound infections, for relief of congestion in the upper respiratory tract and for the treatment of amoebiasis. But it is toxic to the kidneys, and it may be used internally only in hospitals, where patients can be observed constantly. Carefully administered, it is sometimes a life-saving drug in cases where other antibiotics fail.

Polymyxin was discovered independently by R. G. Benedict and A. F. Langlykke at the U. S. Department of Agriculture's Northern Regional Laboratory, by P. G. Stansly and co-workers of the American Cyanamid Company and almost simultaneously by investigators at the Wellcome Physiological Laboratories in England. It comes from a soil bacterium, *Bacillus polymyxa*. As in the case of the penicillins, "polymyxin" actually is a group of closely related compounds which differ quantitatively in their effect upon various sensitive bacteria. In general the drug is most effective against gram-negative bacteria. Like bacitracin, however, it is toxic to the kidneys and it is approved for internal administration only in hospitals. Polymyxin is especially useful for the treatment of infections caused by the so-called "blue-pus bacteria."

Finally there is a drug which is not strictly an antibiotic in the usual sense, but may be put in the same class because it is produced by bacteria (hemolytic streptococci). This is the enzyme combination streptokinase-streptodornase, better known as SK-SD. Discovered as the culmination of research undertaken 15 years ago by William S. Tillett and his associates at the New York University College of Medicine, SK-SD has had dramatic success in clearing up pus-filled tissue. An antibiotic is usually given with it to stop further infection.

The fact that virulent microbes like the hemolytic (blood-dissolving) streptococci can produce healing substances emphasizes that all groups of microorganisms must be regarded as potential sources of useful drugs.

The Continuing Search

Yet in the field of antibiotics it remains true that "many are called, but few are chosen." Although more than 300 antibiotic substances have now been discovered, only five have attained the stature of major drugs. A handful of others—polymyxin, bacitracin, tyrothricin, subtilin, fumagillin, neomycin, thiolutin, viomycin—have important, though limited, uses or are considered promising. All the rest have fallen short for one reason or another. Some are too weak; some work only in the test-tube or on subhuman animals; most are too toxic.

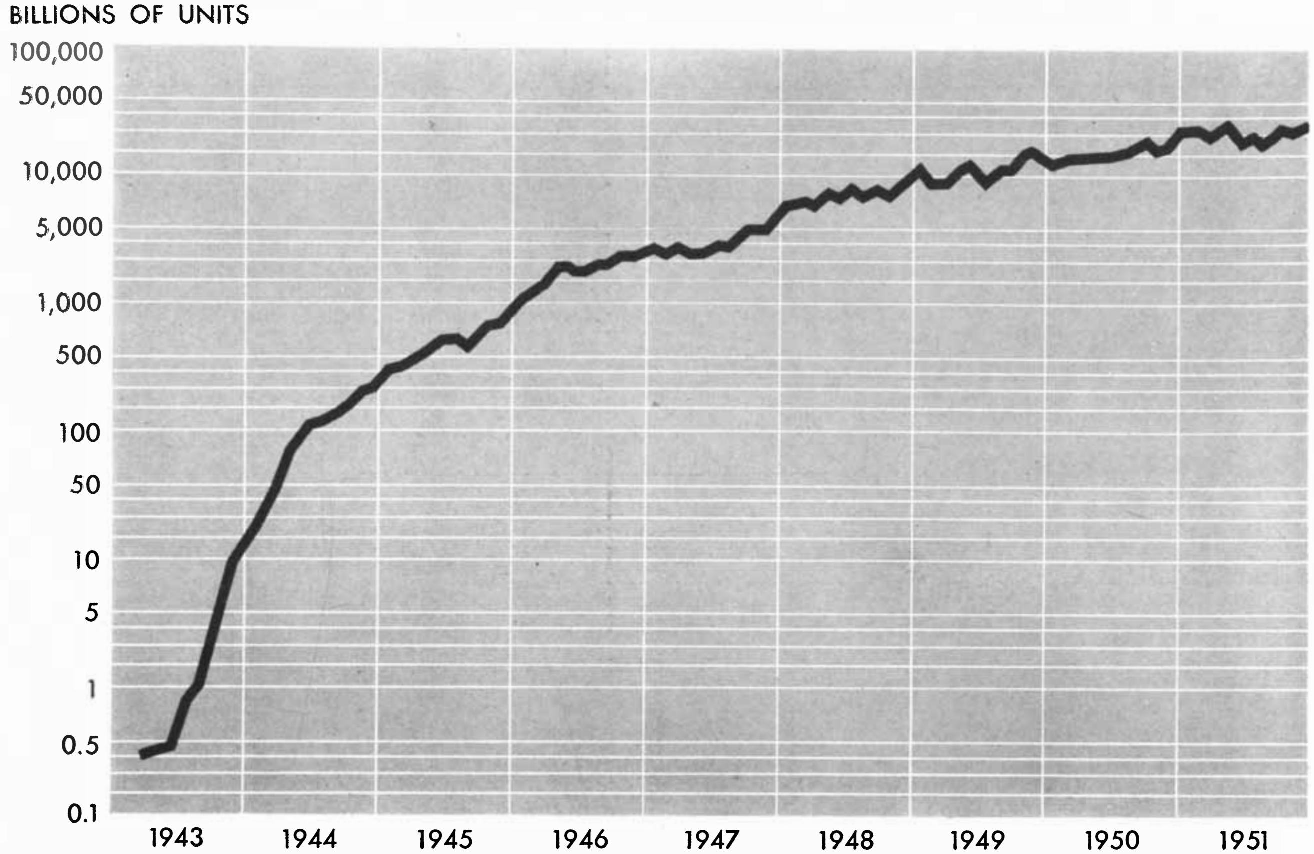
Five out of 300—the percentage is very low. But the occasional "strike" more than compensates for all the disappointments. Naturally the search for potential new "wonder" drugs goes on with undiminished fervor. The field for searching is very wide. There is hardly an area in the plant kingdom that has not yielded antibiotic substances: they have come from seed plants, lichens, many groups of fungi, the actinomycetes, bacteria. The three leading sources of the approximately 300 different antibiotics so far found have been the filamentous saprophytic molds (notably *Aspergillus* and *Penicillium*), bacteria and the actinomycetes.

No one knows how many investigators are engaged in the search, nor in how many laboratories and hospitals research with antibiotics has been carried on. The literature of reported work already is enormous: it is estimated that no fewer than 18,000 research papers on antibiotics have been published since 1940. The bibliography on the three-year-old drug aureomycin alone lists more than 3,000 titles, and the literature on penicillin and streptomycin is much larger.

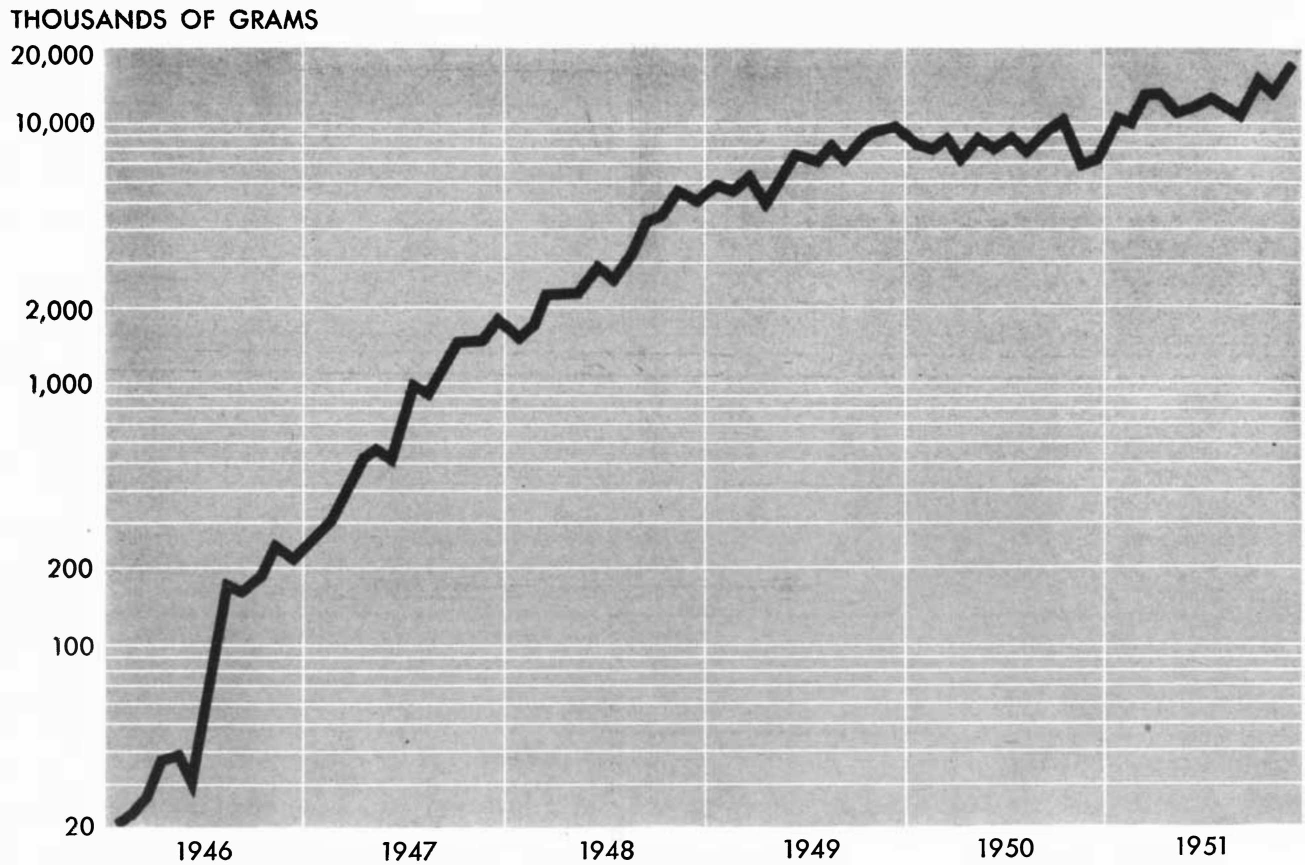
One of the most important aspects of the work in this field is the unprecedented teamwork it has fostered. Few scientific activities have ever brought scientists together on so vast a scale. Disciplines as far removed from each other as mycology and physical chemistry, clinical medicine and chemical engineering, have joined hands to attain the desired goals.

Animal Feed

The fruits of this work are not restricted to medicine. The antibiotics have found another huge field as a growth-accelerator for meat animals.



PENICILLIN PRODUCTION of the U. S. rose from less than half a billion units per month in 1943 to 34,289 billion units in December of 1951. Data from the Department of Commerce and Food and Drug Administration.



STREPTOMYCIN PRODUCTION of the U. S. increased from about 20,000 grams per month in 1946 to 18,006,000 grams in December of 1951. Data from the same sources as those indicated for the chart at the top.

INFECTIVE MICROORGANISM	DISEASE
GRAM-POSITIVE BACTERIA	
Hemolytic streptococci *All serologic groups except Group D*	Scarlet fever, tonsillitis and septic sore throat, puerperal sepsis, erysipelas
Group D	Endocarditis, otitis media, wound infections
Streptococcus viridans	Endocarditis, tooth abscesses
Staphylococcus	Boils, abscesses, osteomyelitis, endocarditis
Pneumococcus	Pneumonia, empyema, meningitis, endocarditis
Bacillus anthracis	Anthrax
Clostridia	Botulism, gas gangrene, tetanus
Corynebacterium diphtheria	Diphtheria
GRAM-NEGATIVE BACTERIA	
Meningococcus	Meningitis, chronic meningococcemia
Gonococcus	Gonorrhea, chronic urethritis, epididymitis, arthritis, endocarditis
Escherichia coli	Cystitis, pyelonephritis, septicemia, peritonitis
Aerobacter aerogenes	Urinary tract infections, cholecystitis, septicemia
Bacillus proteus	Urinary tract infections, gastroenteritis
Pseudomonas pyocyaneus	Endocarditis, pneumonia, abscesses, meningitis, urinary tract infections
Salmonella (*including Salmonella typhosa*)	Enteritis, septicemia, typhoid fever, abscesses
Shigella	Bacillary dysentery
Vibrio cholerae	Asiatic cholera
Brucella	Brucellosis
Pasteurella pestis	Bubonic, septicemic and pneumonic plague; sylvatic plague
Pasteurella tularensis	Tularemia
Hemophilus influenzae	Meningitis, otitis media, pneumonia
Hemophilus pertussis	Whooping cough
Hemophilus ducreyi	Soft chancre or chancroid
Klebsiella pneumoniae *(Friedländer)*	Pneumonia
Granuloma inguinale	Venereal disease
ACID-FAST BACTERIA	
Mycobacterium tuberculosis	Pulmonary and miliary tuberculosis, meningitis, osteomyelitis
Mycobacterium leprae	Leprosy
SPIROCHETES	
Treponema	Syphilis, yaws, pinta
Leptospira	Weil's disease
Spirillum minus	Rat bite fever
VIRUSES	
Lymphogranuloma venereum	Venereal disease
Trachoma	Conjunctivitis, partial or total blindness
Ornithosis	Psittacosis
Other viruses	Variola, vaccinia, influenza, common cold, measles, mumps, herpes zoster, molluscum contagiosum, warts, yellow fever, rift valley fever, dengue fever, phlebotomus fever, encephalitis, poliomyelitis, rabies
RICKETTSIAE	Rickettsial pox, European typhus, typhus exanthematicus, endemic typhus, Rocky Mountain spotted fever, scrub typhus
ACTINOMYCETES	Actinomycosis, endocarditis, cerebral abscess, pulmonary infection
FUNGI AND MOLDS	Blastomycosis, coccidioidomycosis, moniliasis, sporotrichosis

EFFECTIVENESS of the five principal antibiotics against various disease organisms is shown in this chart. A: Drug of choice; usually effective. a: Active drug, but other drug generally preferable. B: Has some activity, but therapeutic results generally not favorable. y: May be of value; data inadequate. O: Of no value. 1: At times useful in combination with penicillin. 2: *In vitro* sensitivity tests essential for correct choice of drug. 3: Antitoxin of prime importance. 4: Sulfadiazine is drug of choice. 5: Polymyxin B or neomycin in certain cases.

PENICILLIN	DIHYDROSTREPTOMYCIN OR STREPTOMYCIN	AUREOMYCIN OR TERRAMYCIN	CHLORAMPHENICOL
A		a	a
A	A	a	a
A	a[1]	a	a
A[2]	a	A	a
A		a	a
A		A	y
B		y	y
B[3]		O	O
a[4]		a	a
A	a	a	a
O	A	A	A
O	A	A	A
O	B	B	B
O	B[5]	O	O
O		a	A
O	a	A	a
O	B	A	y
O	A - - - - - - - -	- - - - - - - - A	a
O	A - - - - - - - -	- - - - - - - - A	y
O	A	a	a
O	a	A	A
O		A	A
O	a	A	A
O	A - - - - - - - -	- - - - - - - - A - - - - - - - -	- - - - - - - - A
	a	A	A
O	A[6]	O	O
O	B		
A		a	a
B	B	B	B
A			
O	O	A	A
		A	
		A	A
O	O	O	O
		A	A
A		y	y
O	O	O	O

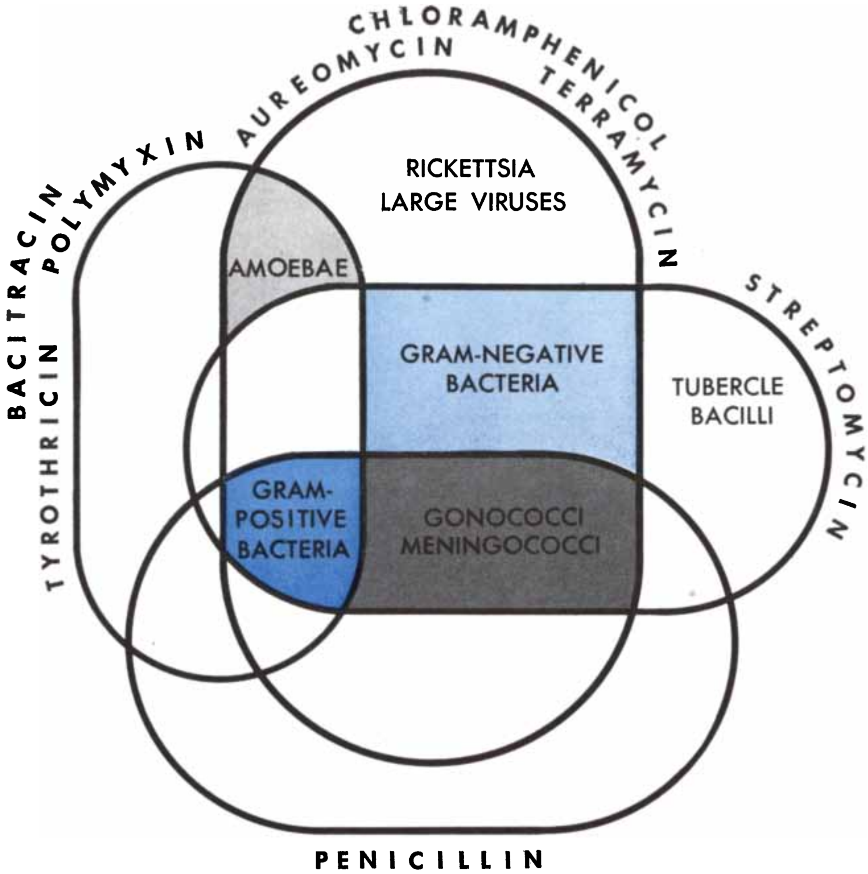
6: Combined with para-aminosalicylic acid. Where two antibiotics are used together, they are joined by a dotted line. Mixtures of antibiotics sometimes used for mixed infections, however, are not indicated. Chloramphenicol is a name frequently used for chloromycetin. The chart was prepared with the assistance of Ralph Tompsett of the Cornell University Medical College.

This story began five years ago when Mary S. Shorb of the University of Maryland discovered that a substance in liver extract, which had long been used to treat pernicious anemia, was active in promoting the growth of certain fermenting bacteria found in milk. A year later investigators at the Merck Laboratories isolated minute amounts of this substance as a red crystalline compound. It was named vitamin B_{12}. Meanwhile animal nutritionists had observed that liver extracts, as well as fish meal and some other animal products, could markedly stimulate the growth of chicks. Their unknown stimulating substance was called the Animal Protein Factor (APF). The Merck group soon demonstrated that vitamin B_{12} had the same growth-stimulating effect on chicks when it was substituted for animal products known to be rich in APF; in other words, B_{12} and APF were primarily one and the same.

Then came a far-reaching discovery. The Merck investigators found that the culture broths of various bacteria and actinomycetes, including the one which produces streptomycin, contained a substance with the same activity as vitamin B_{12}. They soon succeeded in isolating the vitamin itself in crystalline form from streptomycin fermentations. Before long vitamin B_{12} was identified in other microbial fermentations.

The solid material filtered out of streptomycin and aureomycin brews, which up to that time had been thrown away as wastes and considered a costly nuisance, at once became a valuable by-product of the antibiotics industry. B_{12} concentrates obtained from these fermentation "wastes" were widely sold as an animal-feed supplement. The demand by farmers for this miraculous growth-stimulating substance grew so rapidly that the antibiotics manufacturers could not keep up with it, and an intensive search began for other microorganisms capable of producing high yields of the vitamin. Harlow Hall and his associates at the Northern Regional Laboratory found that very high yields can be obtained from a strain of *Streptomyces* isolated from Japanese soil, and several manufacturers are now using this process.

A more surprising discovery, however, was still to come. In 1949 E. L. R. Stokstad and T. H. Jukes of the Lederle Laboratories noticed that when they fed chicks the fermentation concentrate from aureomycin, they obtained a growth response over and above that attributable to the vitamin B_{12} content alone. Knowing that the concentrate contained traces of aureomycin, they reasoned correctly that the antibiotic itself might be exerting some stimulating effect. When they added further small amounts of aureomycin to the chicks' ration, the chicks grew even faster. The



DOMAINS of the five principal antibiotics and three that are less frequently used (*left*) overlap. The three "broad-spectrum" antibiotics at the top of the page are effective against the largest group of organisms.

same results were later obtained in other animals and with other antibiotics. Aureomycin, penicillin, terramycin and bacitracin are all about equally effective in promoting growth; streptomycin and chloromycetin somewhat less so.

The supplement of vitamin B_{12} and an antibiotic stimulates young animals most. It is not unusual for chicks and turkey poults four to eight weeks old to gain weight 20 to 30 per cent faster than those on an ordinary diet. They are also less subject to intestinal diseases. Moreover, they need less grain or mash.

Antibiotics are especially important in the nutrition of baby pigs. Developments of recent months may revolutionize hog farming. Suckling pigs fed on a synthetic sow's milk (made of dried milk by-products, lard, vitamins and minerals) fortified with an antibiotic can be separated from the sow within 48 hours instead of the usual six to eight weeks. The pigs are raised in a brooder with controlled temperature and humidity, and in the more elite installations they are periodically awakened by recorded porcine music to return them to the all-important task of eating. Under this regimen all the pigs in a litter get enough to eat, they grow faster, fewer of them are injured and the sows lose no time for nursing.

Only small amounts of vitamin B_{12} and antibiotic are required to produce a maximum growth response. For poultry the recommended amount of vitamin B_{12} is about two to four micrograms per pound of feed, depending on whether the birds are fed on mash or grain. The antibiotic ration is only about 10 grams per ton of feed—less than 13 parts per million!

Just how the antibiotics promote growth is not known. They have this effect only when they are given orally. It is commonly assumed that the antibiotic helps growth by altering the intestinal flora in some way, but this is far from proved. The interaction between the antibiotic, the animal and its intestinal flora is undoubtedly complex.

Facts and Figures

Today antibiotics are a big business. The 1951 penicillin production of some 350 trillion units was worth about $140 million even at a bulk wholesale value of 40 cents per million units; as the packaged drug its value was much greater. On the same basis the streptomycin production of more than 150 million grams last year, at 38 cents per gram wholesale, was worth nearly $57 million. The other antibiotics amounted to some $90 million in 1950, the latest year for which an estimate is available. We can be sure that production increased markedly in 1951. A substantial share of the U. S. production of antibiotics is going abroad; in 1950 we exported more than $93 million worth, penicillin and streptomycin accounting for most of this total.

Animal feeding now represents a large part of the market for antibiotics. The annual wholesale market value of feed supplements containing antibiotics and vitamin B_{12} is estimated to be at least $40 to $50 million. Their impact on U. S. animal-raising has already been tremendous, and the potential is much greater. For instance, Damon Catron, swine nutritionist at Iowa State College, pointed out recently in *Feed Age* that if the farmers of Iowa, who now raise 20 million pigs annually, fed their pigs antibiotics, they could increase their annual profit by $24 million. H. R. Bird of the U. S. Bureau of Animal Industry reported in the same magazine: "With a fast-growing broiler strain and a good broiler mash, an antibiotic may be expected to give 10 per cent greater weight at 10 weeks and 10 per cent greater efficiency. That means that birds go to market at a given weight about a week earlier and eat 10 per cent less feed." On this basis in the U. S. as a whole the use of antibiotics could achieve a saving of more than $22 million a year in this feed item alone.

Starting from scratch in 1942, the capital investment in buildings and equipment by the antibiotics industry had reached an estimated $200 million by the end of 1950. The industry continued to expand at a rapid pace in 1951, and the end is not in sight.

Along with the mounting production of penicillin and streptomycin has come a very dramatic decrease in price. The first batches of penicillin sold to the Government in 1943 were priced below cost at $20 per 100,000 units wholesale. By 1945 the price had dropped to 60 cents per 100,000 units, and by 1949 to 4 cents, where it has leveled off. Streptomycin prices have fallen from $30 per gram in 1945 to 40 cents or less per gram today. Of course, by the pound the antibiotics are still very expensive (nearly $300 per pound for penicillin), but they are administered in extremely small amounts.

The antibiotics represent an increasingly important part of the drugstore prescription business: they accounted for an estimated 25 per cent of all prescriptions filled in 1950. The *West Coast Druggist* reported in 1950 that the antibiotics were well in the lead over all other prescription products in sales. The estimated annual figures then were: antibiotics, $250 million; vitamins, $200 million; sulfonamides, $150 million; hormones, $100 million.

The greatest value of the antibiotics, of course, is their effect on the nation's health. Each of us knows individuals whose lives have been saved or extended by penicillin and other antibiotic drugs. The cumulative record of such cases, projected on a national scale, constitutes an impressive picture.

The following summary of the national effects of the antibiotics on the major diseases is based on published reports and on personal correspondence the author has had with outstanding authorities, including Chester S. Keefer, Joseph E. Moore, Esmond R. Long and Joseph E. Smadel, and with the offices of the Surgeons General of the U. S. Public Health Service, the U. S. Army and the U. S. Navy.

One of the first groups of diseases to yield to penicillin was the pneumococcic infections. The national fatality rate for pneumococcic pneumonia is now less than 5 per cent; the death rate for pneumococcic meningitis, 99 per cent fatal before penicillin, has dropped to 50 per cent, and pneumococcic endocarditis, which used to be invariably fatal, now shows a recovery rate of 25 per cent. The average hospitalization for pneumonia patients has been reduced from over 19 days in 1935-36 to a week or less now, and many patients with this disease no longer require hospital care at all. The other antibiotics, of course, have helped in this improvement, for the broad-spectrum drugs can stop some pneumococcic infections that do not respond to penicillin.

Next is the large group of diseases caused by streptococci. In blood infections the fatality rate has been reduced from 85 per cent to less than 10 per cent. Complications from streptococcic infections, such as otitis media and mastoiditis, seldom appear any more. The duration and severity of scarlet fever have been greatly reduced. Subacute bacterial endocarditis, which used to be almost 100 per cent fatal, can now be cured about 70 per cent of the time with penicillin.

The record is much the same in the staphylococcic infections. Here, too, the fatality rate for infections of the bloodstream has been reduced from 85 per cent to less than 10 per cent. Penicillin has cut the death rate from staphylococcic osteomyelitis, formerly a common cause of battle casualties, to 1 to 2 per cent. In staphylococcic meningitis the death rate is still very high (65 per cent), but much improved. In staphylococcic endocarditis, invariably fatal in pre-penicillin days, recoveries may be expected in about half the cases.

The antibiotics have also taken control over the gonococci. Gonorrhea in most cases can be cured by a single dose of 300,000 to 500,000 units of penicillin. The drug can even treat successfully severe cases of arthritis and endocarditis

ACKNOWLEDGEMENT

The cooperation of the many individuals and organizations who have furnished information for this article is gratefully acknowledged. Of this number, the following deserve special recognition: Drs. Chester S. Keefer, Esmond R. Long, Joseph E. Moore, Joseph E. Smadel, Henry Welch, Leonard S. Scheele, Robert D. Coghill, Jasper H. Kane, Asger F. Langlykke, J. C. Woodruff, Sylvan B. Lee, A. B. Hatch, J. A. Leighty, John Ehrlich, B. M. Duggar, Myron P. Backus, Marvin J. Johnson, Col. E. J. Knoblauch and Rear Admiral H. L. Pugh.

that stem from these organisms. The gonococci are extremely sensitive not only to penicillin but also to streptomycin and to the broad-spectrum drugs. Nevertheless, the number of reported cases of gonorrhea is today much greater than it was in 1941. Probably the chief reason is the wide public knowledge that an effective cure is available.

Typhoid fever has been made a much less serious disease by chloromycetin and the other broad-spectrum drugs. Chloromycetin is especially beneficial in treating acute typhoid infections due to *Salmonella*. The broad-spectrum drugs have also been helpful against dysentery and other intestinal diseases caused by gram-negative bacteria. Amoebic dysentery can be treated effectively with aureomycin, terramycin or bacitracin.

Rickettsial diseases, such as Rocky Mountain spotted fever, Q-fever, typhus, and scrub typhus, show a rapid and very favorable response to all three of the broad-spectrum drugs. The same drugs lessen the severity of various virus diseases, but it is not yet established that they attack the viruses themselves; they may merely prevent secondary infections or symptoms.

The picture with regard to tuberculosis is still clouded. There is no doubt that streptomycin has prolonged the lives of some tuberculous patients and has accelerated the arrest of the disease in many others. By alleviating the acute symptoms of patients, it often buys valuable time for therapy such as bed rest and surgery to take effect. On the other hand, there seems to be considerable doubt whether the use of streptomycin has had any effect as yet upon the death rate.

Syphilis and other diseases due to spirochetes have yielded to the antibiotics in a spectacular manner. Penicillin, first adopted as a treatment for syphilis by J. F. Mahoney of the U. S. Public Health Service in 1943, has now become the standard therapy for this disease. In resistant cases the broad-spectrum drugs are effective. According to U. S. Public Health Reports, the national incidence of syphilis dropped by almost 50 per cent between 1943 and 1950, and the incidence is even lower now. As in the case of gonorrhea, it can be argued that the means, if not the will, for the eradication of syphilis are now available.

The antibiotic drugs play an increasingly important role in military medicine. In combat areas they are used to forestall the development of gas gangrene and other serious infections. Behind the lines they find wide application in the treatment of osteomyelitis and other deep-seated wound infections, in addition to the multiple uses for which they are employed in civilian practice. Besides saving untold lives, they have greatly reduced the time required to return hospitalized personnel to combat status.

Unfinished Business

Much has been accomplished in the years since 1941, but a great deal of unfinished business remains. There is still a long list of major diseases for which no satisfactory antibiotics have been found.

Cancer has shown no sign of succumbing to any drug, although some heartening work has been done, notably at the Sloan-Kettering Institute for Cancer Research in New York.

Influenza and the common cold still defy treatment, although the broad-spectrum antibiotics can minimize bacterial complications. Research directed toward suppressing the viruses themselves is currently being pursued in many university and pharmaceutical laboratories. Numberless microbial filtrates are being tested in chick embryos and mice for activity against viruses. Outstanding among such investigations has been the work of Richard E. Shope at the Rockefeller Institute and the Merck Laboratories. He has found that a certain common species of *Penicillium* produces an agent with a potent inhibiting effect on some viruses. There are still some uncertainties about the production of this agent, but if they can be resolved, a tremendously significant goal will have been reached.

Poliomyelitis is the center of another wide and determined search for an anti-virus agent. Encouraging results have been obtained by Igor N. Asheshov, W. J. Robbins and others at the New York Botanical Garden. Currently their work is aimed at finding microbial antagonists which will arrest bacteriophages, *i.e.*, virus forms that destroy bacteria.

Measles, chicken pox and mumps, the so-called children's diseases, also are caused by viruses. Currently they are receiving little attention, but if antibiotics are found for the more serious virus diseases, it is probable that control of these infections will soon follow.

Fungus infections in man and animals are another unsolved problem. We urgently need drugs to combat such systemic fungus infections as coccidiomycosis, cryptococcosis and histoplasmosis. Many antibiotics that are powerful killers or inhibitors of fungi have been found, but all of them are too toxic for human beings.

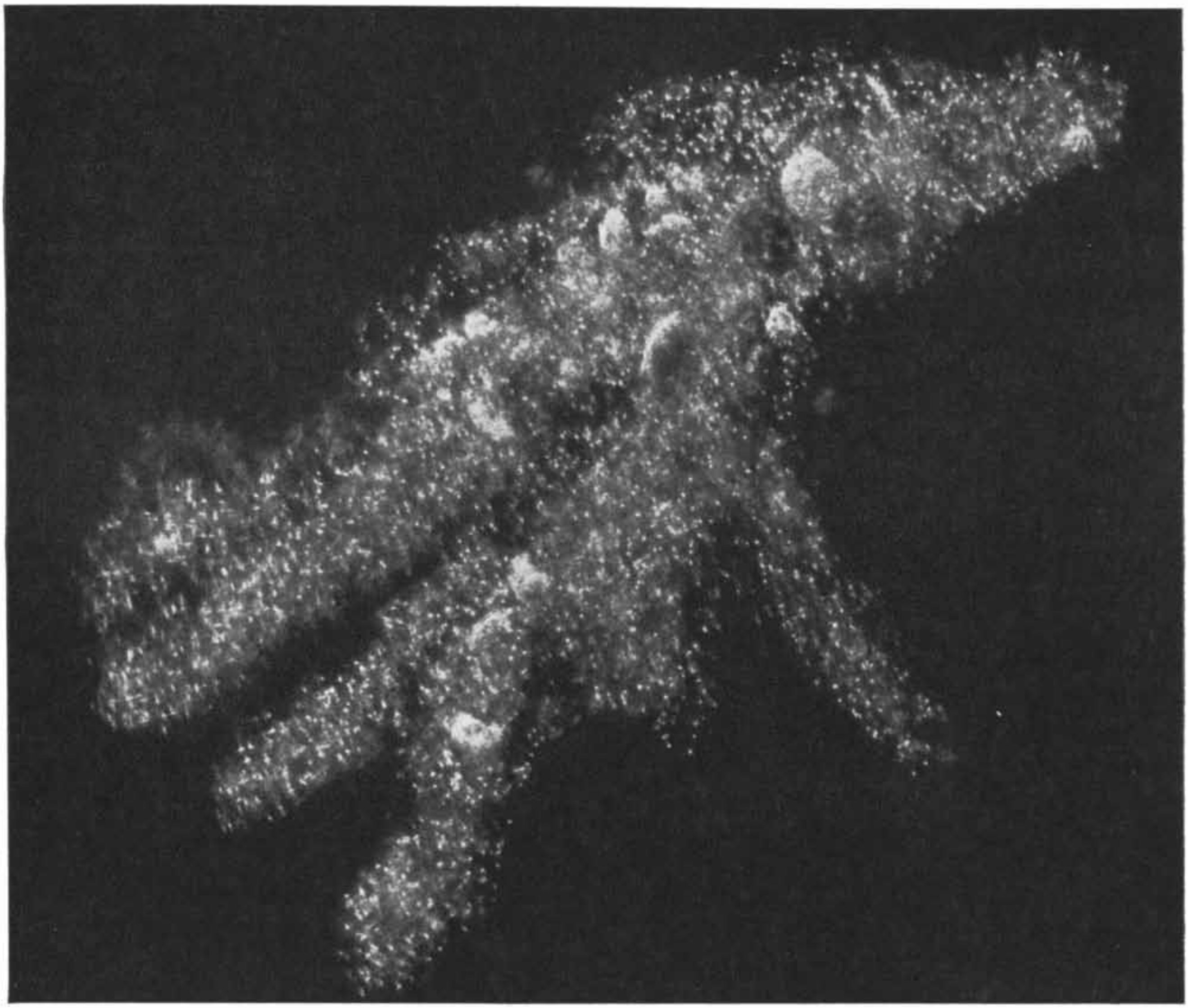
Tuberculosis remains one of the great unconquered infections. To master it we need a better antibiotic than streptomycin. Many clinicians question whether streptomycin itself has actually produced any cures of t.b. What is needed is a less toxic drug that would eradicate rather than merely suppress the tubercle bacillus and would have less tendency to foster resistant strains of the microbe.

Looking beyond man's diseases, we can hope that antibiotics will some day also conquer many diseases of the plants on which he lives. Many substances that show promise in this field have already turned up, foremost among them actidione, viridin, clavacin, gliotoxin, streptomycin, subtilin and a substance known as antibiotic XG. We may even be able to develop new plant varieties that carry their own infection-resisting substances; such a possibility is suggested by work done by G. W. Irving, Jr., and T. R. Fontaine of the Bureau of Agricultural Chemistry at Beltsville, Md.

Another vast potential field for the antibiotics is the preserving of perishable foods. The Bureau of Dairy Industry has studied the possibility of using penicillin to extend the "kitchen life" of fresh milk, but the obstacles so far look too great. At the Western Regional Laboratory in California, Department of Agriculture workers have obtained some promising results in using subtilin to preserve canned foods without complete heat sterilization. Subtilin apparently is not an adequate answer to the problem, however. Investigators are now searching for better antibiotics for this purpose. If the use of antibiotics could replace the present conventional heating process, the nutritional value and flavor of many canned foods would be considerably improved.

Finally, we shall have to keep on searching constantly for new medicinal antibiotics that are better than the ones we have. We are, it must not be forgotten, in a race with the germs, and as they develop resistance to our attacks we shall need bigger and bigger doses and more and more potent drugs to keep them under control. It behooves us to form a second line of defense by continually strengthening our armamentarium.

Kenneth B. Raper is principal microbiologist at the Northern Regional Research Laboratory of the Department of Agriculture.



PHOTOMICROGRAPH of *Amoeba proteus* shows its pseudopods, or "false feet," stretching in the direction of its motion. This amoeba is from a culture grown by J. A. Dawson of the College of the City of New York.

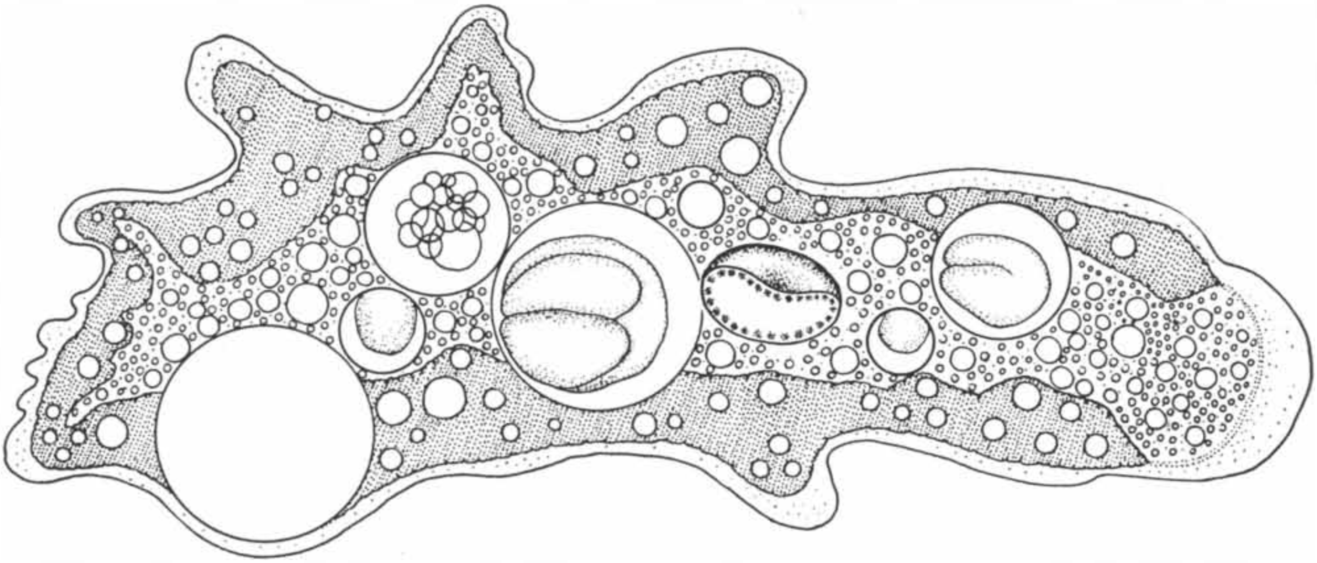


DIAGRAM of *Amoeba proteus* shows its nucleus in cross section at right center. The large circle at left is the contractile vacuole, with which the amoeba excretes wastes. Some of the other structures contain food particles.

On Transplanting Nuclei

Like other cells, the amoeba is divided into nucleus and cytoplasm. By operating upon these organs, the author studies their role in the life of the cell

by J. F. Danielli

EVERY living cell is divided into two main parts: the nucleus and a surrounding fluid called the cytoplasm. One of the most exciting current issues in biology is the question of the respective roles played by the nucleus and the cytoplasm in controlling the heredity and development of the cell. It was long taken for granted that the nucleus was the chief, if not the exclusive, director of the drama. Until recently most biologists would have said that the genes, which carry the hereditary traits of every organism, are always attached to the chromosomes in the nucleus.

This view is now changing. Experimenters have been finding more and more evidence that the cytoplasm also may control the unfolding of the play. Apparently the cytoplasm either possesses some genes of its own or else at times houses genes that move into it from the nucleus. This article will describe some recent studies of the matter made by the simple, direct method of transplanting nuclei from one cell to another and observing the effects on survival and inheritance.

Why bother? Why should biologists go to the great trouble of trying to find out just where the genes in a cell are? Aside from sheer curiosity, or, as some would say, the divine spirit of inquiry, there are several good reasons. A human being arises from a single round egg cell which divides and grows into a great variety of cells of different shapes and sizes. We want to know whether the differences between these cells lie primarily in the nucleus or primarily in the cytoplasm. If we knew this, we would have part of the answer to a major problem of biology: how an animal develops from the egg. Secondly, some of the problems of medicine would probably be easier to solve if we knew just how much responsibility should be attributed to a nucleus and how much to cytoplasm. For example, if, in dealing with a particular type of cancer, we knew whether a drug should be designed to act on the nucleus or on the cytoplasm, progress would be easier.

Transplanting cell nuclei is difficult, and very little work has been done on it in the past. The operation itself looks deceptively simple. To perform it we use a de Fonbrune micromanipulator, an apparatus which manipulates microneedles and microhooks (see "Microsurgery," by M. J. Kopac; SCIENTIFIC AMERICAN, October, 1950). The cells on which we operate are certain species of amoebae. A minute drop of water containing two amoebae is placed on a cover-slip under a thick layer of paraffin, and the cover-slip is then inverted over a special slide and laid on a microscope stage (*see diagram on page 62*). Holding an amoeba in the crook of a microhook, one can push out its nucleus with a microneedle; the nucleus of the second amoeba is then pushed into the cytoplasm of the first.

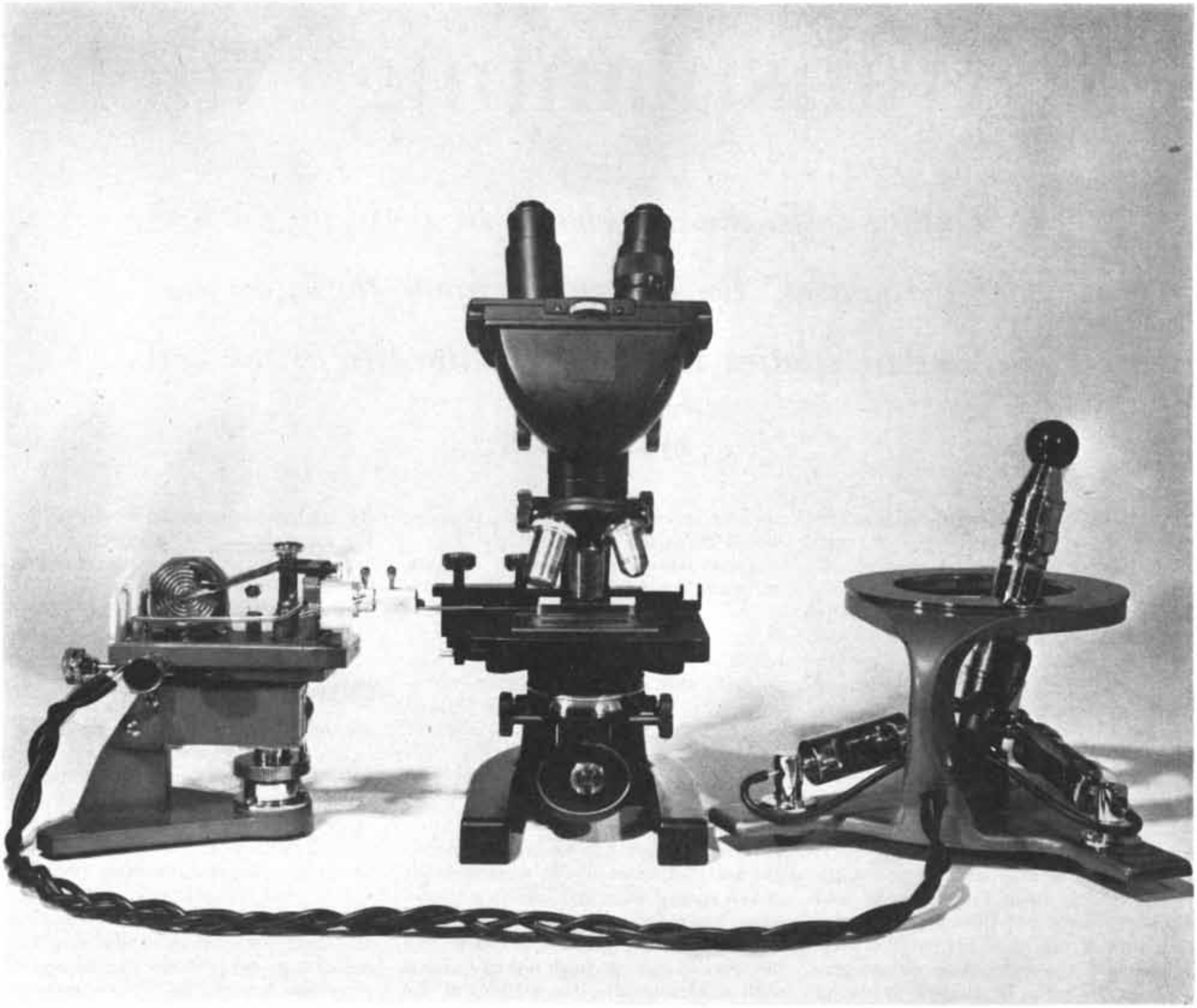
The operation calls for considerable hand-and-eye cooperation, and it takes several months to acquire the skill. The first successful transfers were carried out in 1937-38 by Pierre de Fonbrune and a colleague at the Pasteur Institute in Paris. They used a small amoeba (*Amoeba sphaeronucleus*). At King's College, London, we have used two large species, *Amoeba proteus* and *Amoeba discoides.* With these large amoebae, under favorable conditions, one can make 50 nuclear transfers in a day. My colleagues in various experiments we have conducted have been Joan Lorch and Muriel Ord.

WHAT HAPPENS when an amoeba is deprived of its nucleus? For a few days most of its functions can continue to some degree. It goes on swimming in typical amoeboid fashion, ingests and digests food, maintains its osmotic balance of fluid, conducts nerve impulses, and so on. But before very long a decline sets in and the cell dies. Enucleated amoebae rarely live more than 20 days. And when an amoeba loses its nucleus, apparently it always loses the capacity for reproduction.

But give such an amoeba a new nucleus from another amoeba of the same species, and it becomes a viable animal. Often it is reactivated almost immediately; for example, an amoeba that has been enucleated for three or four days is usually rounded up into a ball, but within a few minutes of renucleation it may push out a pseudopod and resume its normal locomotion. A successfully renucleated amoeba seems normal in every respect: it can reproduce and grow into a mass culture. If the operation is performed under good conditions within 48 hours after the original nucleus is removed, renucleation with a nucleus from the same species is successful nine times out of ten, and it works sometimes even after the amoeba has lived without a nucleus for seven days or more.

As might be expected, the union is not accomplished without a certain amount of adjustment. The cytoplasm and its new nucleus do not immediately settle down to exactly the same relationship as existed in the original amoeba. It takes the rebuilt animal an average of four days to divide and produce its first daughter cells, whereas in a good culture these species normally divide every two days. But after the first division the offspring return to the normal pattern of dividing every two days.

An amoeba that has lost its nucleus can be reactivated even with a nucleus from a different species of amoeba. The hybrid animal may engulf and digest food, grow, divide several times and behave like a normal amoeba for many days. But in almost all cases it eventually goes into a decline and dies. We do not yet know why transfers between different species are less successful than those between individuals of the same species. But the result of these heterotransfers gives us a very valuable piece of information about the relationship between a nucleus and cytoplasm: it shows that a nucleus has a general short-term



MICROMANIPULATOR of the de Fonbrune type delicately moves a fine glass needle beneath the objective of the microscope in the center of this photograph. A second needle is stationary; the first is moved by changing the pressure of the air in three flexible diaphragms at the left. These chambers are connected by the tubes in the foreground to three piston pumps at the right. All three pumps are operated by moving a handle with a ball joint. The micromanipulator was furnished through the courtesy of the A. S. Aloe Co.

effect on cytoplasm which can operate between different species, and that it has another very different influence which becomes evident only after a rather long period and is much more species-specific.

TO FIND OUT to what extent the nucleus and the cytoplasm respectively control the individual characters of amoebae, we chose for study two characters that can be measured accurately: the maximum diameter of the nucleus, and the form assumed by an amoeba when it is moving. Our two species of amoebae ordinarily have different-sized nuclei, the nucleus of *Amoeba discoides* being typically smaller in diameter than that of *Amoeba proteus*. Within each species individuals vary greatly in nuclear diameter, depending on their stage of growth, but when the curves of distributions of sizes in typical cultures of the two species are plotted and compared, the average difference is clearly apparent (*see diagram on page 64*).

Now when a *discoides* nucleus is transferred to *proteus* cytoplasm, the daughter cells (from the first division) tend to fall in the *proteus* range of nuclear diameters rather than in the *discoides* range. That is, the cytoplasm seems to have a dominant influence on the growth and size of the nucleus. The same is true when we make the converse transfer of a *proteus* nucleus to *discoides* cytoplasm; in this case the growth of the nucleus is greatly reduced, and the distribution of nuclear diameters tends to approximate the *discoides* type.

When we make a similar study of the second trait—the amoeba's form—we find again that the cytoplasm has the predominant effect. *Amoeba proteus* in movement is typically elongated and has very few pseudopods, while *Amoeba discoides* is stubbier and tends to stretch out a number of small pseudopods. If we transplant a *discoides* nucleus into *proteus* cytoplasm, the offspring tend to take on the *proteus* shape, while an amoeba composed of a *proteus* nucleus and *discoides* cytoplasm tends to assume the *discoides* shape.

The nucleus of course has some influence on these first progeny, but it seems significant that both the traits studied—the form of the amoeba and the diameter of its nucleus—are mainly determined by the cytoplasm.

Over the long run the nucleus comes to assert a more pronounced influence. We have one mass culture, derived from an amoeba with a *proteus* nucleus in *discoides* cytoplasm, which we have kept reproducing for three years. The substance of the original amoeba is so diluted by now (not as much as one molecule from the original amoeba in each

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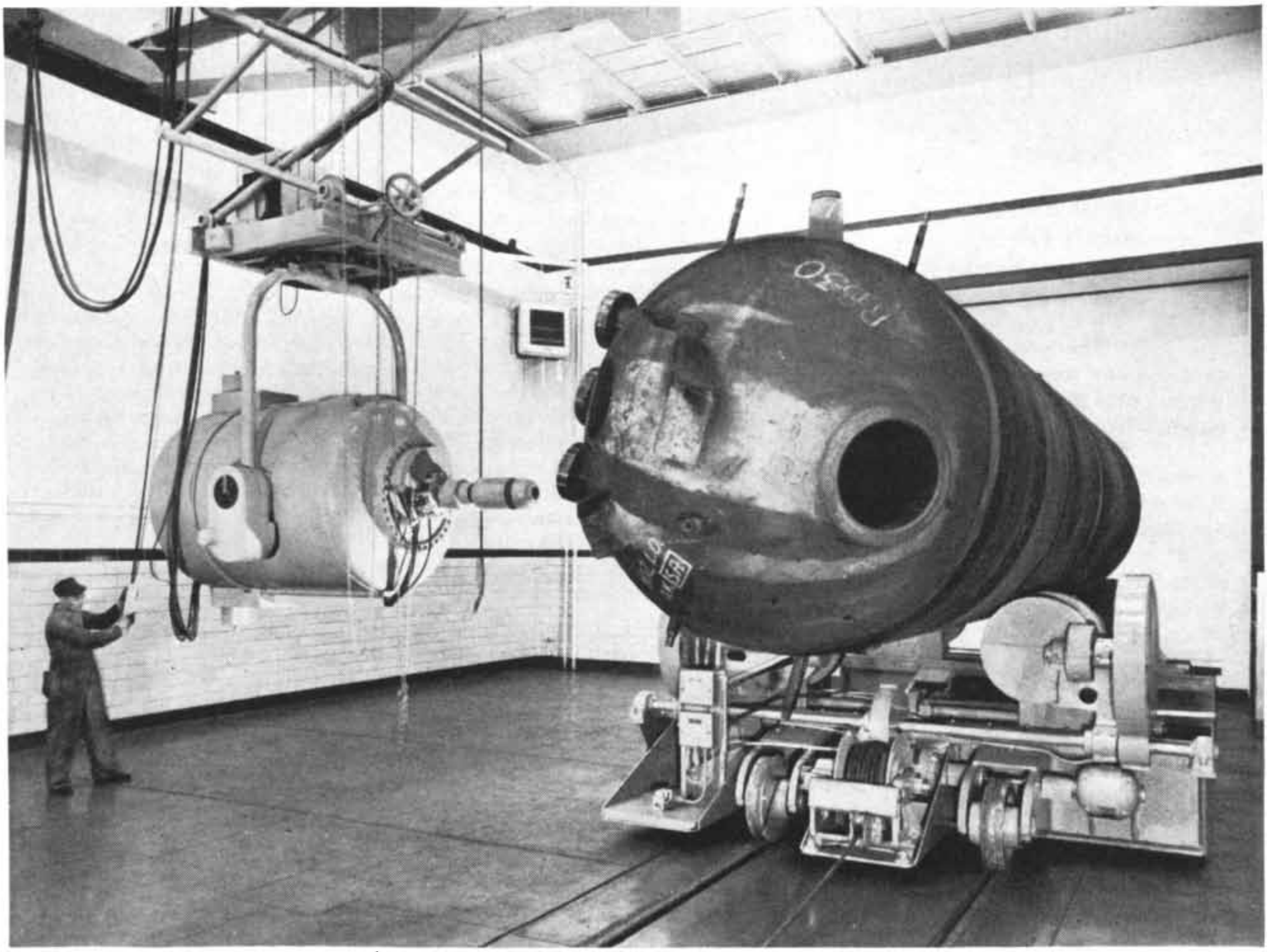

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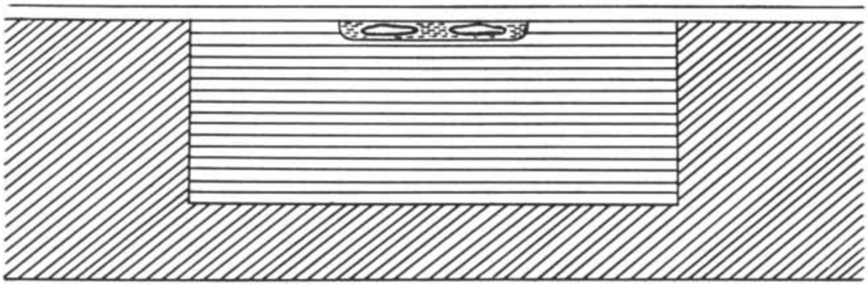


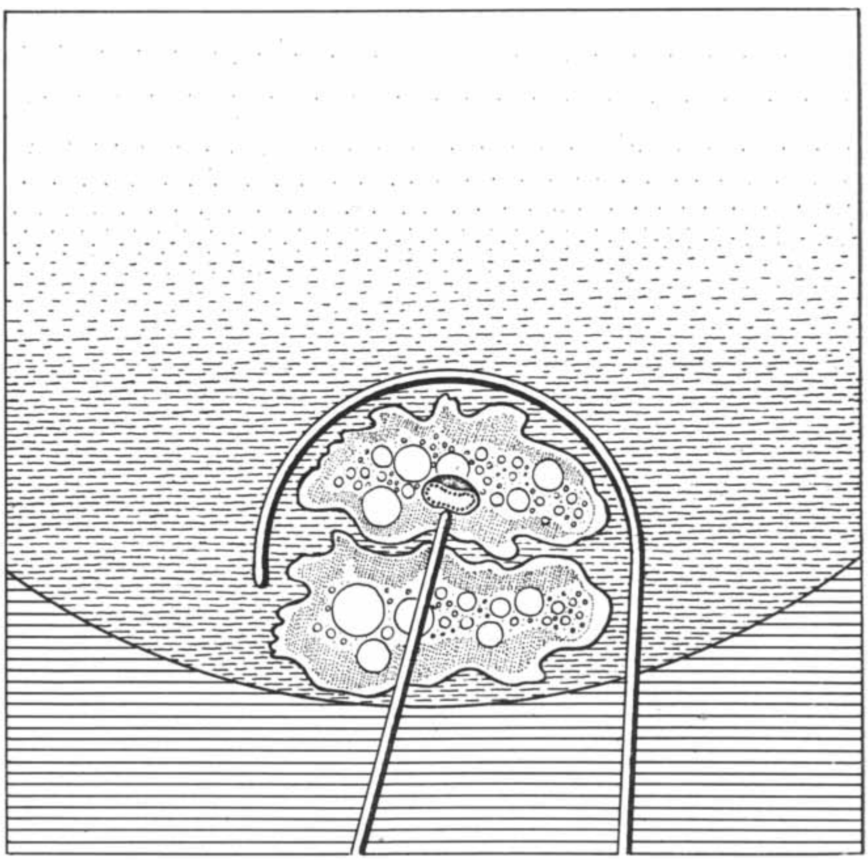
CHAMBER for the author's operations on amoebae is a depression in wax set in a special microscope slide. The top of the chamber is a cover glass.

of our present amoebae) that the traits of the amoebae we now have must depend entirely on inheritance factors (genes) which have reproduced themselves very many times. The characteristics of this culture are illuminating. In nuclear diameter the amoebae still reflect predominantly the influence of the *discoides* cytoplasm from which they were derived, though the nucleus has had some effect, making the average diameter somewhat larger than that of a pure *discoides* culture. On the other hand, the form, or shape, of the present amoebae has been strongly affected both by the nucleus and by the cytoplasm: most of the amoebae have an intermediate form between *discoides* and *proteus*.

It is evident, then, that the cytoplasm exerts at least as great an influence on the morphological characters of these amoebae as does the nucleus. The experiments prove conclusively that the cytoplasm either is able to reproduce directly many of the factors which determine cell morphology or can direct the reproduction of such factors by the cell nucleus. The same would hold for the nucleus also.

WE HAVE USED the nuclear transfer techniques to study the action of X-rays and of one drug (so far) on amoebae. The drug we chose to study first was a nitrogen mustard compound which has been widely used in the treatment of some types of cancer.

This drug is known to cause great damage to the chromosomes and associated structures of cells. It is therefore tempting to conclude that it acts directly upon the nucleus, possibly directly



OPERATION of transferring a nucleus from one amoeba to another is performed by holding amoebae with a hook and pushing nucleus with a needle.

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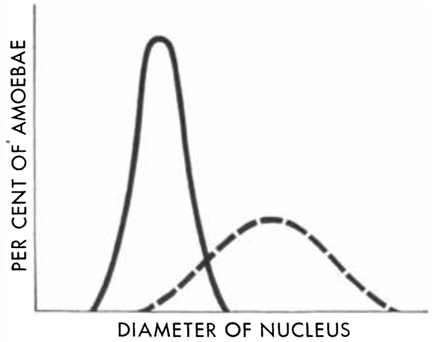


NUCLEI of *Amoeba proteus* (*dotted line*) tend to be larger than those of *Amoeba discoides* (*solid line*).

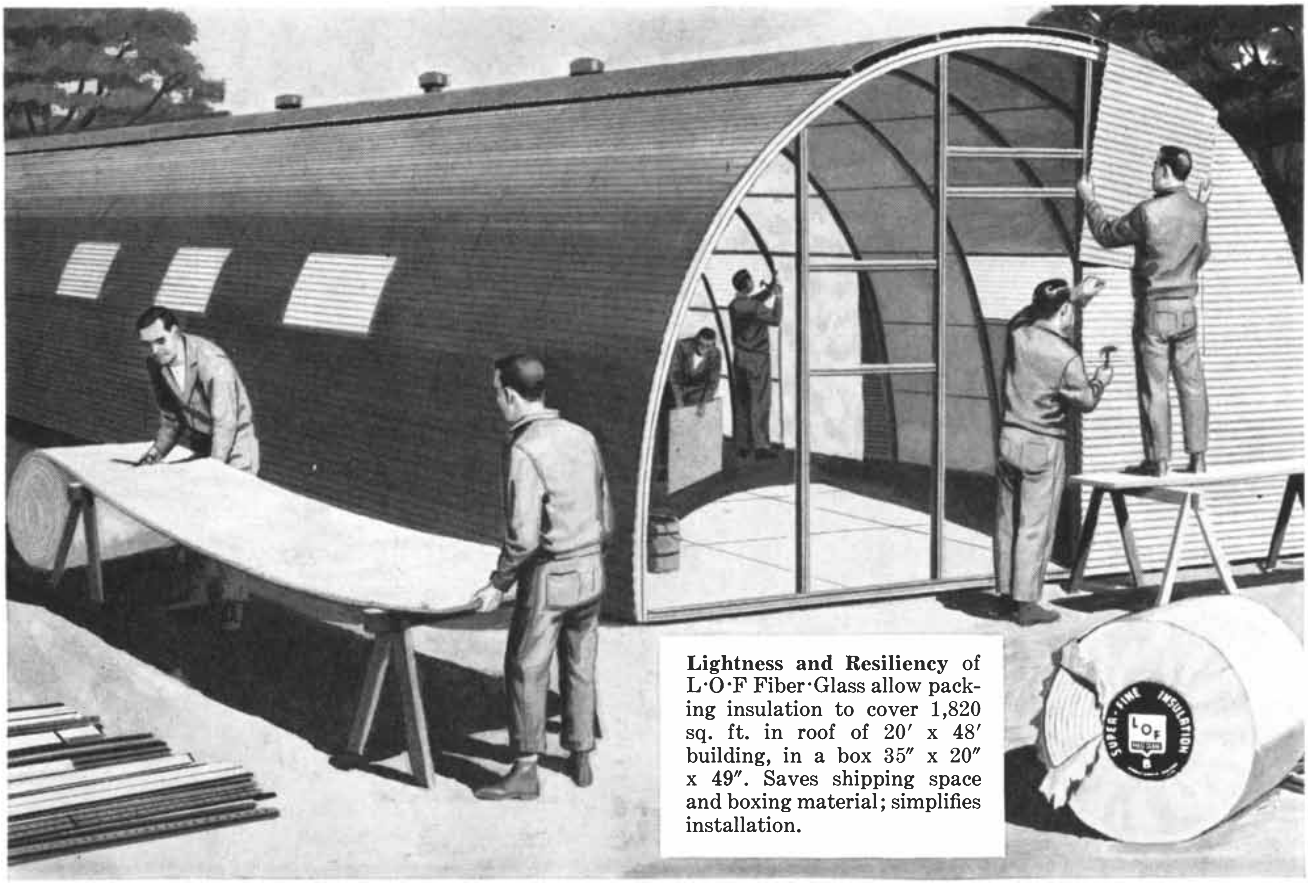
upon the chromosomes. Our studies with nuclear transfer, however, show that the situation is more complicated. The drug appears to damage both the nucleus and the cytoplasm equally and independently. When it is administered in such a way as to damage only the cytoplasm, the cell dies in a few days. When only the nucleus is treated, the cell lives somewhat longer, but the damage is equally serious at any given dosage. The life of a lethally damaged nucleus can be prolonged by inserting the injured nucleus into normal cytoplasm, but damaged cytoplasm is not helped by insertion of a healthy nucleus. Work is now in progress to find out whether changes in chemical structure of nitrogen mustards will alter the distribution of damage between the nucleus and cytoplasm.

The preliminary studies with X-rays indicate that radiation is much more selective: it causes some damage to cytoplasm but has more serious effects on the nucleus. This result agrees with calculations made many years ago by various researchers on X-rays.

The results with nitrogen mustard show that the cell nucleus can be damaged in at least two distinct ways. One kind of damage results in rapid death; the other in relatively slow death. This result confirms the conclusion that nuclei do two different things for the cytoplasm, one of which is of short-term significance, the other of long-term significance.

THE CONCLUSION we have reached from this work is that nuclear transfer is a valuable weapon for investigating many fundamental biological problems, some aspects of the cancer problem and many aspects of the mode of action of drugs. Various parts of this work have been supported by grants from the British Empire Cancer Campaign, The Nuffield Foundation, The Rockefeller Foundation and the Royal Society of London.

J. F. Danielli is professor of zoology at King's College of the University of London.



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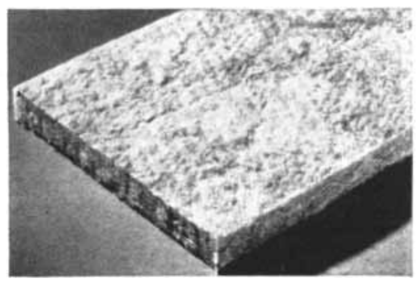

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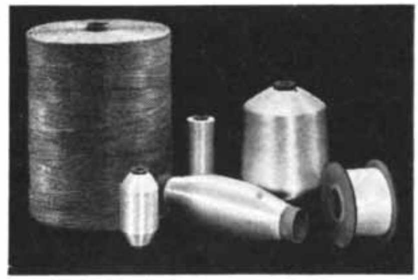

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The Strange Life of Charles Babbage

This remarkable Englishman tried to build modern computing machines a century ahead of their time. His failure left him hating mankind in general and organ-grinders in particular

by Philip and Emily Morrison

DURING last summer's Festival of Britain the center of the stage in a section of the Exhibition of Science at the South Kensington Science Museum was held by a glowing, streamlined computer called Nimrod. A visitor who wandered away from the main attractions might have found, tucked away in a remote gallery, a dust-covered ancestor of Nimrod. It is a complicated collection of wheels and rods labeled Babbage's Difference Engine. Made in 1833, it was the work of a designer who consumed his years and his fortune in the attempt to build mathematical machines for which his age was not ready but which have now been realized.

Charles Babbage is a name known to some mathematicians today. Few of his own contemporaries recognized the value of his work, and he was held a crackpot by his London neighbors, who knew him chiefly as a crotchety crusader against street organ-grinders; indeed, when he died the London *Times* identified him in the first paragraph of its obituary as a man who had lived to almost 80 "in spite of organ-grinding persecutions." Today mathematicians recognize him as a man far ahead of his time. To an article on one of the modern U. S. calculating machines the British magazine *Nature* gave the title "Babbage's Dream Comes True."

Babbage was a versatile fellow. He wrote a book, *On the Economy of Manufactures and Machinery*, which foreshadowed what is now known as operations research; he made a determined campaign for government subsidy of scientific research at a time when research was still to a large extent a gentleman's hobby; he published a widely-used table of logarithms from 1 to 108,000; he plotted mortality tables and made a pioneering attempt to popularize life insurance; he designed machine tools; he proposed a number of inventions, from schemes for preventing railroad wrecks to a system of lighthouse-signaling; he wrote papers on physics, geology, astronomy and archaeology. But mathematical machines were his great lifelong passion.

BABBAGE was born in Devonshire in 1792, the son of a banker, from whom he eventually inherited a considerable fortune. Because of poor health he was educated by private teachers until he entered Trinity College at Cambridge in 1810. Already passionately fond of mathematics, he was discouraged to find that he knew more than his tutor. His most intimate friends at the University were John Herschel, son of the eminent astronomer William Herschel, and George Peacock. The three undergraduates entered into a compact to "do their best to leave the world wiser than they found it." In 1812, as their first step in this direction, they founded the Analytical Society, primarily to encourage English mathematicians to replace the Newtonian mathematical notation with the Leibnitz scheme used on the Continent. Newton denoted a rate of change by placing a dot over the symbol in question; Leibnitz, by placing a d in front of it. Babbage founded the Society, he once remarked, to advocate the "principles of pure 'd-ism' as opposed to the '*dot*-age' of the University." In spite of considerable opposition, the Society had a profound effect on the future development of mathematics in England.

Babbage, believing that he was certain to be beaten in the tripos by both Herschel and Peacock, transferred from Trinity College to Peterhouse in his third year, preferring to be first at Peterhouse rather than third at Trinity. He did, indeed, graduate first from Peterhouse, and went on to take his M.A. in 1817. Babbage, Herschel and Peacock continued to be friends after they left school. Each in his own way lived up to their joint compact, though their careers were very different. Peacock joined the ministry and soon became Dean of Ely. Herschel, after a brief apprenticeship at law, decided to follow his father into astronomy. Not only did he distinguish himself in astronomy, but he was knighted by the Crown, served as master of the mint, avoided all scientific feuds, and his biographers report that his life was full of serenity and innocence.

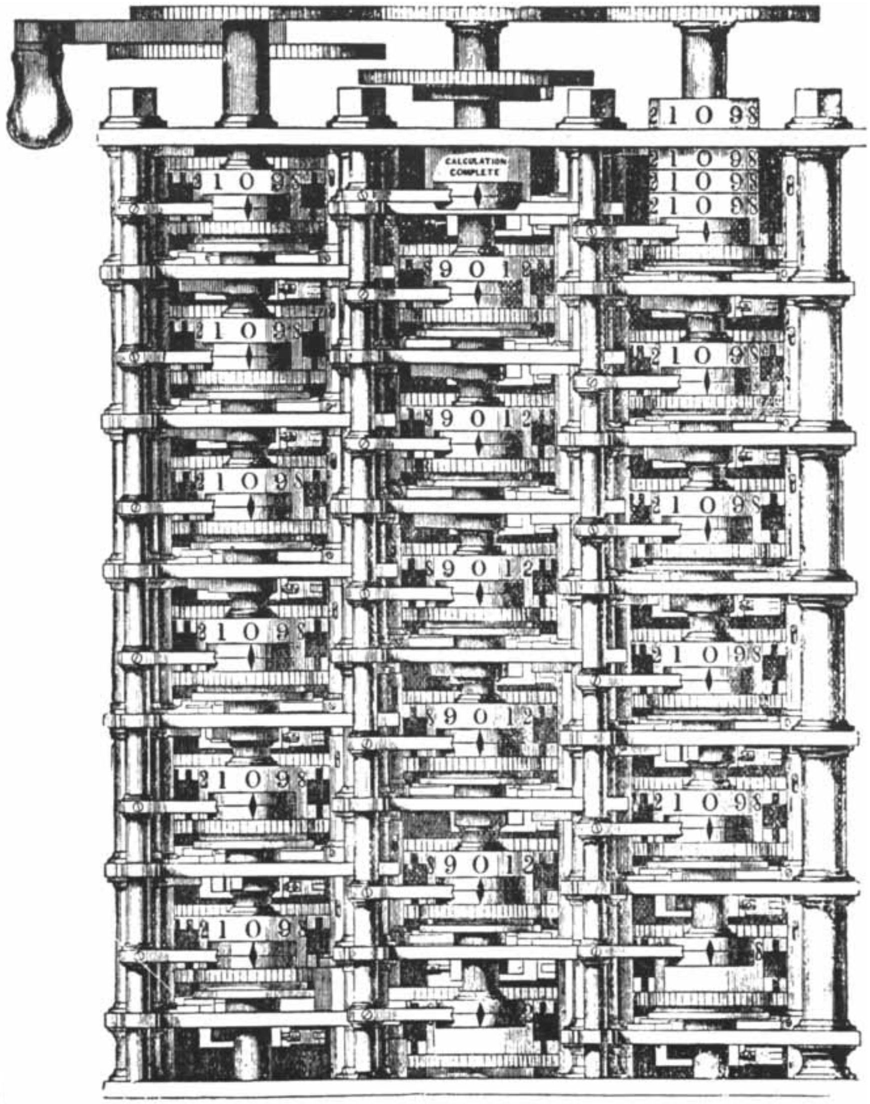
Babbage, in contrast, was to spend a life of bitter frustration on his mathematical machines. Toward the end of his life he remarked once to friends that he had never had a happy day in his life, and spoke "as though he hated mankind in general, Englishmen in particular, and the English Government and organ-grinders most of all." Actually it was not as bad as that: for much of his life he was a most social and gregarious man with a sense of humor. Once, on a visit to France with Herschel, Babbage ordered two eggs for each of them for breakfast by telling the waiter "pour chacun deux." The waiter called out to the kitchen, "Il faut faire bouillir cinquante deux oeufs pour Messieurs les Anglais." They succeeded in stopping the cook in time, but the story preceded them to Paris and quickly ran through several editions. Asked by a guest at a dinner party soon afterward whether he thought the tale of two young Englishmen who had eaten 52 eggs and a pie for breakfast was probable, Babbage replied soberly that "there was no absurdity a young Englishman would not occasionally commit." An Edinburgh professor who was once asked to dinner by Babbage reported that "it was with the greatest difficulty that I escaped from him at two in the morning after a most delightful evening." On his frequent trips to the Continent Babbage constantly sought the company of all sorts of people: members of the aristocracy, mathematicians, skilled mechanics.

NONETHELESS, Babbage's obsession with his machines transformed him from a cheerful young man into a bitter old one. He was first seized with this obsession, according to the most credible of his own differing versions, as the result of a chance conversation with his friend Herschel. The latter had brought in some calculations made for the Astronomical Society. In their tedious checking of the figures Herschel and Babbage found a number of errors, and at one point Babbage said, "I wish to God these calculations had been executed by steam." "It is quite possible," remarked Herschel. The more Babbage thought about it, the more convinced he became that it was possible to make machinery to compute and print mathematical tables. He set down a rough outline of his first idea, and made a small model consisting of 96 wheels and 24 axes, which he later reduced to 18 wheels and 3 axes. In 1822 he wrote a letter about his idea to Sir Humphry Davy, the president of the Royal Society, pointing out the advantages of his "Difference Engine" and proposing to construct one for the Government's use. The Royal Society reported favorably on his project, and the Chancellor of the Exchequer made a vague verbal agreement to underwrite the enterprise with Government funds.

Babbage had expected the project to take three years, but he was constantly having new ideas about the machine and scrapping all that had been done, and at the end of four years he was not yet in sight of his goal. The Government built him a fireproof building and workshops next to his home. After a visit by the Duke of Wellington himself to inspect the shops, it made a further liberal grant to continue the work. After a time Babbage and his very excellent engineer Joseph Clement had a "misunderstanding" about salary payments. Clement abruptly dissolved the workshop, dismissed his men and departed with all the tools, of which he was legally the owner, and all the drawings.

At this critical juncture Babbage had a brand-new idea: an Analytical Engine, which would be simpler to build, would operate more rapidly and would have

BABBAGE was born in 1792 and died in 1871. This drawing of him was made from a photograph in his son's book *Babbage's Calculating Engines.*



DIFFERENCE ENGINE was Babbage's first great conception. This woodcut is described in *Babbage's Calculating Engines* as "a portion of Mr. Babbage's Difference Engine. . . . It was commenced 1823 . . . abandoned 1842."

far more extensive powers than the Difference Engine. He put the scheme enthusiastically to the Government, asking whether he should continue with the Difference Engine or work on the new idea. For eight years he pressed for an official decision; at last he was advised that the Government must regretfully abandon the project. The Government had already spent £17,000 on it; Babbage had also spent a comparable amount from his own pocket. Now the unfinished Difference Engine, in which he had lost interest, was deposited in the Museum of King's College, London; eventually the bones of his dream went to the South Kensington Museum, where they are now.

For several years Babbage worked on his analytical engine, using his own funds. Then he dropped it and decided to design a second difference engine, which would include all the improvements and simplifications suggested by his work on the analytical engine. He again asked for Government support, but the Chancellor of the Exchequer declined. Babbage bitterly denounced him as "the Herostratus of Science, [who] if he escapes oblivion, will be linked with the destroyer of the Ephesian Temple."

IN THE END Babbage never completed a working engine. His vision was greater than the means then available for achieving it. Babbage aimed at something higher than a mere desk calculator; he planned to make a machine that could compute lengthy mathematical tables and set them up directly in type. He remarked: "Machinery which will perform . . . common arithmetic . . . will never be of that utility which must arise from an engine which calculates tables."

His Difference Engine was to be based on the principle of constant differences. To illustrate the principle let

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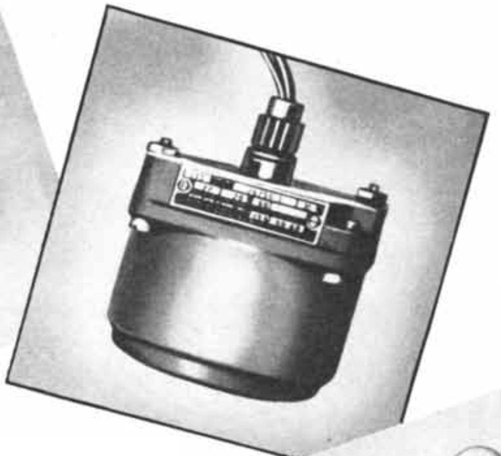

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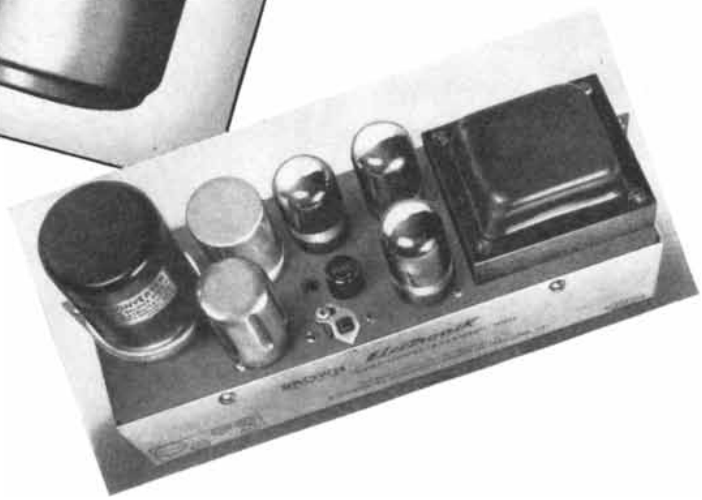

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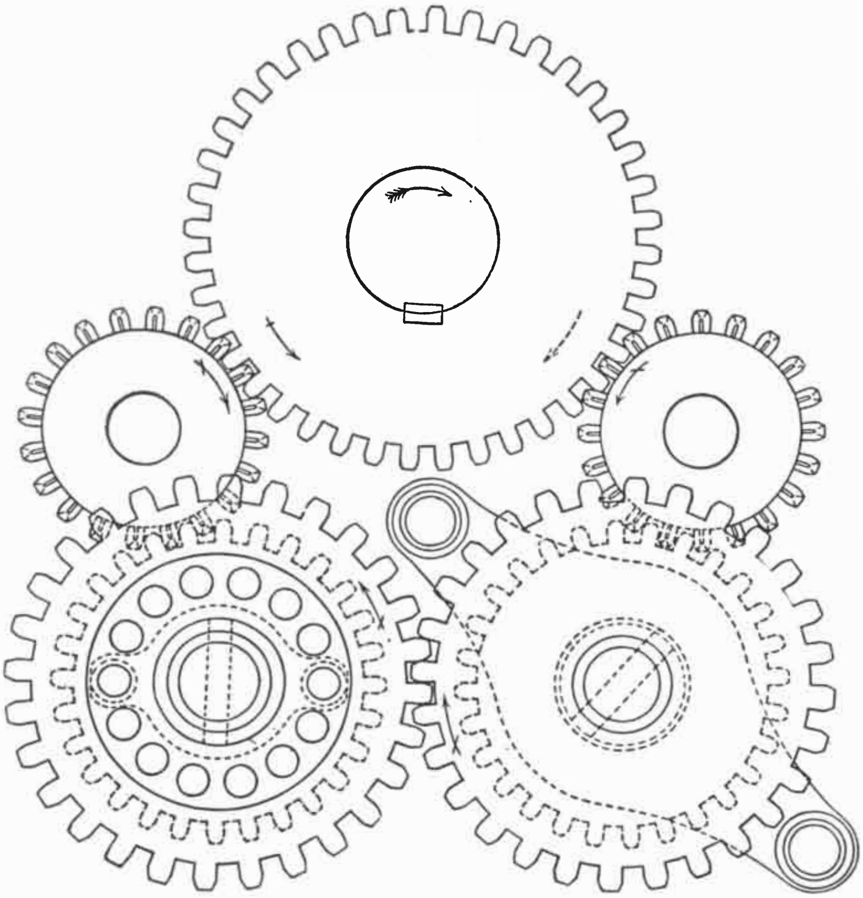


ANALYTICAL ENGINE was designed to carry out any mathematical operation. This part of it is described in Babbage book as a device which "performs the operation of multiplying or dividing a number by any power of ten."

us take a problem the engine was designed to solve, namely, to compute the squares of the successive numbers: 1^2, 2^2, 3^2, 4^2, and so on. The squares of all whole numbers, as far as we have the patience to go, can be obtained by the simple process of addition, with the use of the number 2 as the constant difference. We set up three columns. In the first we always set down the constant 2 (representing the second power). The second column starts with 1 and adds the constant 2 at each successive step. This sum is fed into the third column, which starts with 1, and then gives the answer. For example, 1 plus 2 plus the square of 1 gives 4, the square of 2; 3 plus 2 plus 4 gives 9, the square of 3; 5 plus 2 plus 9 gives 16, the square of 4; and so on. The table looks like this:

I	II	III
	1	
2 ——>		1
	3 ——>	
2 ——>		4
	5 ——>	
2 ——>		9
	7 ——>	
		16

Now these simple operations can easily be performed by a machine, in much the same manner as the mileage indicator on an automobile, which adds by turning wheels with numbers on them. Babbage's first preliminary model for the Difference Engine, made with toothed wheels on shafts that were turned by a crank, could produce a table of squares up to five places. But the engine he proposed to build was to be on a much grander scale. Babbage's plans called for no less than 20-place capacity, up to differences of the sixth order, instead of only the second. Furthermore, each number as it appeared in the answer column was to be transmitted through a set of levers and cams to a collection of steel punches, which would stamp the number on a copper engraver's plate.

Mechanically all this was an enormous order. Imagine the variety and number of bolts and nuts, claws, ratchets, cams, links, shafts and wheels that would be needed, and remember that standardized machine parts, not requiring hand-fitting, were practically nonexistent! Babbage attacked the problem with great skill. He and his assistants designed each part with great care, pro-

viding supplementary mechanisms to minimize wear. He became an expert technician, developing tools which were superior for the time, and methods which foreshadowed some of the modern practices of instrument design. But perhaps the very care and thoroughness of the design were its greatest weakness. If the machine had ever been finished, it would have comprised some two tons of novel brass, steel and pewter clockwork, made as nothing before it to gauged standards.

WHAT Babbage saw when he went on from the Difference to the Analytical Engine idea was a really grand vision. He had early conceived a notion which he picturesquely described as "the Engine eating its own tail." By this he meant that the results appearing in the answer column might be made to affect the earlier columns, and thus change the instructions set into the machine. The Analytical Engine was to be capable of carrying out *any* mathematical operation. The instructions set into it would tell it what operations to carry out, and in what order. It would be able to add, subtract, multiply and divide; it would have a memory with a capacity of 1,000 50-digit numbers; it would draw on auxiliary functions such as logarithm tables, of which it would possess its own library. It could compare numbers, and act upon its judgments, thus proceeding on lines not uniquely specified in advance by the machine's instructions.

All or much of this, of course, has come to pass in modern computers. But Babbage was limited to trying to carry it out mechanically; his design did not envision any help from electrical circuits, to say nothing of electronic tubes. He proposed to do it all with punched cards—not the fast-shuffled Hollerith cards moving over handy electrical-switch feelers that we have today, but cards modeled on those used in the Jacquard loom. The instructions and numerical constants would be punched in the cards as coded columns of holes. When the cards were fed into the machine, feeler wires would brush over them. Whenever the holes were in the appropriate pattern, the wires would pass through them and link together the motion of "chains" of columns and whole subassemblies. In this manner the machine would carry out all its operations. The great complexity of the system did not discourage Babbage, for he owned a colored portrait of Joseph Jacquard, woven in silk, in the weaving of which some 20,000 punched cards had been employed!

This is the barest sketch of the machine. Charles Babbage would be proud to see how completely the logical structure of his Analytical Engine has been adopted in today's big electronic computers.

Besides the concept itself, Babbage

originated many mechanical devices of immediate practical use. Just as a team designing mathematical machines today soon becomes involved in a welter of problems about the properties of vacuum tubes and electronic circuits, so Babbage became deeply involved in the problems of the machine shop and the drafting room. He and his group invented a number of new tools to use with a lathe. Among the highly skilled workmen who worked in his shop was one J. Whitworth, later Sir Joseph Whitworth, Bart., who became the foremost manufacturer of precision tools in England. Babbage's drawings for his various machines, covering altogether more than 400 square feet of paper, were described by contemporary experts as perhaps the best specimens of mechanical drawing ever executed.

Babbage's operations-research book, *On the Economy of Manufactures and Machinery,* ran through several editions, was reprinted in the U. S. and was translated into German, French, Italian and Spanish. In it he took to pieces the manufacture of pins—the operations involved, the kinds of skill required, the expense of each process—and suggested improvements in the current practices. He proposed some general methods for analyzing factories and processes and finding the proper size and location of factories. Babbage treasured as one of the best compliments he ever received a remark by an English workman who told him: "That book made me think."

When he was past 70, Babbage wrote an autobiography which he titled *Passages from the Life of a Philosopher.* A peevish but not humorless book, it bears on the title page a staggering list of learned societies (chiefly foreign) after his name. His autobiography is as much a record of his disappointments as of his achievements. He wrote it, he said, "to render . . . less unpalatable" the history of his calculating machines.

But there was no need for apology. The conception of the engines was genius. His whole story bears witness to the strong interaction between purely scientific innovation, on the one hand, and the social fabric of current technology, public understanding, and support on the other. His great engines never cranked out answers, for ingenuity can transcend but not ignore its context. His monument is not the dusty controversy of books, nor priority in a mushrooming branch of science, nor the few wheels in a museum. His monument, by no means wholly beautiful but very grand, is the kind of research that is epitomized today by the big digital computers.

Philip Morrison is a physicist at Cornell University. Emily Morrison is his wife.

VOLCANOES AND WORLD CLIMATE

What causes ice ages? A current theory rests upon the fact that as much as 20 per cent of the sunlight received by the surface of the earth can be blocked by the dust of a volcanic explosion

by Harry Wexler

THE EASTERN U. S. has just had another mild winter, which again raises the perennially fascinating subject of weather trends. Two years ago George H. T. Kimble, director of the American Geographical Society, called attention in an article in this magazine to the fact that winters in the Northern Hemisphere have been growing warmer for some time ("The Changing Climate"; SCIENTIFIC AMERICAN, April, 1950). That the earth has long-term spells and seesaws of climate is attested both by recorded history and by the vastly longer geological records of the ice ages.

Theories about the causes of long-run fluctuations in climate are almost as numerous and various as the kinds of weather we have. This article will discuss one theory that seems to gain support from recent events in the world's weather. But to place it in the context of thinking on this subject, let us first consider very briefly some of the other leading theories.

To begin with, there is the theory long favored by some geologists: that major changes in the earth's climate have been due to geological revolutions which altered the planet's topography. The main objection to this idea is that we have apparently had large climatic changes during the last few thousand years in regions of the earth where the topography has been stable. In recent years a very different idea has been growing in popularity: namely, that climatic shifts are caused by variations, one way or another, in the radiation the earth receives from the sun, which of course is the prime source of our weather. One school of thought suggests that climatic swings may be due to fluctuations in the sun's energy output. To this there are two objections: 1) variations of the magnitude suggested (10 per cent) have never been observed by the high-altitude instruments that measure solar radiation, and 2) such large variations are also ruled out theoretically by the steady carbon-cycle process by which the sun produces energy. Another theory is that fluctuations in the sun's ultraviolet radiation, related to sunspot activity, may affect our weather, but this has not been proved, either theoretically or statistically.

Then there is the theory recently described by George Gamow ("Origin of the Ice"; SCIENTIFIC AMERICAN, October, 1948). This theory attributes the earth's ice ages and long-range climate trends to wobbles in the planet's spin on its axis and to periodic shifts in its path around the sun, which would change the amount of solar radiation received by the earth's Northern and Southern Hemispheres, respectively. This theory has been answered devastatingly by the British meteorologist Sir George Simpson. He pointed out, among other flaws, that geological evidence indicates the ice ages occurred in both hemispheres simultaneously, not alternately, and that the theory fails to explain the absence of ice ages for a long period before the beginning of the Pleistocene Epoch 700,000 years ago.

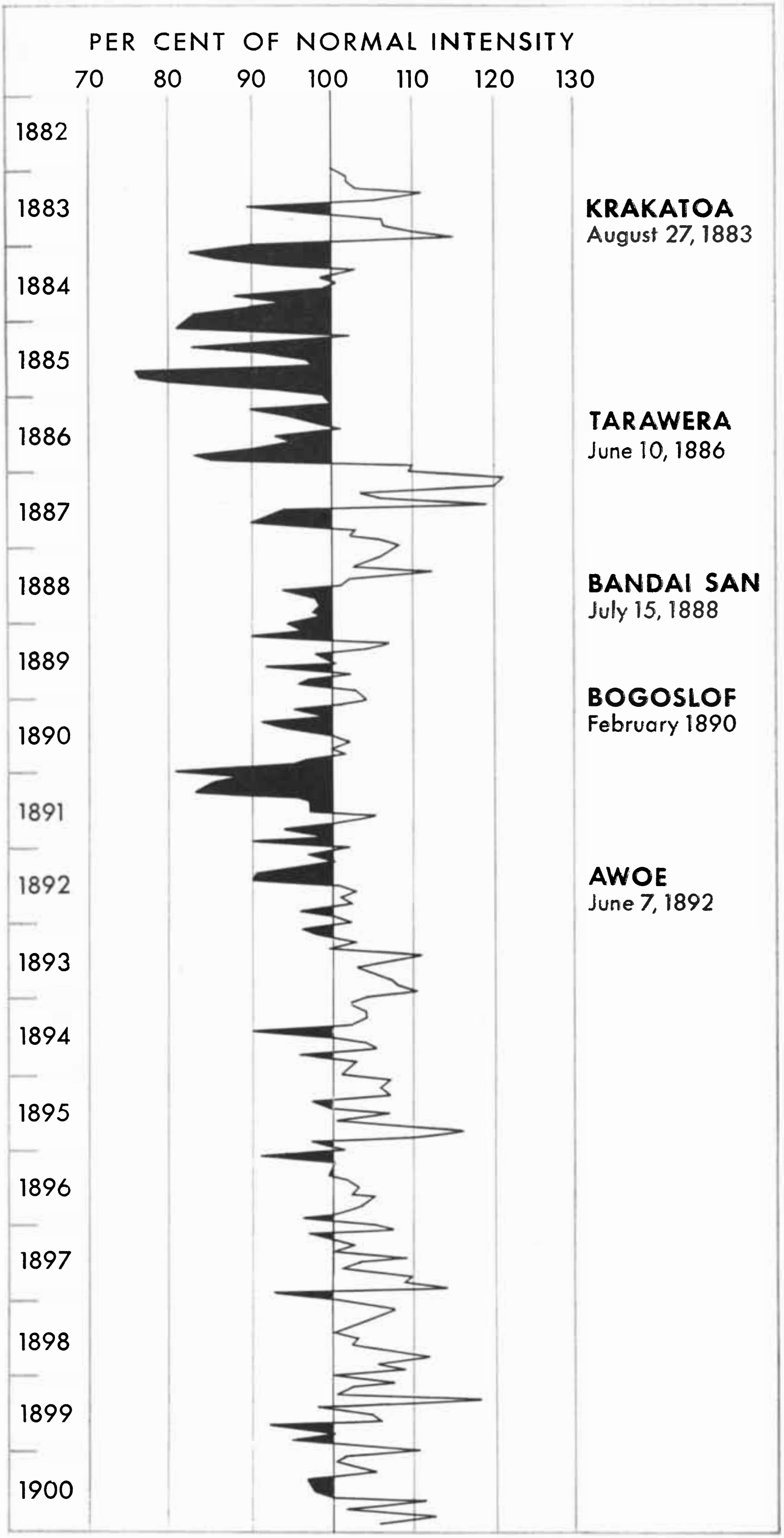
THE HYPOTHESIS I wish to discuss here is that explosions of volcanoes may play an important part in shaping long-term variations in the world's climate. It is not a new theory, but there are new reasons now for reviving and reconsidering it. The beginning of the story goes back to a spectacular event almost 69 years ago.

On August 27, 1883, the island of Krakatoa in the Dutch East Indies blew up in a huge volcanic explosion. It threw into the air some 13 cubic miles of rock, dust and ash. Great clouds of the fine volcanic ash rose 20 miles or more into the atmosphere and drifted across the seas and continents of the earth. Many people alive today remember vividly the colorful results. All over the Northern Hemisphere the dusty haze made the sun and moon look blue, purple or green, and produced gorgeously-hued sunsets and rose-colored twilights that lasted more than an hour after sunset.

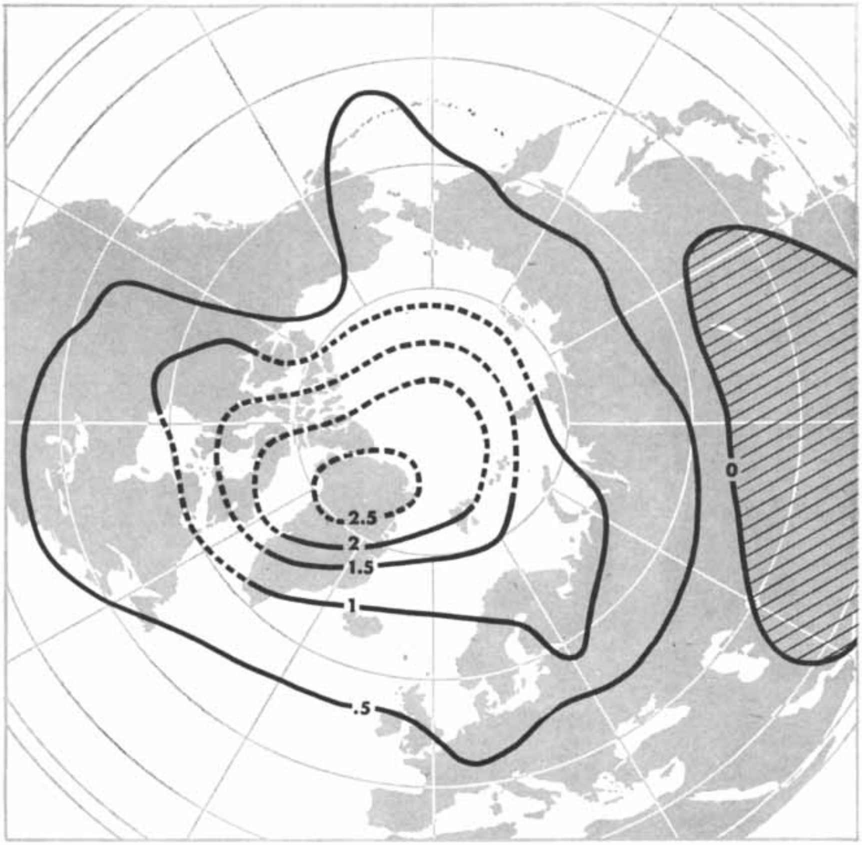
Three months after the explosion the great drifting dust pall arrived over Europe. During the whole of the last week of November, 1883, it startled and delighted Europeans with its displays of color. But at the Montpellier Observatory in the south of France astronomers noticed something even more remarkable: the sun's radiation, as recorded on their instruments, dropped suddenly from 30 per cent above normal to 20 per cent below normal.

The solar energy received at this Observatory remained 10 per cent below normal for three years after the explosion, as the Krakatoa dust pall hung in the air. In the next three decades there were several other major volcanic explosions, and observers found that these, too, cut down solar radiation at various places over the world; for example, the pall of ash from the explosion of the Katmai Volcano in the Aleutian Islands in 1912 brought about a 20 per cent reduction in the sun's radiation in Algeria, many thousands of miles away.

The remarkable sunlight-reducing effect of the Krakatoa dust pall led two Swiss scientists, the cousins P. and F. Sarasin, and later the famed U. S. meteorological physicist W. J. Humphreys, to investigate the question whether volcanic dust could influence the earth's weather. Dust in the air scatters, reflects and absorbs the sun's radiation. If volcanic ash in the upper atmosphere could intercept sunlight and appreciably reduce the amount reaching the ground, it might well cool the area below it. Investigation showed that while a dust



CHANGES IN INTENSITY of solar radiation at Montpellier, France, between 1882 and 1900 suggest that five volcanic explosions (*right*) affected the climate of the earth. The intensity was measured on clear days at noon. Krakatoa is between Sumatra and Java; Tarawera, in New Zealand; Bandai San, in Japan; Bogoslof, in the Aleutian Islands; Awoe, in the Malay Archipelago.



CHANGE IN CLIMATE of the earth is indicated by the deviation of regional mean annual temperatures for 1929-1938 from those for the period 1881-1938. The numbers on the contours in this polar projection of the earth show in degrees Centigrade how much warmer those regions have become. Only in the interior of Asia has the temperature dropped slightly.

blanket shuts out some of the sun's radiation, it does not hold in the longer heat waves radiated back from the ground. Humphreys calculated that a volcanic dust pall might reduce the ground-level temperature by several degrees. This alone would mean a noticeable change in climate. But in addition dust clouds would reduce the "sunfall" by different amounts at different places and different latitudes. And since differences in sunfall between the tropics and higher latitudes are what drive the atmospheric currents responsible for weather, volcanic dust clouds could well have far-reaching effects on the world's climate. By increasing temperature differences between regions they might accelerate air circulation currents and produce cold, stormy winters and cool, cloudy summers.

Dust particles can float in the air for an amazingly long time. Even the heavier particles take several months to settle, and the finest ash, if thrown high enough, may remain suspended in the atmosphere for many years. A long series of volcanic explosions that built up the dust pall, making the winters stormy and cold and the summers cool, might nourish glaciers and bring on an ice age. On the other hand, in a period of volcanic inactivity the earth's climate would gradually grow warmer as volcanic ash settled down and the air cleared.

SUCH IS the theory. Humphreys and his contemporaries were unable to find evidence that the volcanic dust pall actually had the predicted effects on climate. The records at weather stations around the world failed to show any consistent or significant cooling of the globe after the Krakatoa explosion or other great volcanic eruptions. This is not surprising, however, even assuming the theory to be correct, because there were too few weather stations to tell whether an over-all temperature change had occurred. Even today it would be difficult to determine the world-wide temperature mean, for with all our weather stations large areas of the earth, notably the oceans, are still not covered. It is risky to base conclusions on the temperature records over a small area. Regional temperatures, as everyone knows, vary a great deal. For example, the winter of 1948-49 was unusually cold in the Western half of the U. S. (five degrees below normal) and unusually warm in the Eastern half (five degrees above normal).

The scattered temperature readings surveyed after the Krakatoa explosion therefore prove nothing. Nevertheless, the lack of corroborating evidence dis-

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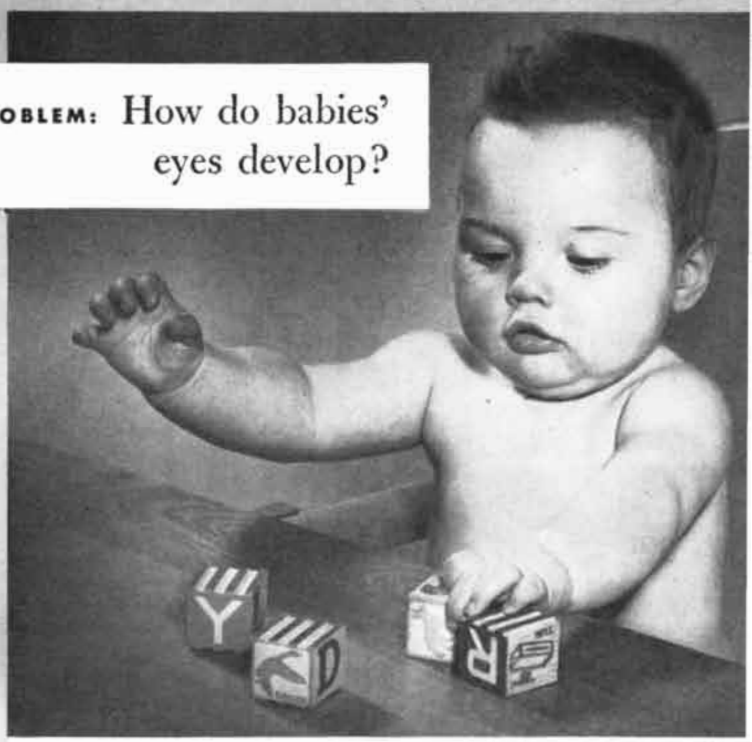
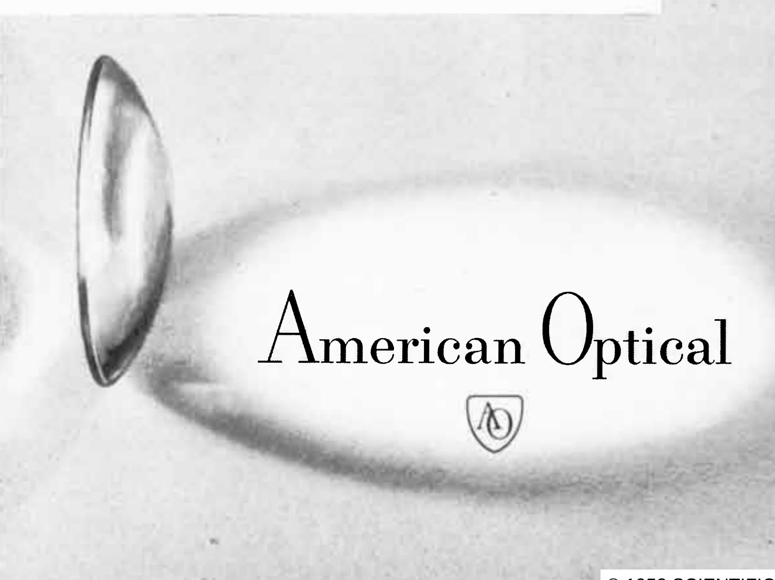
PROBLEM: How do babies' eyes develop?



ANSWER: What does a healthy baby see first? When should his eyes and hands start to work together? To investigate these and similar important questions, American Optical supported a specialized research project conducted by experts, who created an entirely new field . . . Developmental Optics.



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couraged the volcanic climate theory, and it was dropped.

Two recent developments make it seem worth reviving. One is the discovery that dust particles can act as nuclei to form ice crystals in subfreezing air saturated with water vapor. Vincent J. Schaefer has found that particles of volcanic ash are effective nucleating agents at below-freezing temperatures such as exist in the high atmosphere. It therefore seems likely that floating ash may cause clouds to form in supersaturated air. A pall of volcanic ash thus might increase cloudiness in the atmosphere, which would add to the effect of the dust itself in reducing our sunshine.

The second development is the striking fact that since 1912 no major volcanic explosion has occurred in the Northern Hemisphere and during this period the winters have been growing steadily warmer in large parts of the Hemisphere. The average winter temperature at Spitsbergen, for instance, is now 18 degrees higher than 40 years ago. None of the other theories can explain this marked warming up: there have been no continental upheavals, no astronomical vagaries of the earth's axis or orbit, no appreciable changes in the output of energy by the sun. Nor is the warming related to sunspots, for the trend has marched on through three full sunspot cycles. The one conspicuous change has been that whereas during the 150 years before 1912 volcanoes erupted in one great explosion after another in the Northern Hemisphere, since 1912 they have been comparatively quiet.

Presumably as the dust of the Krakatoa and other explosions settled and the atmosphere cleared, the Northern Hemisphere has been receiving more solar radiation during the past 40 years. This would account for the warmer weather in middle and low latitudes. In the Far North the clearing of the atmosphere would not itself make winters warmer, because during the long Arctic night there is no sunlight anyway. But the Northern winters may have been warmed by warmer air from the lower latitudes, turned northward by new circulation patterns. The increased solar heating of the earth at middle latitudes, combined with the lack of such an effect in the more northern latitudes, would speed up the westerly winds over the continents, *e.g.*, North America. When the winds exceeded a certain critical speed, they would break down into large eddies over the oceans and adjacent land areas. Such eddies would transport large amounts of heat from the middle to the north latitudes.

While the Northern Hemisphere has been free from major volcanic outbreaks, the Southern Hemisphere has had at least two in recent years—in 1921 and in 1932 in the Southern Andes. If the volcanic theory is correct, these should

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have affected the Southern Hemisphere's climate. There is some evidence that in the last 30 years or so temperatures have decreased and the ice has grown at the higher latitudes in the Southern Hemisphere. The British-Scandinavian meteorological expedition, which has just completed its observations in the Antarctic, is expected to throw new light on this important question.

THERE IS one major objection to the volcanic theory of climatic change: the geological record shows no consistent connection between periods of volcanic activity and ice ages. Geologists look for evidence on this point by analyzing cores from the bottom of the ocean which contain sections of successive strata of deposits. It has been found that the glacial deposits of an ice sheet sometimes do lie on top of deposits of volcanic ash, indicating that an ice age followed a period of great volcanic activity, as the theory predicts. But often there are ice ages without any apparent evidence of preceding volcanic activity, and, contrariwise, there are heavy deposits of volcanic ash that were not followed by ice ages.

As to the first of these discrepancies, Humphreys calculated that the amount of ash required to cut solar radiation by 20 per cent, if discharged by volcanoes each year for 100,000 years, would make a layer of dust only one fiftieth of an inch thick—hardly enough to detect in an ocean-core sample.

The fact that extensive volcanic activity sometimes failed to produce ice ages also can be explained. It would take a special kind of volcanism to yield the ash required to reduce solar radiation substantially for long periods. Only a catastrophic explosion would create such a dust pall; ordinary eruptions would not suffice. To produce major effects on climate, two important conditions would be necessary: 1) the volcano must throw high into the atmosphere a fine material that will float there for many years, and 2) the ash particles must be of the type that are efficient as nuclei for forming clouds. The clouds would help screen out the solar radiation. Volcanic activity, however intense, that does not meet these conditions might have little or no general effect on the climate.

It would be foolish to argue that volcanic explosions are the sole cause of long-range climatic variations, but this is the one theory for which we have been able to find any kind of check by direct observation. Its chief strength is the established fact that a single volcanic explosion can substantially reduce the amount of solar radiation reaching the earth for as long as three years.

Harry Wexler is Chief of the Science Services Division in the U. S. Weather Bureau.

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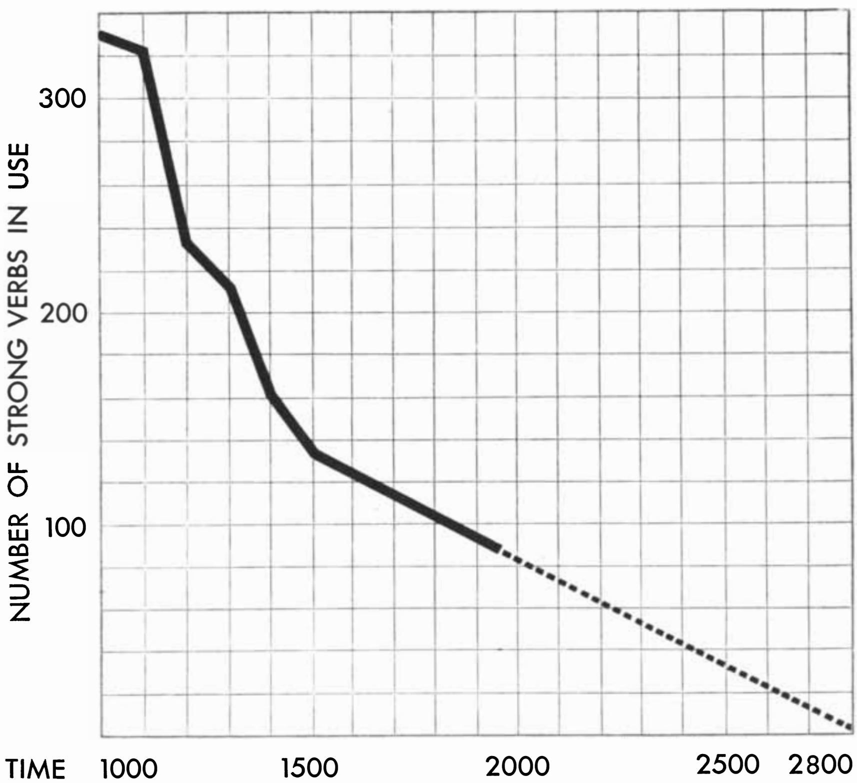
NATURAL SELECTION IN LANGUAGE

Some recent studies making use of history, grammar and the mathematical theory of communication shed light on the origin of language types and even of language itself

by Joshua Whatmough

LANGUAGE is a form of order. How did it arrive at the particular varieties of order expressed in the languages of the human race today? This is the central problem of linguistics, and the problem has been attacked in many ways. One way is to study the family histories of languages—what might be called their genetic relationships. English, German and Danish, for example, all descended from a common Germanic tongue; the various Romance languages came from Latin. We can trace the regular steps by which they have been transformed from the original parent into distinctive languages.

Another way to get light on how languages have developed is to classify them into structural types. There are four general types. One, represented by Chinese, is called isolating or positional. It consists mainly of one-syllable words, and their meaning depends on the order of their arrangement; for example, *wǒ pú p'à t'ā* means, "I do not fear him," while *t'ā pú p'à wǒ* means "he does not fear me." The second type of structure builds meaning by adding syllables to a word; it is called the agglutinating type. Turkish is such a case: *sev* is "love"; *sevmek,* "to love"; *sevmemek,* "not to love"; *sevdirmek,* "to cause to love," and so on. The third type, which includes English, Latin and many others, creates new meanings by inflections of a root word. In English we have *sing, sang, sung*. In Arabic the root word *ktb,* meaning "write," yields *kutiba,* "it has been written"; *kataba,* "he has written"; *kitāb,* "school"; *maktāb,* "writing table"; *kitābu,* "book." Finally, there are languages like Eskimo in which the unit is not a word but an entire sentence; their structure is called "polysynthetic."



EVOLUTION OF ENGLISH is one of the subjects studied by the technique described in this article. "Strong" verbs (*e.g.,* "sing, sang, sung") are disappearing. By A.D. 2800, predicts the study, "sang and sung" will have become the weak "singed" and all other strong verbs will also have gone.

It used to be believed that the monosyllabic type of language structure tended to develop into the agglutinating and inflectional forms and these into polysynthetic, which in turn dissolved into an isolating type, so that the whole process went in a circle. Whether the isolating or the polysynthetic type came first at the very beginning of human language was a matter of debate.

I shall discuss here a new approach to the study of language development which combines historical linguistics, structural analysis and the recent investigations of the mathematics of communication. This approach is based on a striking feature of structure, common to all languages of the present and past, which I call selective variation. I believe that the theory provides a satisfactory account of the origin of linguistic types and perhaps of the origin of language itself. It appears we may be able to apply the theory to reconstruct the past evolution of a language and to predict its future course with some confidence.

What is selective variation? The term

at once suggests an analogy with biological evolution. The analogy is quite superficial; language is not an organism. Yet it is a form of behavior of the human organism, and it represents a form of adaptation of certain human organs to specific ends. Languages yield under the pressure of external forces; they either die out or are adapted to the new environment.

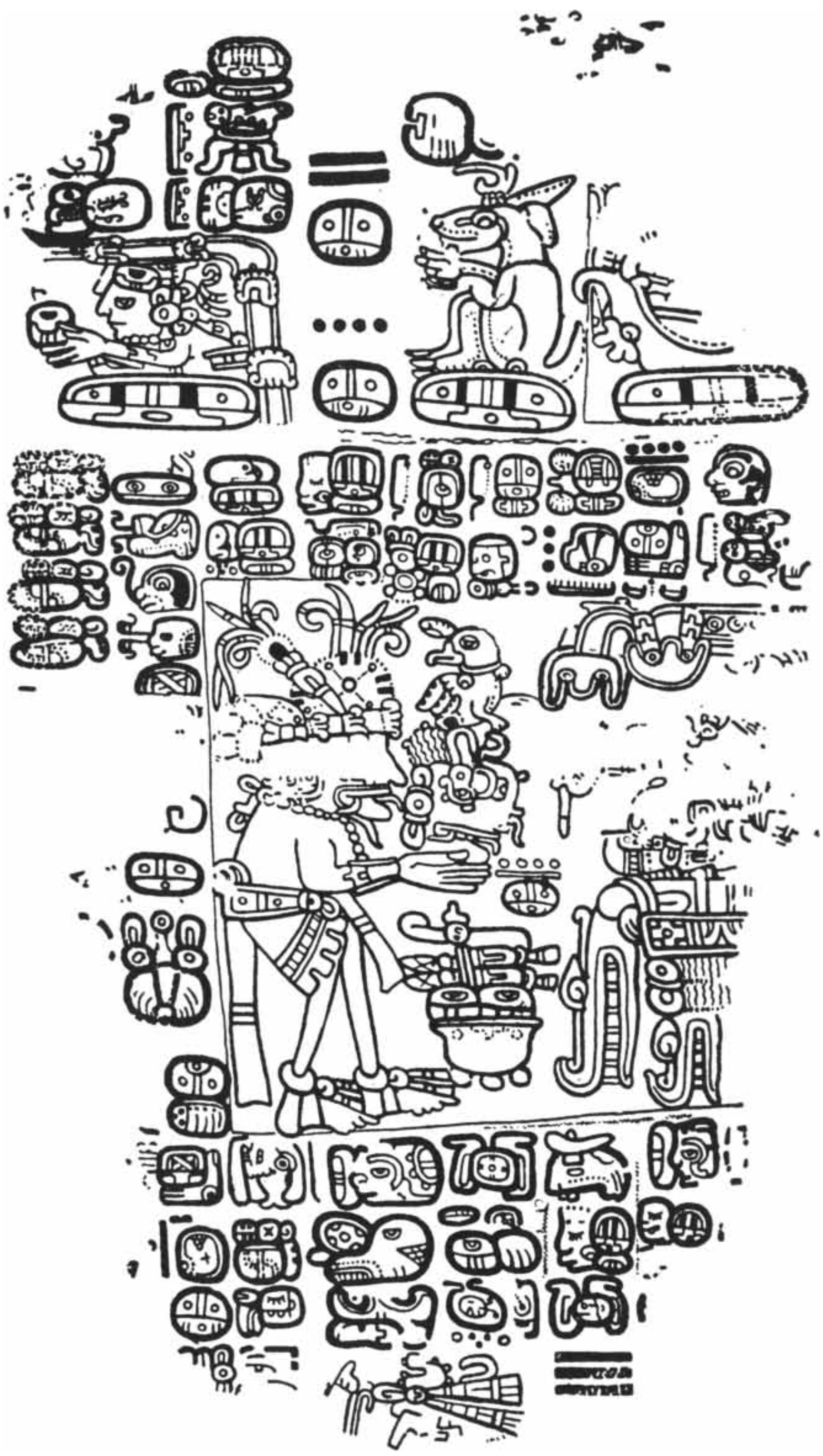
Obviously variation and selection enter into the building of language. If there were no variation, everybody would forever talk alike—but after the manner of poultry, not of human beings. The human race might have been limited to a single sound, like the cry of an infant or the bleating of a sheep. On the other hand, without selection we could have no order, and hence no language. If we could freely utter a different sound every time we opened our mouths, that would be the gibberish of a congenital idiot. In speech-sounds, syntax, vocabulary and structure, it is selection that makes it possible to communicate, and the changes rung on it that give a language its character.

Language is forever undergoing change, sometimes rapid, sometimes slower, but unceasing. Compare modern English with Shakespeare or Chaucer. But the changes are regular. When one speech-sound is substituted for another, it is applied systematically throughout the language without exceptions, provided the change is original in the language and not borrowed from another tongue. For example, in Latin between 450 and 350 B.C. the consonant *s* was changed to *r* wherever it came between two vowels. Thus *genesos*, the possessive of *genus*, became *generis; meliosem* became *meliorem*, and so on. The departures from this rule are only apparent exceptions; for instance *causa*, a word that developed later in Cicero's time, was derived from *caussa*, and *rosa* is not Latin at all but was borrowed from Southern Italy.

Changes in inflection, in syntax, in meaning—these, too, are commonly regular and systematic. Once a change disturbs the established pattern of a language, selection sets to work and eventually creates a new pattern.

IN STUDYING the trend of these changes we are helped greatly by modern information theory and the mathematical theory of communication. The new tools of analysis derive from the statistical investigations of the late George Zipf of Harvard University and from the mathematical methods developed by telephone engineers and mathematicians, notably Claude Shannon of the Bell Telephone Laboratories. The application of the calculus of probability to communication by Shannon and Norbert Wiener of the Massachusetts Institute of Technology set the coping stone on this part of the theory of selective variation.

Their work confirms a conclusion suggested by the historical and structural analyses: namely, that language strives toward equilibrium. The telephone engineer has not only found evidence of statistical regularity in language, but has provided us with an elegant and rigorous mathematical proof that the probabilities of choice in the selection of successive speech elements in modern English and other languages depend on the information conveyed. The formula that measures information is $H = -\Sigma p_i \log p_i$. This formula again indicates a striving toward equilibrium, a tendency of the system "to become more and more perfectly shuffled." For, as Shannon points out, H is "the H in Boltzmann's famous H-theorem."



MAYA HIEROGLYPHICS, like all other forms of language, may be considered a code. In the case of these symbols, however, the point is underlined by the fact that they have not thus far been successfully translated.

This principle can be observed at work in the history of languages. For instance, the parent Indo-European language from which Greek, Latin, Sanskrit and the rest developed had the vowels e, ē; o, ō; a, ā. But we know that in an earlier form this parent language had only the single vowel e, combined with just one laryngeal consonant. That is to say, there was considerably less perfect shuffling in the primitive early stage of the language. Its vowel system was as simple as that of modern Aranta or Hawaiian. Not that the latter are "primitive"; rather, they are barbarous reversions to type.

IF WE look at language from this point of view, we can predict its trends and deduce forms it must have had in the unknown past. Actually the 19th-century Swiss scholar Ferdinand de Saussure, by means of a historical analysis, inferred the existence of the Indo-European laryngeals at a time when they were still unknown. Thirty-five years later archaeologists who uncovered Hittite records of 1500 B.C. in Asia Minor found these consonants in the language, as de Saussure had foretold. In 1877 Karl Brugmann, studying the structure of Greek, deduced that the first person singular of the optative mood, signified by the ending *-mi,* must once have had the ending *-a.* In 1913 this form was actually discovered in an Arcadian inscription. Similarly in Latin historical patterns of different dates had suggested that the word *iumentum* ("beast of burden") must have had a g before the *m: i.e., ioug(s)mentom.* As predicted, an inscription was later unearthed with the spelling *iouxmenta.* This showed that the word is connected with *iugum* ("yoke") and not, as Theodor Mommsen insisted, with *iuuare* ("help")—as if a mule were eager to help you!

Now that we have the sharp tool of probability of choice to help us, there is reason to suppose that with some exercise of imagination we can envisage the emergence of languages from a prelinguistic use of vocal noises. The principle of selective variation would certainly apply there. At least this much may be said now: selective variation makes unnecessary any guesses about whether primitive language was monosyllabic or polysynthetic in structure. One caution is necessary here, however: statistical laws break down when only a small number of cases is involved, as is the situation in our knowledge of early language.

Prediction of the direction a language is going also is possible wherever the evidence covers a long enough span of time. A number of authorities have suggested that strong forms of verbs are

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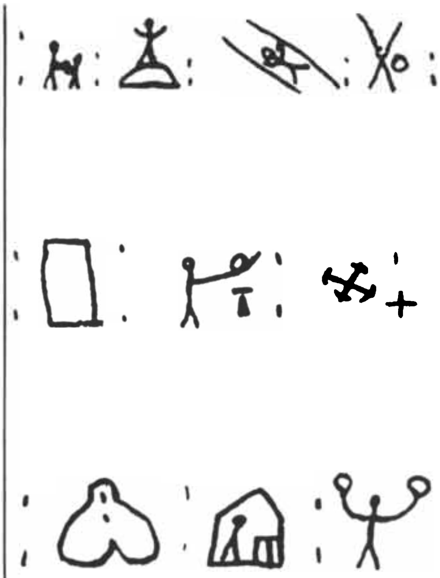
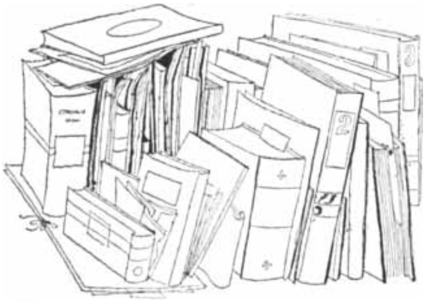


MODERN HIEROGLYPHICS are used by Eskimos of Western Alaska. Their language is polysynthetic.

disappearing from English and will be replaced by the weak type; for example, that *sing, sang, sung* will give way to *sing, singed,* as we already have *love, loved*. One of my students, Robert Abernathy, calculates that the strong forms will have completely disappeared by about 2850. Another student, Leonard Opdycke, Jr., has found increasingly numerous occurrences of a new type of compound in English since about 1900; an extreme example is *better-than-leather-miracle-covering,* which appeared recently in a popular magazine. Fifty years is too short a time to give assurance of a trend; linguists are in the same situation as astronomers, who often must have observations covering several centuries before they can decide whether a theory is on the right track. But compound words do seem to be gaining in popularity, notably in the attempt to make articulate some concepts in physical theory, such as space-time, for example. A good illustration of the substitution of words for the symbolism of mathematical logic is the technical terms of Sanskrit Navya-Nyāya logic, which uses extremely long compound words.

NOW THAT language has finally been reduced to mathematical formulation, we shall understand it better. Perhaps we shall learn even to guide it better, and especially be able better to verify the validity of inferences made in ordinary (as distinguished from mathematical) discourse.

Joshua Whatmough is professor of comparative philology at Harvard University.



BOOKS

The beginnings of life in the context of the second law of thermodynamics

by Sir George Thomson

TIME'S ARROW AND EVOLUTION, by H. F. Blum. Princeton University Press ($4.00).

THE arrow of time is a phrase invented by the late Sir Arthur Eddington, astronomer and exponent of relativity, to indicate the fact that the future and the past are not interchangeable. The nonscientist may reasonably ask why anyone should expect that they should be. The physicist would reply, or at least would have replied before the discovery of the quantum theory, that the world is made of particles, and that, according to his best understanding of the laws which govern the ultimate particles, if the velocities of all the particles in a closed system were reversed, the system would relive its history like a film run backwards. Water would run uphill; the kettle boiling on the fire would grow cold, and the tongues of fire would run back and reform themselves into lumps of coal! To which the obvious answer, by way of explaining the facts of nature, is: Who is to reverse the velocities? This gives no real escape. We can imagine two systems: one a real one and the other exactly like it but with every velocity reversed. There is apparently nothing in the laws of physics to exclude the latter possibility.

Actually, of course, the irreversibility of certain processes, particularly the fact that heat can flow to a cold body from a hot one but not in the reverse direction unless accompanied by some compensating effect, has proved of immense value as an essential part of the science of thermodynamics. The theory of irreversibility certainly works within very wide limits. But how wide are they, and how is irreversibility to be reconciled with the fundamental laws of physics? Quantum theory, which so profoundly modifies our idea of a particle, may offer a way out, but at first sight it is not at all obvious how it does. For the moment I will continue to speak in the old language of Newtonian physics.

The ideas of thermodynamics can be expressed by saying that the entropy of a system always tends to increase—this is for an isolated system. If you consider a system always kept at the same temperature by a bath with which it can exchange heat at will, you have to allow another property: the so-called free, or available, energy. Apart from the fact that it is taken with the opposite sign so that it tends to decrease, the difference between free energy and entropy is for many purposes not very important. In *Time's Arrow and Evolution* Dr. Blum writes more often in terms of free energy, because he is concerned with the earliest forms of life, which may be supposed to have been in a roughly constant temperature environment. But to the physicist entropy is more fundamental.

A great advance was made in the third quarter of the 19th century by Ludwig Boltzmann, who showed that the entropy of a system is closely connected with the probability that the particles composing it will be arranged so as to give the effect observed. Thus take the case of air in a closed vessel. If the air molecules are distributed at random, it will obviously be extremely unlikely that all will be in the right-hand half of the vessel. But of course you can force all the air into that half if you have a suitable piston in the vessel and drive the air before it. Entropy has diminished, but this is not contrary to thermodynamics, because you have had to do work to reduce it. The gas passes on this work as heat to the containing vessel and so to the surroundings, causing them to expand. Thus the entropy of the surroundings increases, and it turns out that on the whole the entropy of the gas together with its surroundings has increased.

Now suppose there is a small hole in the piston. The gas will leak through until there are equal amounts in the two halves of the vessel. It has increased its entropy. In this case no work was done, and the surroundings remain unchanged. If many molecules of air are involved, the probability of an increase in entropy is overwhelming. But strictly speaking, it is only a probability. Lord Kelvin explained that there is a finite chance that a kettle of water placed on a fire will freeze and make the fire hotter—but it is a very, very small one!

We seem to have reached the rather tautological statement that it is probable that the probability of a system will increase. The statement is not as tautological as it sounds, for fairly definite rules can be given to calculate the "probability of the system," and the law is really a statement that these do their job. For an example, let us return to the gas in the vessel. The law says that if there is a hole connecting two halves equal in volume, any chosen molecule in the long run is as likely to lie in one half as in the other. This seems nearly self-evident, but some of the other rules are much less obvious, and indeed different rules are needed for different kinds of particles.

If all the states of the system that are compatible with its energy and constraints (such as the size of the vessel holding the gas) occur in the long run equally often or nearly so, then it is vastly probable that the system will be found in one of the common states and vastly unlikely that it will get into a very rare state, even though a mere reversal of the actual velocities of its particles would lead it there. This is called the ergodic theorem. Many have tried to prove the theorem, both in Newtonian and quantum mechanics, but with rather doubtful success. One difficulty is the artificiality of the idea of a completely isolated system. The only system that can be really free from outside interference is one comprising the entire universe. There one becomes entangled in questions of the curvature of space and the exact form of the relativistic universe in which one believes. At the other end of the scale of sizes, entropy does not apply to a system of only a few particles, such as the fragments of an atomic nucleus broken up by cosmic rays. In spite of its apparent generality, entropy may be one of those ideas, so numerous in physics, which work perfectly within a certain range but break down if pressed too far.

The writer would like to suggest that the true meaning of entropy is closely related to the act of observation. Perhaps what is changing is not so much a property of the system as our knowledge of it. After we have made an observation of the system, our knowledge is a maximum; from then on it steadily decreases, or at the very best, as a never-quite-realized ideal, remains the same. Thus, to return to the gas in the box, when it is all in one half of the vessel we have a better knowledge of the possible whereabouts of a given molecule than when the gas has distributed itself throughout the entire box. This fits in well with certain quantum ideas. A "wave packet" representing an electron has uncertainty both in position and velocity, and these are correlated, as Werner Heisenberg showed. If the wave packet is left alone in free space, the uncertainty in position increases, while the uncertainty of velocity remains the same. Our over-all knowledge has decreased.

But I must not allow the fascination of these speculations to draw me away from describing the use of thermodynamics made by Dr. Blum in his careful and well-written discussion of the origin of life and the possible early course of evolution. Dr. Blum begins by describing at some length, and with a little easy mathematics, certain preliminaries. These include the fundamental ideas of thermodynamics and their application to chemical reactions, the constitution and probable early history of the earth before it became the home of life, its fitness for such a purpose, a discussion of photosynthesis (the process by which plants use the energy of the sun to build up their substance) and an account, which I found especially interesting, of the details of the fermentation of glucose as an example of the processes of metabolism. All are well described, and conflicting arguments are weighed with appreciation.

On the whole, one is struck by how little is known with certainty of the early history, or even the constitution, of our earth. Thanks to radioactivity, we know with some accuracy the age of many rocks. But as to such questions as why the earth has the apparently odd constitution that it has, or whether the atmosphere was once very different in composition from what it is now, one can only give a balance of inconclusive arguments. The questions, indeed, are fascinating. Is our earth peculiarly well suited to life in general, or is it life that has fitted itself to the earth? Could life as we know it, or something like it, have developed equally successfully in quite a different environment? One must, of course, beware of arguing that it is unlikely that the earth should be uniquely fitted for life. However rare the conditions of life may be, a living observer must of necessity be situated where they are found. Life certainly involves immense complexities of chemistry and changes of chemical composition which can occur only within a limited range of energy. It seems rather unlikely that anything resembling the life we know could happen in a very different temperature range, or in the absence of reasonable amounts of the main elements found in living matter. Perhaps, however, ammonia, which seems to be very common in the atmosphere of some planets, could be made to play a part analogous to that of water on the earth.

Dr. Blum stresses the importance of phosphorus in the transfer of energy during chemical change in living matter. Is this the best way in which the transfer could be made, or is it only that life started like that and cannot change? It seems just one example of what one may call the chemical conservatism of life. Proteins are molecules built up of very long chains as backbone, to which are linked amino-acid groups as ribs. Although only about 20-odd amino acids are known to occur in living proteins, the number of apparently similar compounds possible is enormous. Further, nature is parsimonious in its choice of arrangements of the amino acids on the protein molecule; it uses, according to Dr. Blum, only a very small proportion of the vast number of permutations possible.

It may be, of course, that these amino acids are the very best suited to life and that no others would be quite so good, but it seems odd that the same set should be the best for all kinds of living matter. Dr. Blum inclines to the view, though without dogmatism, that they have worked themselves into a privileged position which they retain by influence rather than by intrinsic merit. One can easily understand in a general way how this might be so. Imagine an animal born now with a mutation which required it to use a deviant amino acid. The animal would not find this molecule in any organic matter that it ate, and it would have to invent some way of synthesizing the substance for itself. That disadvantage might well outweigh any gain that might accrue from the new amino acid, assuming it were superior, and the mutation would therefore have a lower survival value. Then, too, the mysterious method by which like produces like, the very central principle of life, may act through a mechanism which makes it harder to change the type of brick than the architecture of the building. Nature is like a good engineer, who prefers to use standardized nuts and bolts for his minor fittings and only designs one especially for the job if it is quite impossible to get anything that will serve from the store.

Many people have asked whether life is not an exception to the law of entropy. Dr. Blum is at some pains to show that this is unlikely. The apparent exceptions to increasing entropy in biology—such as the building up of highly organized, and therefore improbable, systems from simpler components—are always accompanied by compensating degradations, just as in our example of the piston the decrease of entropy in the gas was accompanied by compensating changes in the containing vessel and its surroundings. Nearly all physicists would agree with Dr. Blum in this view. Personally, I feel that attempts to apply the laws of thermodynamics to systems of this kind are of doubtful value. In most cases living matter is subject to sunlight, and the usual laws that relate to steady or quasi-steady states do not apply; the flow of energy (from the sun) is all one way. The radiation is more than a catalyst; it determines the whole life process.

Even if the sun's radiation were absent, there are always the cosmic rays, which strike the earth with vastly larger concentrations of energy than solar radiation. Now X-rays have been shown to produce mutations in insects. The ionization produced in the atmosphere by cosmic rays is only about a hundred-fold smaller than what would be produced by an amount of radiation thought to be sufficient to cause appreciable genetic effects on man. During geological time it may have been responsible for much in the way of hurrying evolution and in determining the kind of change that may occur. Cosmic rays might cause simultaneous changes in more than one part of a gene molecule—a result which mere thermal action is extremely unlikely to produce. Not only the frequency but the kind of change would be different.

One of the most interesting problems that Dr. Blum discusses is how living matter managed to invent the very complicated chains of synthesis which are known to operate in some cases. A substance is transformed into one the organism needs through a number of stages. During the transformation it forms various intermediate products which seem quite useless to the organism except as the raw material for the next stage. Following an idea of the U. S. biochemist N. H. Horowitz, Dr. Blum suggests that this state of affairs was a gradual development, and that the last stage came first in the evolutionary process. The organism wanted A and found it could make it from B; then the supply of B gave out, but the organism developed a way of making B from C, and so on through the alphabet as the several raw materials became unavailable.

To few of the problems posed in this study is it possible to give certain answers. Just enough is known about the conditions that must have governed the beginning of life and the earlier stages of evolution to rule out some views as at least unlikely. For some of the processes of life it is possible to suggest very tentative mechanisms. Dr. Blum knows how to present ideas without dogmatism and how to lead his reader on to think and wonder. There are a few ideas I miss. One might like to speculate, for example, on the possibility that the adsorption of molecules of carbon compounds on the surface of clays may have helped to give them a pattern leading to growth and life, just as one crystal can grow on another following the pattern of the surface on which the growth occurs. But there is plenty of meat in Dr. Blum's book for the thinker interested in this most fascinating subject: the history of our progenitors at that most early stage when they were barely alive.

Sir George Thomson, who shared the Nobel prize in physics for 1937, is professor of physics in the Imperial College of Science and Technology.

THE APE IN OUR HOUSE, by Cathy Hayes. Harper & Brothers ($3.50). The author and her husband, a psychologist, adopted a two-day-old girl chimpanzee, named her Viki and for three years have raised her exactly as they would a child of their own. Viki wears clothes; eats at the table; has her own room; goes to the movies (and pays special attention to animated cartoons); accompanies her "parents" on social visits and long automobile trips; plays happily with other children; does small chores around the house; amuses herself with building-blocks, puzzles, toys and dolls; has a favorite stuffed dog; understands a good many commands; is highly imitative; enormously enjoys kissing and being kissed; grins, moans, weeps, frets and sulks according to circumstance; is mischievous, fabulously destructive, affectionate, obedient and forgetful. Viki also gets colds and indigestion (but not other childhood diseases); likes to bite people (but has given up biting Mrs. Hayes since Mrs. Hayes, having lost her temper, once bit *her*); has a high regard for chocolate, marshmallows, pork and beans, frankfurters and cookies (but has been known to drink with evident relish, and without obvious damage, an entire bottle of laundry starch). The chimp romps with Dr. Hayes when he comes home; emits Bronx cheers when things do not please her (or please her greatly); is toilet-trained (on alternate days); and has a vocabulary consisting, so far as can be definitely ascertained, of three words: "Mama," "Papa," and "Cup." Mrs. Hayes writes of all these matters lovingly and entertainingly.

THE GREEKS AND THE IRRATIONAL, by E. R. Dodds. University of California Press ($5.00). The Regius Professor of Greek at Oxford discusses in these lectures the role of irrationalism and primitive modes of thought in ancient Greek society. The emphasis of the inquiry is on "certain relevant aspects of Greek religious experience." By the third century B.C. the Greeks had traveled further toward the goal of an "open society"—defined as a society whose "modes of behavior" are determined by rational choice and whose adaptations are "conscious and deliberate"—than any people before them; indeed, they had reached a summit perhaps not regained by Western society until the 19th century. While it cannot be asserted that rational beliefs were prevalent among the majority of Greeks, there is ample evidence, according to Professor Dodds, that "centuries of rationalism" had weakened the social influence of "neurotic guilt-feeling," "irrational anxieties," the "fear of freedom" and assorted "religious neuroses." Yet at this high point of Hellenic civilization these disorders began to reappear, for reasons not fully understood, "in new forms and with a new intensity." Thus was launched a retreat from reason which continued for centuries, and for which the symptoms of our own times provide an alarming parallel. An erudite, readable and uncommonly interesting book.

LAZARUS ERCKER'S TREATISE ON ORES AND ASSAYING, translated by Anneliese Grünhaldt Sisco and Cyril Stanley Smith. The University of Chicago Press ($10.00). Mrs. Sisco and Dr. Smith present a modern translation of one of the three great metallurgical treatises of the 16th century, the other two being Biringuccio's *Pirotechnia* and Agricola's *De Re Metallica*. Ercker, who was Superintendent of Mines for the Holy Roman Emperor Rudolf II, furnishes remarkably clear descriptions of the assaying of gold, silver and copper ores; the smelting, refining, "stewing," "liquation" and reduction of various metals; the making, use and care of the assayer's balance, weights, furnaces and other items of equipment. The assayer, says Dr. Smith in his introduction to the *Treatise*, was the practical man; the alchemist, for all his mysticism, was the intellectual. Each made an indispensable contribution to the growth of chemistry: the alchemist as a votary of knowledge and human understanding beyond mere utilitarian ends, the assayer "for providing numerical data and establishing the tradition of accurate measurement without which modern science could not have arisen." This elegant volume, beautifully illustrated by old German woodcuts, will delight the booklover, whatever his interests, no less than historians of science, chemists and metallurgists.

THE STUDY OF INSTINCT, by N. Tinbergen. Oxford University Press ($7.00). The primary problem to which this book is addressed is that of the causes of instincts. The author utilizes experimental and observational material drawn, in the main, from the work of European students of birds, fishes, insects and other animals in developing a cogent and fascinating account of unlearned behavior. He shows clearly that instinctive behavior usually results from the interaction of internal stimuli, hormones, the central nervous system and external stimuli. Usually the internal factors are not enough to produce instinctive behavior, but serve to lower thresholds so that appropriate external stimuli can "release" instinctive patterns

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of action. There is a good deal of evidence that instinctive behavior is organized hierarchically: first, generalized seeking or searching behavior is released; this is followed by the release of more specific "purposive" activity; followed in turn, when appropriate external stimuli are encountered, by specific and stereotyped consummatory acts. A well-reasoned and thoroughly readable book which points up the complexity of even the simplest unlearned behavior.

THE BATTLE FOR MENTAL HEALTH, by James Clark Moloney. Philosophical Library ($3.50). Statistics on crime and mental illness are quoted to indicate that people in the U. S. enjoy poor mental health, and these facts are contrasted with the situation among certain primitive peoples. The chief difference between mentally healthy primitives and Americans, according to Dr. Moloney, lies in their child-rearing practices. The author is a leading exponent of permissive methods of infant and child care, such as rooming-in plans in maternity wards, prolonged breast feeding, delayed toilet training and "mothering" in general. He feels that such methods, associated with mental health in primitive peoples, will improve the mental health of this country.

DRINK: AN ECONOMIC AND SOCIAL STUDY, by Hermann Levy. Routledge and Kegan Paul, Ltd. ($4.50). Although the extent and the degree of "the drinking habit" in Great Britain have declined appreciably in the past several decades, the late Professor Levy believed it to be still an important social and economic problem. His book presents a sober and thorough summary of the social and economic implications of the habit, of the policies and attitudes of the brewing and distilling industries, of the merits and deficiencies of means to ameliorate the extent of drinking, such as educational programs, temperance activities and legislative controls.

CHARLES DARWIN: THE NATURALIST AS A CULTURAL FORCE, by Paul B. Sears. Charles Scribner's Sons ($2.00). This is one of the best of the brief biographies in Scribner's Twentieth Century Library. Dr. Sears gives a concise account of Darwin's major scientific work and then with sensitivity and disinterestedness traces the social and political consequences of evolutionary theory and its place in contemporary thought.

THE COURTIS-WATTERS ILLUSTRATED GOLDEN DICTIONARY FOR YOUNG READERS, by Stuart A. Courtis and Garnette Watters. Simon and Schuster ($3.95). This is an intelligent and attractive dictionary designed for third- and fourth-grade youngsters but also useful for more advanced age groups. Over 7,500 words plus their variants are listed; there are 2,100 colored illustrations; the type for entry words and definitions has been well selected; the definitions, including examples, are unusually skillful. On the debit side: somewhat pulpy and unattractive paper and a rather high price. Nevertheless a book which may be strongly recommended.

PSYCHOANALYSIS AND CULTURE, edited by George B. Wilbur and Warner Muensterberger. International Universities Press, Inc. ($10.00). Twenty-seven essays by various specialists on sociological, anthropological, and psychoanalytic subjects, offered as tribute, on his 60th birthday, to Dr. Géza Róheim, a leading student of psychoanalysis whose research, field work, and writings have dealt mainly with primitive behavior and culture patterns and with the contribution of psychoanalytic theory and method to their understanding.

LIVING WITHOUT HATE: SCIENTIFIC APPROACHES TO HUMAN RELATIONS, by Alfred J. Marrow. Harper & Brothers ($3.50). The author, a professionally trained psychologist and president of a textile firm, believes that the only effective way to combat prejudice is to use methods whose effectiveness has been demonstrated empirically. To illustrate the value of research on the ways of combatting prejudice, he has summarized in this book a number of studies dealing with methods of overcoming prejudices of all sorts. The result is an interesting, stimulating and valuable book, which shows clearly the guiding influence of the late Kurt Lewin of the Massachusetts Institute of Technology.

REMINGTON'S PRACTICE OF PHARMACY, edited by E. Fullerton Cook and Eric W. Martin. The Mack Publishing Company ($16.00). In this, the 10th edition of a standard text, emphasis has been placed on the newer physical concepts of electronic structure and the physiological aspects of biochemistry and pharmacology. The work has been substantially revised to include the latest information on the antibiotics, vitamins, lipids, autonomic drugs, hormones, amino acids, enzymes, surgical dressings and sutures, pesticides, venereal-disease control, antidotes.

AN INTRODUCTION TO THE THEORY OF STATISTICS, by G. Udny Yule and M. G. Kendall. Hafner Publishing Company ($7.50). The 14th edition of the best-known elementary text on statistical method, "suited to those who possess only a limited knowledge of mathematics." Kendall states in his introduction that the extensive bibliography included in earlier editions now appears in his *Advanced Statistics* and has therefore been omitted—a serious error of judgment diminishing the usefulness of the present work to the student.

THE AMATEUR SCIENTIST

Conducted by Albert G. Ingalls

BEGINNING with the present issue this department of SCIENTIFIC AMERICAN is extending its coverage to include the work of amateurs in all departments of science. Information on telescope making and amateur astronomy will continue to appear here regularly, as it has for nearly 27 years. But in addition the department will report the work and adventures of investigators in the many other branches of science in which amateurs are active. We invite all those who find relaxation in the study of nature, directly or vicariously, to share these pages.

No one knows just how many U. S. citizens spend all or part of their leisure in scientific study and experiment. One thing is sure: the awesome setup of modern science, with its million-dollar cyclotrons and billion-dollar research centers, has by no means frightened amateurs off the scene. Not long ago the American Philosophical Society made a study, financed by the Carnegie Corporation, of adult education in science in Philadelphia, the onetime home of one of the nation's great amateur scientists—Benjamin Franklin. W. Stephen Thomas, who conducted the survey, had no trouble in compiling a list of more than 8,000 laymen in that city who were actively interested in science. Of these no fewer than 700 had made contributions to knowledge important enough to merit professional attention. These citizens of multifarious workaday occupations—dancers, lawyers, housewives, loom fixers, plasterers, bankers, X-ray repairmen, advertising men—were probing a range of scientific subjects that extended from the atom's nucleus to the visible boundaries of the universe.

The study also turned up the interesting fact that in Philadelphia there were 200 science clubs with national affiliations. Judging from the membership enrollments in some representative national societies, it seems safe to say that the number of scientific-minded laymen in the U. S. runs into the hundreds of thousands.

The collective contributions of amateur workers to science and technology are not trivial. The story of the achievements by amateur telescope makers in making roof prisms and other precision optical parts for the Navy during World War II is well known. For years the U. S. Weather Bureau has depended on the observations of some 3,000 well-organized amateur meteorologists. Still other groups cooperate with professional scientists in observing bird migrations and populations, radio disturbances in the ionosphere, the behavior of variable stars, earth tremors, soil erosion and so on. It was an amateur who discovered the planet Pluto, and an amateur who played a leading part in the development of vitamin B_1.

The amateur is generally a fellow of boundless curiosity who enjoys digging for facts—and sharing them with everyone he knows. It is not the hope of epic discoveries that keeps him at his avocation. If he should chance to learn something important to mankind, that would indeed be a thrill, but he finds reward enough in the fun of the free quest.

TO FIND a happy amateur, as good a place as any to start is in the basement of a cottage at Elma, N. Y. There, in a tiny corner cubicle that looks like a photographer's darkroom, is one of the most interesting seismological stations in the U. S. It is owned and operated by Harry H. Larkin, Jr., who during business hours is vice president of Larkin Warehouse, Inc., in nearby Buffalo. An amateur meteorologist and seismologist, Mr. Larkin is a cooperative observer for two branches of the U. S. Government. He makes regular weather reports to the U. S. Weather Bureau, and whenever his instruments record an earthquake, he dispatches his readings by teletype to the U. S. Coast and Geodetic Survey. Mr. Larkin's special interest in seismology is the study of microseisms, the constant tiny tremors of the earth that seem to link the planet's structure with its weather but are still an unsolved puzzle ("Microseisms," by L. Don Leet; SCIENTIFIC AMERICAN, February, 1949).

The earth sciences have fascinated Mr. Larkin for as long as he can remember. As a boy he used to visit every weather station within range of the family car with his father. Later, after taking up flying, he began his career as a meteorologist by installing a barograph in the Larkin den. Today his back yard bristles with rain gauges, thermometer shelters, towers supporting anemometers, wind vanes, sunshine recorders, time-lapse sky cameras—a full complement of professional instruments.

Two years ago Mr. Larkin's growing reputation as a cooperative weather observer prompted a professional seismologist to invite him to help in the investigation of microseisms. Mr. Larkin added two sheets of recording paper to the daily dozen already coming off his instruments and embarked hesitantly on what has since become an absorbing and often thrilling experience. As he puts it, "I entered seismology through the back door and can perhaps be described best as an amateur meteorologist with seismology as a hobby, or *vice versa*."

Practically everything a seismologist knows comes from the interpretation of wavy lines traced on a sheet of paper, and to understand seismology one must first understand the instrument that makes this record. The heart of the seismometer is a pendulum, which serves as the sensing element. Its movement records the strength and character of each tremor of the earth. The standard Weichert seismometer of the professionals is a complicated affair with a 175-pound pendulum and a stone foundation extending down to bedrock. But the instrument in Mr. Larkin's basement is astonishingly simple (*see drawing at the bottom of the opposite page*). On a slab of concrete embedded two feet deep in clay beneath the basement floor stand two slender, upright cylinders: one to measure earth movements in the east-west direction, the other, north-south. Inside each cylinder is a taut vertical wire with a small copper vane attached to it. The vane is the "pendulum," though it extends out horizontally from the wire, instead of hanging. When the earth trembles, the vane swings slightly. A beam of light, reflected from a mirror on the vane, makes a tracing of this movement on a roll of photographic paper wrapped around a slowly rotating drum. In essence, that's all there is to it.

This instrument is known as a torsional seismometer. It is comparatively inexpensive and can be bought in kit form and assembled in a few hours by any amateur. The apparatus was made available commercially about two years ago by the late William F. Sprengnether, Jr., president of the Sprengnether Instrument Company of St. Louis. Says Mr. Larkin: "Mr. Sprengnether, an advanced amateur astronomer and telescope maker, wished to encourage amateur interest in seismology and in placing this equipment on the market ignored the conventional profit motive."

Mr. Larkin describes the instrument as follows:

"The sensing element consists of a copper vane about a quarter-inch wide and an inch and a half high, attached along one edge to a hairlike wire held taut by a vertical framework. When earthquake waves or other tremors move the assembly back and forth, the vane rotates in precise response. The swinging of the vane twists the wire slightly, which accounts for the name 'torsional' seismometer.

"A small mirror with a focal length of one meter is cemented to the vane. A light beam reflected from it, acting as an optical lever, amplifies the vane's movements and registers them on photographic paper carried by the recorder.

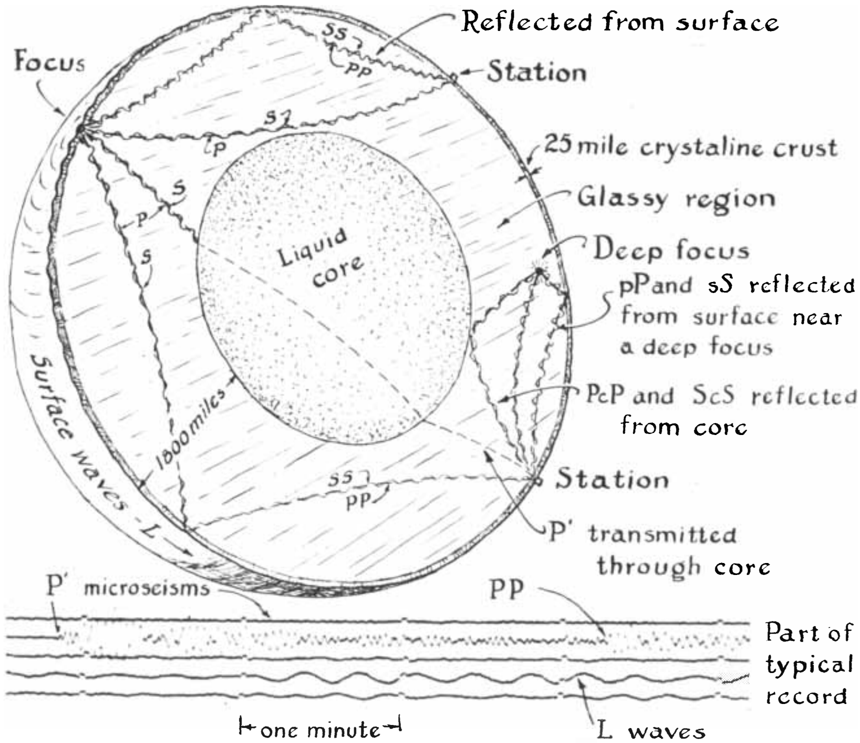
"The recorder is simply a metal box containing a drum to carry the photographic paper. Driven by a small synchronous motor, the drum revolves at the rate of one revolution in 30 minutes and also moves along its axis. Thus the light beam makes a spiral trace on the record sheet. The beam comes from a small lamp in a tubular housing attached to the front of the recorder. At regular intervals the time is marked automatically on the record sheet. These marks were originally made by means of an electric clock, but I have been fortunate in obtaining an International Business Machines master clock which now provides really accurate time control.

"The cost of a single instrument, including material for a room and pier but not providing for an accurate clock, should not be much over $200. This figure will yield, more or less, to the amateur's ingenuity and patience. The cost of photographic paper will run around $25 per year."

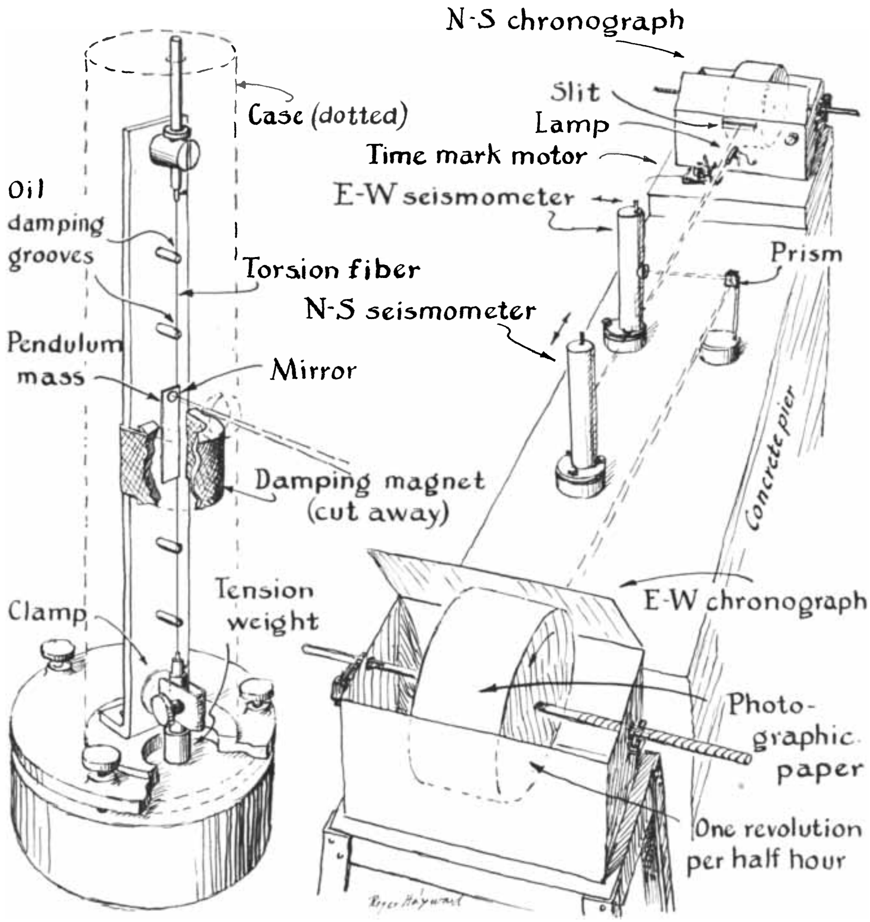
At this point it seems appropriate to ask: How does seismology pay off as an avocation? How much fun and action do you get for your money?

Microseisms, tracing their patterns on the sheet hour after hour and day after day, are an endlessly diverting show, and the study of these tremors alone is an undertaking that well justifies building a station. Some microseisms record the tiny shakings of the earth by storms at sea. Some appear to be associated with low pressure systems in the atmosphere. Some come in harmonious groups from no-one-knows-where. Some appear fixed, as standing waves. Others crisscross in random array. The pattern is ever-changing: waves that herald tomorrow's weather, waves that record the onward travel of yesterday's cold front, perhaps even waves that still reflect the earth's dying response to an ice age long past.

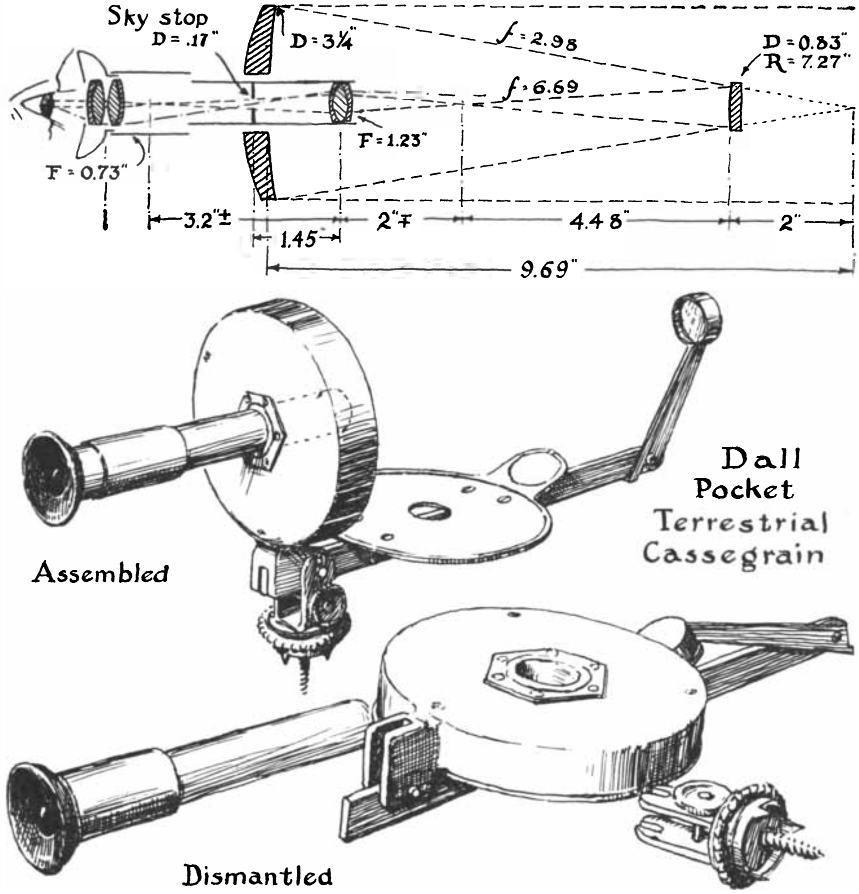
But the greatest thrill is to catch the dramatic reverberations of an earthquake, sometimes from far across the globe. Three kinds of waves record this happening. The first is the P or pressure wave, a compressional wave like that of sound, in which the wave motion is in the direction of the waves' travel. The next is the S or shake wave, which vibrates at right angles to the waves' path.



The origin of earthquake waves



Larkin's Sprengnether seismometer



A powerful pocket telescope made in Britain

Finally there is a long L wave, undulating like a water wave, which journeys around the surface of the earth.

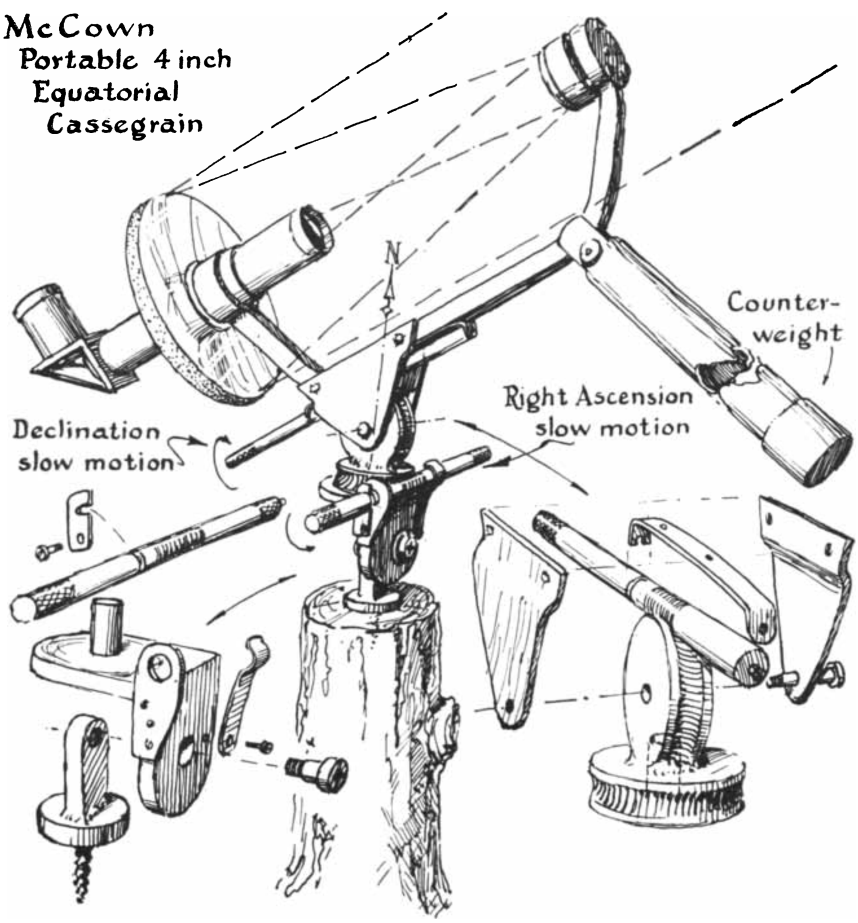
The three waves travel at different speeds. An earthquake is heralded by the sudden appearance on the seismometer scroll of the harsh jagged pattern of P waves, which speed through the earth at five miles per second. After a minute or so, depending on how far the quake is from the station, the P waves begin to die. But the show is far from over. Soon the slower S waves (three miles per second) arrive, as abruptly and violently as the first. They mark a very different pattern, easily distinguishable from the P. Some time later, again depending on the distance of the quake from the station, come the lazy, snake-like L waves (two and a half miles per second) that close the show. The difference in speed between P and S waves makes it a simple matter to determine from a travel-time chart the distance they have traveled and the time when the quake occurred.

Time and distance data provide clues to the structure of the earth. The waves are reflected by its layers of differing material; some of them literally bounce around inside the earth. The reflected waves, differing slightly from those that travel directly to the station, tell something about the depth of these layers. Furthermore, S waves are not detectable at a distance of more than 7,000 miles, indicating that they are blocked somewhere in the depths of the earth. Since S waves can travel only through a solid, this suggests that the earth has a liquid core. The core also slows the passage of P waves; those that have passed through the core are designated P′.

Most earthquakes originate in the outer crust of the earth, but shocks from levels all the way down to about 400 miles have been recorded. Deep-focus earthquakes are recognized by the absence of L waves and the presence of wave trains which have been reflected from the surface above.

Seismologists estimate that about one million true quakes shake the earth each year, and of these something like 150,000 are strong enough to be felt. The magnitude of earthquakes is measured by a scale based on the height to which the pen or light beam of a standard instrument will swing when a quake occurs at a specified distance from the station. On this scale a great shock such as the Japanese quake in December, 1946, has a magnitude of about 8.6; an atomic explosion may produce a quake rated at 5.5, and a mild quake that causes dishes to rattle in the vicinity of the quake center has a magnitude of 2.5.

Earthquakes of course are sporadic



In California the pocket telescope grew larger

and unpredictable. Mr. Larkin's seismometer has recorded two or three major shocks in a single day, while at times several weeks or more pass without a large one. On the average his station registers about one major quake every five days.

The U. S. Coast and Geodetic Survey, with the cooperation of Science Service and the Jesuit Seismological Association, mails out cards after each major earthquake giving the "epicenter" (source) and time of origin of the quake. Any amateur who operates a seismological station as a cooperative observer may get on the mailing list to receive the cards by writing to the Survey. With this information and travel-time charts, it is an easy matter to review seismograph records and become proficient in interpreting them.

By analyzing the wave motion of light, man has solved riddles of celestial mechanics lying billions of miles beyond the trembling surface on which he dwells. But the earth waves, which might tell us a great deal about our own planet, have been comparatively neglected. Do mountain-building convection currents flow within the earth's plastic core? Is that core plastic, liquid—or neither? Although the seismograph was invented 110 years ago, science has yet to resolve these and related questions. Seismologists would like to have many additional workers and a closely spaced network of observing points to supplement the fewer than three score stations now thinly distributed over the North American continent.

Here is a frontier awaiting exploration, one in which the professional geophysicist eagerly invites the amateur's help. Father Joseph Lynch, S.J., head of Fordham University's seismological observatory, has said: "There is a seismological job to suit everyone's purse and everyone's ability—there is seismic work for all—but no financial remuneration." That, indeed, would seem to qualify seismology as an amateur pursuit.

SEVERAL years ago Horace E. Dall of 166 Stockingstone Road, Luton, Bedfordshire, England, built the remarkably compact terrestrial and astronomical telescope shown in Roger Hayward's drawing on the opposite page. It is a modified Cassegrainian of 3¼-inch diameter, mounted mainly on light aluminum and duralumin parts. It weighs only eight ounces, and can be folded so flat that it juts no farther out of a vest pocket than a fat fountain pen. It gives erect images, and the magnification is continuously variable (pancratic) from 35X to 80X by pulling out the eyepiece. Dall found it a treasure for either day or night use. It has a better light grasp than a three-inch refractor and resolves stars down to Dawes' limit.

Starting from Dall's specifications for diameters, distances, ratios and radii, as shown in the drawing, Frank McCown of Holtville, Calif., has built a similar telescope of four-inch diameter, still small enough to be carried disassembled in a thin 8- by 15-inch box. In the drawing on the preceding page McCown's mounting is shown, for convenience, with polar axis vertical. The polar axis is the little stub projecting from a 90-degree angled member in the lower left-hand corner. When this is pointed at the Pole Star in the direction N by adjusting that member, the mounting becomes equatorial.

"This little portable four-inch instrument has performed so well," McCown writes, "as to retire a more cumbersome six-inch Newtonian reflector."

Dall's specifications are shown instead of McCown's so that other builders can work directly from the originals, choosing their own desired sizes. It is sound optics to alter the size of a telescope by reducing or enlarging all measurements by the same proportion. (Preferably not including the indexes of refraction, dispersion and density, or the type number from the glass manufacturer's list.)

The telescope is a modified Cassegrainian of the Dall-Kirkham type with spherical secondary and near-ellipsoidal primary mirrors. The finicky job of figuring the little hyperboloidal secondary of the straight Cassegrainian is eliminated; this advantage is why the Dall-Kirkham is supplanting the old-fashioned type. Design data for the Dall-Kirkham were rounded up and elucidated in the September, 1951, issue of SCIENTIFIC AMERICAN. Dall figured the primary, an ellipse of eccentricity .873, by the direct focal test that was described in *Amateur Telescope Making* and further elucidated in the last issue of this magazine by Kirkham.

Just as the Dall-Kirkham is a modification of the Cassegrainian, so Dall's own telescopes are a further modification of the Dall-Kirkham. The modification of the modification which might be called the Dall Cassegrainian, and which Dall regards as a most valuable addition to the spherical secondary, is the placing of an erecting lens between the primary and secondary mirrors.

Some years ago Dall made a 15½-inch telescope of this kind and listed the rewards from adding the little erector. It enables the sky-flooding diaphragm to be moved from the eyepoint (where it is an infernal nuisance, having to be fitted to each eyepiece and impossible to keep adjusted because its aperture is so small) to a position between the erecting lens and the eyepiece, where it is out of the way. It has a large aperture, and therefore is easier to keep aligned. It permits the use of wide-field eyepieces with comfortable eyepoint, greatly appreciated by spectacled observers. An iris diaphragm can be used for the sky stop, permitting the aperture of the telescope to be varied by a lever from full to nothing during observation. The long focus of the Cassegrainian can be shortened. Variability of lens-to-secondary and lens-to-eyepiece distance gives a final image varying in angular aperture (on the 15½-inch) from $f/10.5$ to $f/25$, permitting continuously varying power from 1 to 2½ for each eyepiece. And the final image is erect.

Dall designed and built cemented triplet erectors for his two telescopes. The one for the 3¼-inch gives uniform zonal focus at mean cone focus 1.23-inch, with .62-inch diameter. The focal ratio of the 3¼-inch is variable from 7.5 to 18. As an avocation Dall makes eyepieces and refigures telescope, microscope and camera objectives, his vocation being research in fluid dynamics. A recent book, *Some Aspects of Fluid Flow,* contains his contribution to the Institute of Physics on fluid flow in orifices, nozzles and Venturi tubes.

In *Fundamentals of Optical Engineering* Donald H. Jacobs briefly discusses the triplet form of erecting lens and mentions the preference of the British for it. The symmetrical, two-doublet form is more commonly used in the U. S. Data for designing two-doublet erectors were given in this department in March, 1951 (where the denominators 2, 2, in equation 5 should be deleted). McCown escaped this problem by making a two-doublet erector out of coated lenses from a war-surplus collection. His erector's combined focal length is 1.9 inch. He found it satisfactory, especially since less than its full aperture is used.

"I am enthusiastic about the Dall erecting telescope," McCown writes, "as the erector serves the purpose of a Barlow lens, also making possible a smaller secondary. The self-collimating feature of the centrally supported mirror has been successful. The threaded ring on the large eyepiece-erector tube screws against a cork ring at the back of the mirror and holds everything in alignment. Once it is collimated, no flare is visible even after repeated takedowns.

"My midget slow-motion mounting is far from perfect. The rods interfere with one another in some positions, but this can be quickly remedied by reversing the base. All but a small part of the sky is accessible. The pressure springs have enough give to allow either rod to be pushed out of gear for a change of view."

In the tubeless telescope, fogging of the mirrors from the observer's breath may be avoided by selecting only breathless views. In McCown's case, which may be unique, this is facilitated by the fact that his farm is below sea level in the Salton Sea depression, so that the instrument is a submarine telescope.

What GENERAL ELECTRIC People Are Saying

H. H. WATSON

Construction Materials Division

Higher Voltage Branch Circuits For Commercial Building Lighting: The ever-increasing trend toward higher levels of illumination in office buildings has for some time invited the use of higher voltage branch circuits. But it was not until the remote control wiring system was introduced that higher voltage branch circuits became practicable here. The Underwriters' Laboratories, Inc., standard for snap switches recognizes two voltage classifications: 0 to 250, and 250 to 600. Snap switches made to the 600-volt rating are much too large and costly to be used for the control of individual office lighting. The remote control system uses an electro-magnetic relay for switching which is built to the Underwriters' Laboratories, Inc., 0-300-volt specifications for magnetic switches. It is, therefore, properly rated for use in the 277-volt circuits of a 480Y/277-volt branch circuit system. With this new switching means available, the problem of a switch is solved. Not only is the problem solved, but the resulting system has the added safety factor of 24-volt control circuits.

Western New England Chapter
I.A.E.I.
December 5, 1951

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A. D. MARSHALL

Corporate Affairs Department

Social Security—A Problem For American Business: A recent report by the Chamber of Commerce of the United States estimates that 300 welfare plans take a third of all government tax dollars.—$22,800,000,000 during the fiscal year of 1949-50—or $575 for every taxpaying family.

Over the years the leaders of our business enterprises have solved many problems through their own individual initiative. They have made more products available at less cost to the American worker than any nation in the history of the world. But we are now confronted with the fundamental problem of whether American business can face and solve, through the initiative of its managers and businessmen, the problems involved in social security, or whether these are to be taken over by bureaucratic government control and resolved in a way which will lead us directly from social security into socialism. There appears to be little doubt that when a government takes over the savings of all the people for the emergencies of life—sickness, death of the breadwinner, unemployment, old age, and the many other things which the social planners include in the so-called social security program—and directs to whom and under what circumstances that money shall be paid, the government which does that must soon take the responsibility of directing the lives and actions of all of us.

Many social planners and government bureaucrats see in the desire for individual security an opportunity for more and more government control. This may be one form of security, but most of you people will agree with me that real security lies in the productive success of the enterprise with which we as individuals are connected.

We should not let the battle go to the social planners by default. We must spend time and effort in analyzing and presenting the necessary facts to our legislators with respect to these problems and, more than that, we must present the solutions which will not only meet the problem, but will also serve to fit into our concept of the free enterprise system.

Annual Meeting,
Framingham Chamber of Commerce
January 15, 1952

E. D. TROUT

X-Ray Department

Cobalt-60 Irradiator For Teletherapy: In 1951, a Cobalt-60 unit was constructed by General Electric to the basic design of L. G. Grimmett, Ph.D., Head of the Department of Physics of the M. D. Anderson Hospital for Cancer Research at Houston, Texas.

The Cobalt-60 irradiator has now been installed at the Oak Ridge Institute of Nuclear Studies and it has been loaded with a 200 curie source loaned by Dr. Max Cutler of the Chicago Tumor Institute. A preliminary report on the irradiator was presented before the Radiological Society of North America at its recent annual meeting. Further studies of the shielding about the source, beam characteristics, and depth dose are underway, as are biological studies. When these are completed the irradiator will be reloaded with a 1000 curie (effective) source from the Chalk River pile and transferred to the M. D. Anderson Hospital for use in the treatment of cancer.

The 1000 curie source should deliver approximately 90 roentgens per minute at the end of the 50 cm. treatment cones. An x-ray generator operating at 1 mv. and 3 ma. produces 150 roentgens per minute, and a 2mv. x-ray unit operating at 1.5 ma. delivers 600 roentgens at this distance. The Cobalt-60 beam, being nearly monochromatic at 1.2 mev, should be more nearly comparable to the 2 mv. x-ray unit in the matter of depth dose.

Until such time as Cobalt-60 becomes available at a much lower cost, or until some other artificial source becomes available, the supervoltage x-ray machine will not be supplanted by artificial radioactive substances.

AIEE, New York City
January 7-8, 1952

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