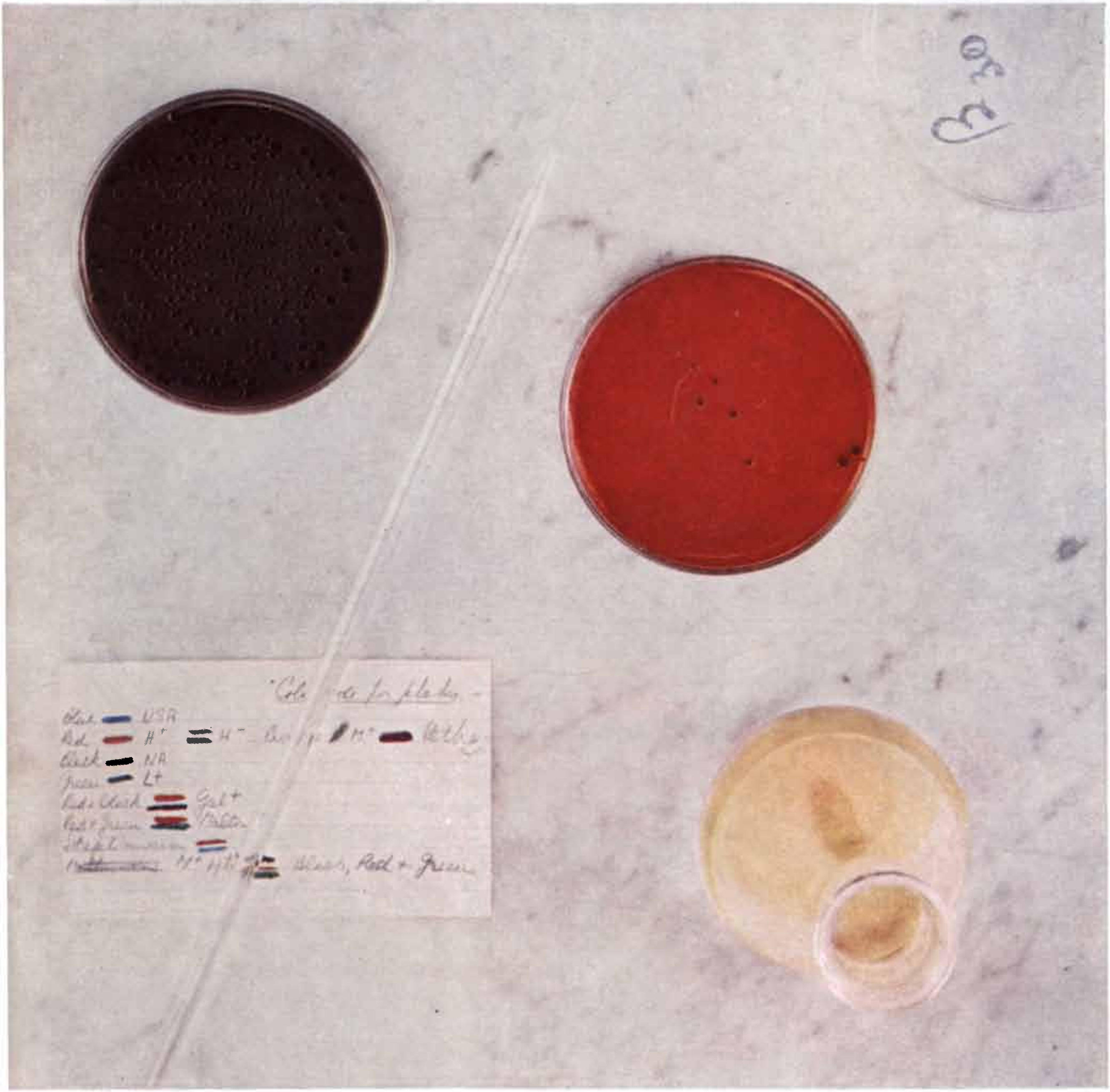
SCIENTIFIC AMERICAN



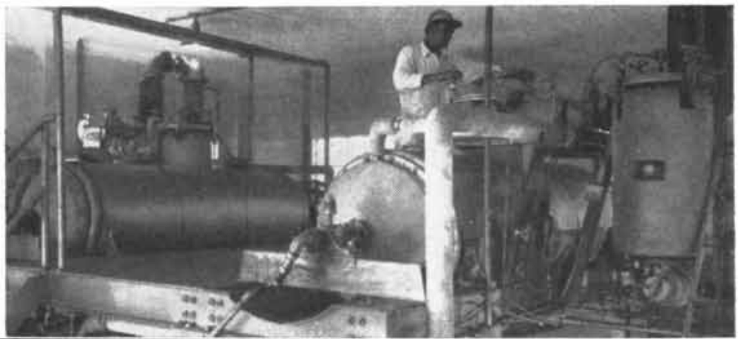
EVOLUTION IN BACTERIA

FIFTY CENTS

SEVENTY-FIVE CENTS OUTSIDE THE AMERICAS

October 1953

Operator removes boxes of tubular paper capacitors from Stokes Vacuum Impregnator at Pyramid Electric Co., North Bergen, N. J. Capacitors have been impregnated with mineral oil to improve stability and lengthen service life.



Installation of Stokes Rotary Vacuum Dryers used by Metals Disintegrating Co., Berkeley, California, for drying of aluminum powder. Highly oxidizable materials can be handled without any danger of combustion or explosion when processed in vacuum.

Operator transfers evacuated retort from heating to cooling station of Stokes Vacuum Annealing Furnace, built for processing, annealing and other heat treatment of titanium, zirconium, hafnium and copper.

Operator loads shell-frozen human blood plasma into one of the Stokes drying chambers of the lyophilizing plant at the Sharp & Dohme, Inc. biological laboratories, Glenolden, Pennsylvania.

There is no romancing about Vacuum at Stokes!

Vacuum processing starts with a vacuum-tight system and pumps to exhaust the air.

These are simple truths, the significance of which is never forgotten among men who have worked for many years in vacuum engineering.

Stokes men have many years of *engineering* experience, *shop* experience, *operating* experience in the design, construction and installation of vacuum processing systems.

But the absence of romancing in Stokes' thinking implies no want of imagination! Indeed, the practical application of vacuum processing— which gives us blood plasma, the "wonder drugs", costume jewelry, diesel locomotive motors, radio and electronic communication— had much of its inception in Stokes laboratories; takes practical shape in Stokes vacuum processing equipment for industry.

Stokes is FIRST in Vacuum . . . in great and small industrial plants, in schools, hospitals, and laboratories throughout the world.

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

STOKES

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LETTERS

Sirs:

In their very interesting article on "The Desert Rat" in your July issue, the Schmidt-Nielsens remark that "so far as is known, no other mammal can drink sea water with impunity."

It occurs to me that numerous exceptions to this statement could be found among whales and porpoises, seals, manatees and, possibly, sea otters. I write, therefore, not to bring up a relatively harmless oversight, but to raise the question of what sort of kidneys and other such gear these pelagic mammals use, and how they managed to acquire them.

Assuming that the ancestors of these animals lived on dry land, where fresh water was available, and that they subsequently abandoned the land for the sea, some rather drastic internal rearrangements must have been made somewhere along the line, or we should be faced with the anomaly of dehydrated sea dwellers—rather like the Ancient Mariner of Coleridge! Either that, or proclaim them voluntary teetotalers!

For my part, though I have eaten porpoise kidney—and it's quite good—I have never examined or studied it in any other way.

JOSEPH B. TUCKER

Clarksville, Tennessee

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THE USES OF THE PAST
Patterns of SEXUAL Behavior
A Grammar of Motives
OEDIPUS MYTH AND COMPLEX
The Story of English
MAN AND HIS GODS
TOULOUSE-LAUTREC
The Growth of Scientific Ideas
Genetics AND THE Races OF Man
The Evolution of Physics
WHITE COLLAR

ZORBA
LIVING IDEAS IN AMERICA
How the Great RELIGIONS Began

The Age of Jackson
MALE AND FEMALE
Don't Be Afraid of Your Child

Sirs:

Mr. Tucker raises an interesting physiological question. It is quite true that oceanic mammals may drink sea water, but it is not known whether they really do.

An investigator once calculated that a seal living on fish would obtain, from this source alone, enough water to excrete the salts and the urea formed, as well as to cover that evaporated from the respiratory tract. According to these calculations, the seal should never have to resort to drinking the surrounding sea water. The situation may be somewhat more difficult for whales eating planktonic crustaceans, which have a higher salt content than fish, but it still seems possible that they could get along without resorting to the drinking of sea water.

Our remark, as quoted by Mr. Tucker, is probably too rash a statement; and although it could be didactically defended, it should be modified.

The kidney of cetaceans has been studied by the outstanding Swedish scientist, Dr. Ivar Sperber. It shows some deviations from other mammalian kidneys, but it is at this time difficult to say whether these are connected with an exceptional water and salt metabolism, or with the unusual circulation of diving animals. During a dive the pulse rate of seals and whales is reduced to a few beats per minute, and blood pressure departs radically from normal. It must be expected that such unusual circulatory features could have profound influence on the structure of the kidney.

Though we have eaten cetacean steaks, we must concede that Mr. Tucker is 'way ahead of us in his investigation of the culinary qualities of porpoise kidney.

KNUT AND BODIL SCHMIDT-NIELSEN

Durham, North Carolina

Sirs:

In his article on underwater television in your June issue, W. R. Stamp suggests that red filters or red lights be used to eliminate the "Rayleigh Blue" scattered light. Actually, this is not generally possible in water due to the strong selective absorption of red by all water, both distilled and natural.

Underwater photographers, using black and white film, have for years used yellow filters (*i.e.*, a Wratten K) to eliminate the scattered, blue background light. Photometric experiments by various investigators in inshore water have amply justified this choice, showing that

this coastal water is most transparent to yellow or green-yellow light.

The whole problem of underwater photometry is almost infinitely complex, involving multiple scattering by all sizes of suspended particles, surface light loss involving the state of the sea, wind, fetch, *etc.*, clouds, sun, and sky combinations over the sea, variable selective absorption by different waters, *etc.*, *etc.*

Here is a problem that your Amateur Scientist Department might introduce to the lung divers featured in the department in your August issue. Data from many localities are needed and the professional oceanographers have too many other problems to give this one the time it deserves.

HILBERT SCHENCK, JR.

East Hartford, Conn.

Sirs:

I have never encountered quicksand —except in the pages of fiction—and probably never will. The article on the subject by Gerard Matthes in your June issue was, nonetheless, extremely interesting to me.

On one point I am still confused! It is stated several times that the density of the quicksand is greater than that of water alone. ("How fast it sinks will depend on its weight and the extent of its surface area . . ." and ". . . and even at its worst will support a great deal more weight than water alone.")

In quicksand, as in water, it would seem that a body would be buoyed according to Archimedes Principle. The weight of "liquid" displaced would be equal to the weight of sand and water in whatever proportions they happen to be present. If the proportions happen to be equal, the specific gravity of the combination would be around 1.6.

With such a high specific gravity, a man or animal would be expected to float rather high. Drowning under such circumstances would seem impossible. Yet, I gather from your article, and the widespread fear of quicksand, that rather many men and animals have achieved this feat, impossible or not.

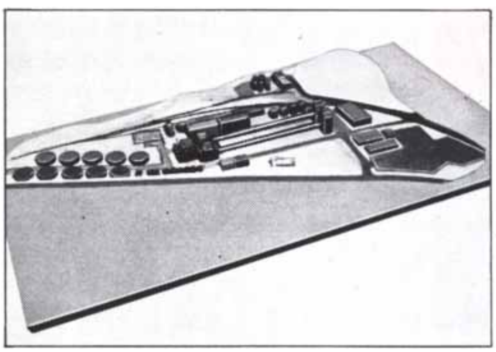
Would you kindly indicate the fallacy in the above line of reasoning?

I am also curious about the origin of the pressure which causes animals to sink to their necks, "their eyes bulging from the pressure on their bodies."

DONALD E. WILLIAMSON

Lexington, Massachusetts

FOOTE advances its "Leadership in Lithium" with THE WORLD'S LARGEST LITHIUM CHEMICAL PLANT



THIS MODEL of the Foote Mineral Company's project at Sunbright, Va. was used as a visual aid in planning the functional arrangement of buildings, material flow, accessibility and utility service distribution . . . Visual aid early in the planning saves the customer many engineering dollars.

The productive capacity of the entire lithium chemical industry will be *doubled* when this new plant at Sunbright, Va. goes "on stream." Its output will enable Foote Mineral Company to satisfy the unprecedented demand for lithium chemicals as basic ingredients in multi-purpose greases, welding rod coatings, ceramics, air conditioning, TV glass, porcelain enamels and many other industrial products. From original plans, through layout, engineering, procurement and construction of this unique plant, Blaw-Knox worked in close harmony with Foote personnel. Every phase of the work proceeded according to plan, effecting numerous economies.

This Blaw-Knox project is but one of the many different chemical and process plants engineered and constructed by Chemical Plants Division—behind each of which go years of background experience applied to today's competitive situations and technological advances. If you are thinking of new or improved facilities, a discussion may prove profitable to you.

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BLAW-KNOX

Sirs:

The points raised in Mr. Williamson's letter regarding the buoyancy of human and animal bodies in quicksand are well taken. The difficulty in most cases of miring is that people are not aware of the fact that their bodies could not sink if they would only lie down instead of struggling in an upright position. The weight of that part of the body which is not supported by the quicksand operates to push the legs in deeper. Worse than that, any effort that is made to pull one foot up and out only serves to sink the other foot deeper. Since quicksand contains no air—all spaces between sand grains being filled with water—the pulling up of a foot creates a strong suction for lack of air to take its place. This powerful suction is responsible for the common saying that quicksand sucks a person down, which of course is wrong. Lying down backward is recommended as the quickest, easiest and safest course for immediate action. This is, of course, the only way that one can lie down when sunk in quicksand up to the knees. Engineers and geologists, who are accustomed to stepping into quicksand, do not wait until they mire knee-deep, but at once throw themselves forward and crawl with body flat down, "alligator fashion," as one noted geologist terms it. In that position the quicksand holds up a man's weight together with his accouterment.

To answer Mr. Williamson's question about cattle "sunk up to their necks with eyes bulging," it was not intended to convey the idea that their bodies sink entirely. They do not; they continue to sink to a depth where equilibrium with buoyancy is established. However, unlike a horse with head set on a long neck, a cow's head is no higher than her back. When her body sinks to equilibrium depth, her head is barely out, the skull being very heavy. The pressure of the quicksand on heart and lungs then is considerable and causes the tongue to hang out of the mouth and the eyes to bulge. On the basis of Mr. Williamson's computation for specific gravity of quicksand at about 1.6 (with which I am in agreement), the pressure on heart, lungs and stomach should be over 200 pounds per square foot of belly surface. Unlike a mule, a cow keeps her legs vertically downward, and as long as she has the strength to move them she promotes her own sinking.

GERARD H. MATTHES

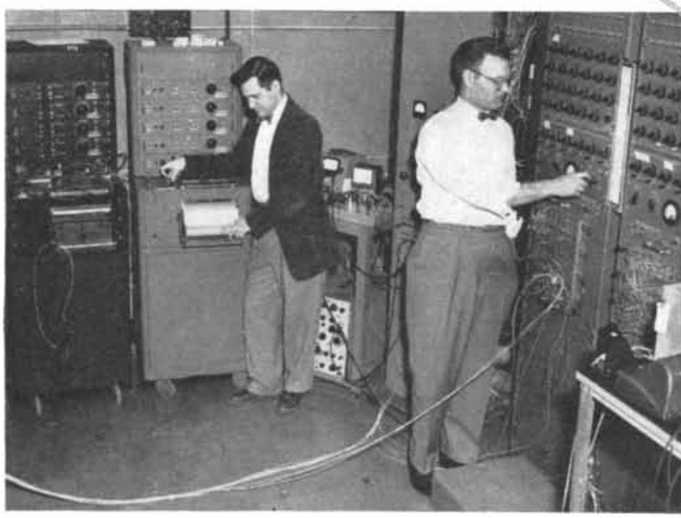
New York, N. Y.

SANBORN OSCILLOGRAPH RECORDING SYSTEMS HAVE MANY APPLICATIONS

Sanborn Recorders Help Speed Flight Design

SPERRY GYROSCOPE COMPANY uses a two-channel Sanborn Recording System for basic research on their Zero Reader* Flight Director, a device which simplifies the manual control of aircraft. The Sanborn System shown above is recording the output of a flight simulator that solves Zero Reader equations.

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



At McDONNELL AIRCRAFT CORPORATION the movements of a guided missile are simulated by high-precision analog computers which in turn send *eight* different resultant electric signals into two Sanborn four-channel Recording Systems (left) for the graphic recording of the hypothetical results of the guided missile problem.

FOUR CHANNEL

TWO CHANNEL

ONE CHANNEL

At DOUGLAS AIRCRAFT COMPANY'S Flight Test Section, a Sanborn two-channel Recording System (shown removed from case for field operation) is used in conjunction with a telemeter radio link to record surface motion vibration in a flying aircraft while it is performing tests requiring continual monitoring. Recorded tracings provide the necessary permanent visual time history for comparison of the two events recorded and a study of their individual characteristics.

How can Sanborn help you?

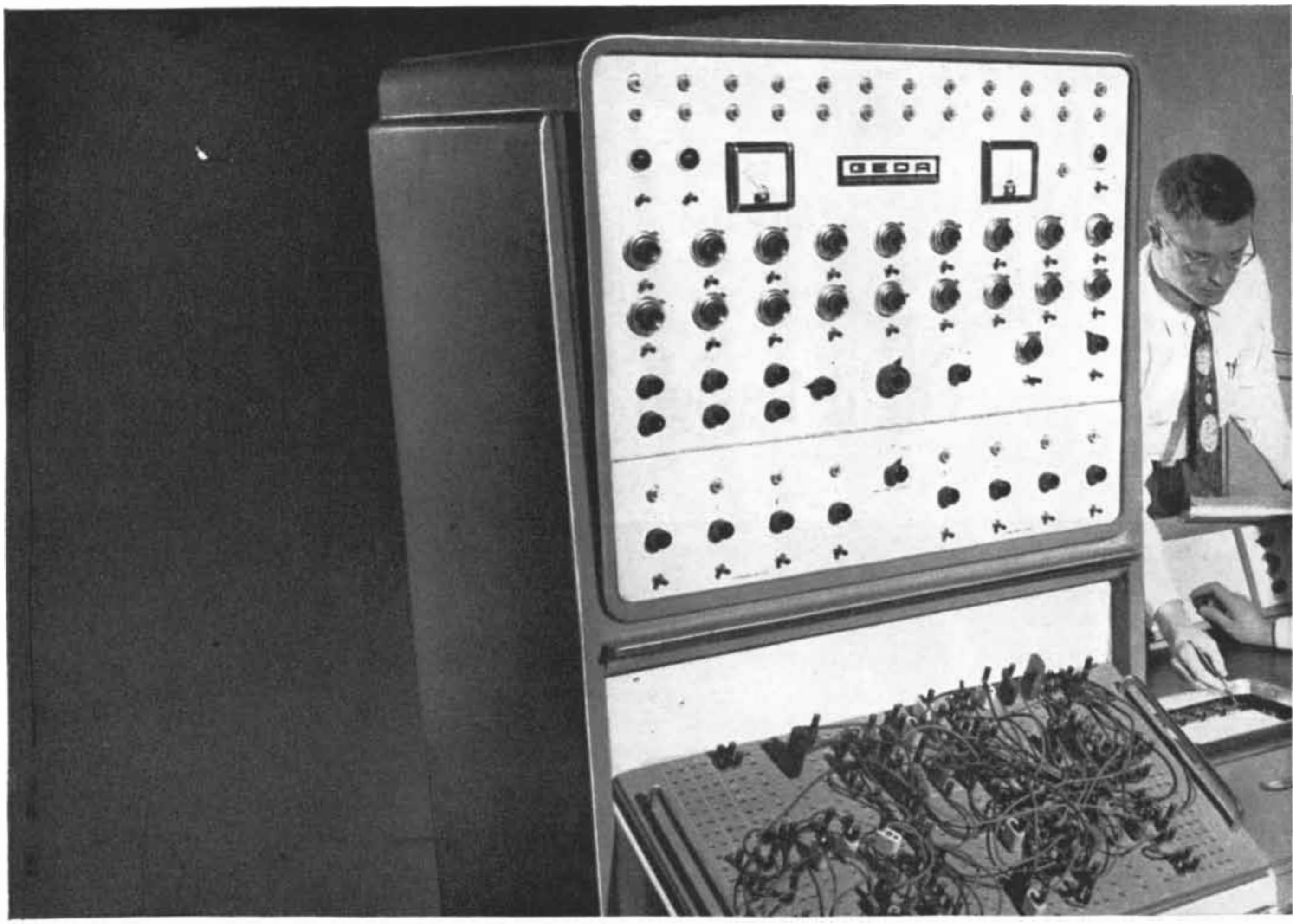
Sanborn one-, two-, and four-channel Recording Systems can provide an accurate and permanent graphic registration of almost any electrical phenomena whose frequency spectrum falls within the range of zero to 100 cycles per second. The availability and ready *interchangeability* of amplifiers and preamplifiers offer a wide range of use.

Records are traced by heated stylus on plastic coated strip-chart paper, and are in true rectangular coordinates. Other Sanborn advantages include: a high torque movement (200,000 dyne cms per cm deflection); built-in code and time markers; and a wide choice of paper speeds and channels.

Sanborn engineers will be pleased to make recommendations as to what type of equipment will best solve your recording problem. When writing, include the lower and upper limits and the frequency range of the phenomena to be recorded, and the type of transducer.

Ask for a copy of our "Applicability Folder" which presents a table of uses, complete performance data and specifications, brief descriptions of Sanborn Recording Systems and explanations of how their amplifiers may be readily interchanged.

SANBORN CO. INDUSTRIAL DIVISION
CAMBRIDGE 39, MASSACHUSETTS



Best way to give your hunch a

ENGINEERING processes are undergoing a revolution, thanks to GEDA — Goodyear Electronic Differential Analyzer — which enables engineers to tackle studies which otherwise would be too time-consuming to carry out.

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These compact analog computers accelerate the design of complicated equipment—particularly when the problems deal with dynamic systems where analytic solutions seem impossible.

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The versatility of GEDA constantly suggests new avenues of approach to problems. A new idea can be tried out, the components of a system changed so easily—profitably explored at last—because of GEDA's tremendous savings in engineering man hours.

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A big advantage of GEDA is the fact that engineers *do not have to learn specialized mathematics* in order to use this computer. Once the block diagram is laid out, it is a simple matter to set it up on a GEDA's problem board. The results are shown through voltages and wave forms — can be readily translated. Consequently, GEDA provides the engineer with a better understanding of the system under study because the solutions are produced in forms already familiar to him.

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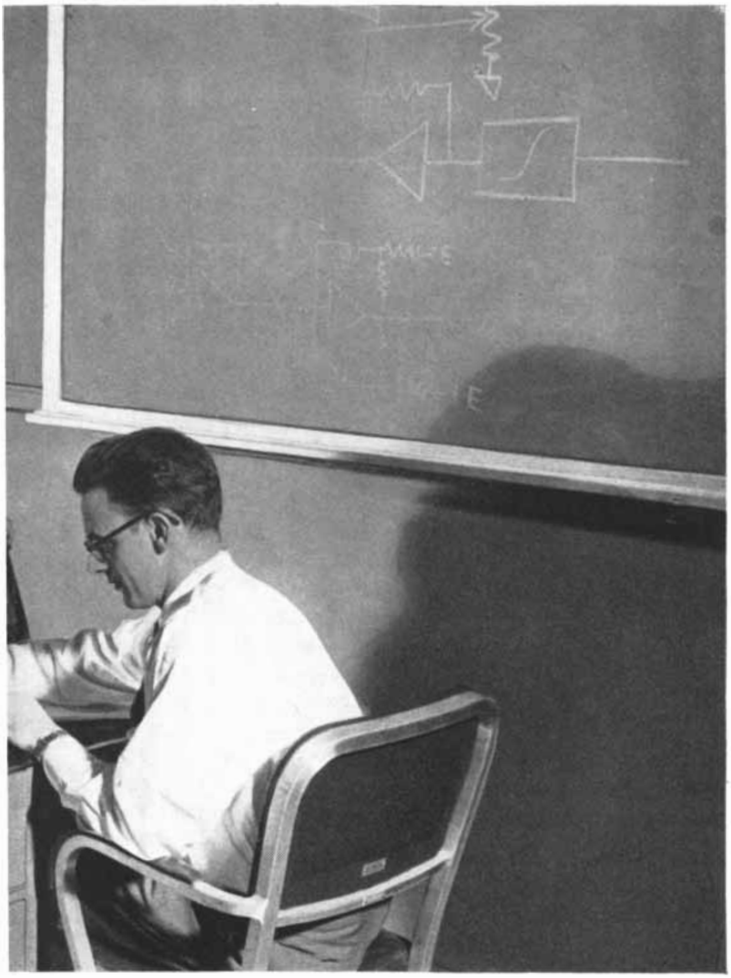

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recorders, and curve-followers. Each is a self-contained unit with its own power supply, each is extremely easy to service, and engineered to eliminate obsolescence.

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The flexibility and scope of GEDA equipment can serve you well. We invite you to write for brochure and complete details: Goodyear Aircraft Corporation, Dept. 65C, Akron 15, Ohio—for over five years a major supplier of computing equipment, operator of one of the world's largest computer application laboratories.

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- How much backlash can be tolerated?
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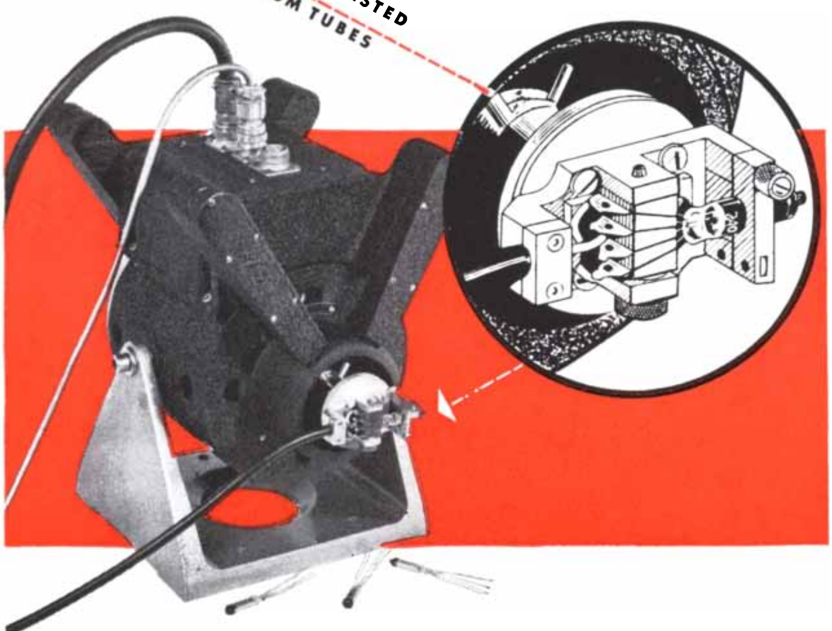


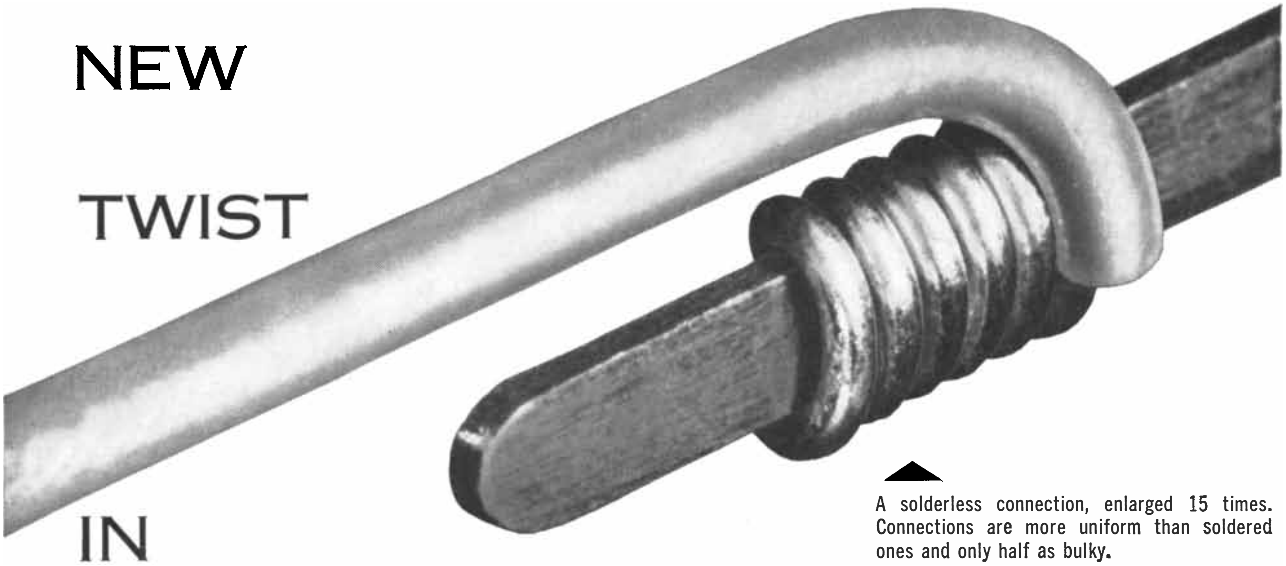
50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

OCTOBER, 1903: "At a meeting of the science branch of the British Association, Lord Kelvin made an interesting suggestion in connection with the perpetual emission of heat by radioactive substances. He said that if the emission of heat went on for 10,000 hours, there would be as much heat as would raise the temperature of 900,000 grammes of water 1 degree Centigrade. It seemed utterly impossible to Lord Kelvin that this would come from the store of energy lost out of a gramme of radium in 10,000 hours. It seemed, therefore, absolutely certain that the energy must somehow be supplied from without. He suggested that ethereal waves might in some way supply energy to radium while it was emitting heat to matter around it. Lord Kelvin illustrated his theory by the following comparison: Suppose a piece of white and a piece of black cloth, hermetically sealed in similar glass cases, were submerged in similar glass vessels of water and exposed to the sun. The water in the vessel containing the black cloth would be kept very sensibly warmer than that containing the white cloth. Here the thermal energy was communicated to the black cloth by waves of sunlight, and was given out as thermometric heat to the water in the glass around it."

"The constant existence of some electrical condition in the atmosphere lends interest to inquiries as to the extent of the earth's electric field. Investigations at the highest altitudes it is at present possible to reach seem to show that the upper limit is in the area between 10,000 feet and 15,000 feet above sea level. Above this area the electric potential may be regarded as constant. The cause of this phenomenon has not yet been satisfactorily elucidated, and various theories have been brought forward to account for it. These all agree in regarding friction between particles of the same or different materials, such as water and air or water and ice, as the initial cause. These researches seem to indicate that the impact of rain on the surface of a lake or sea, or even the wind blowing on

A NEW TWIST IN TELEPHONY



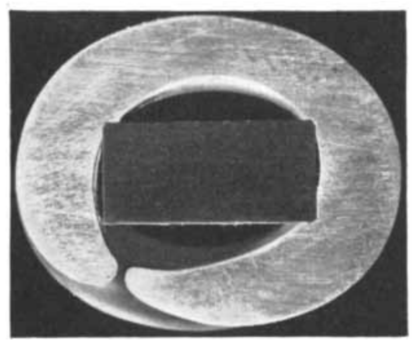
A solderless connection, enlarged 15 times. Connections are more uniform than soldered ones and only half as bulky.

For years the accepted way to connect wires to telephone apparatus was with solder. Now, Bell Laboratories engineers have discovered how to make connections faster and better—without solder.

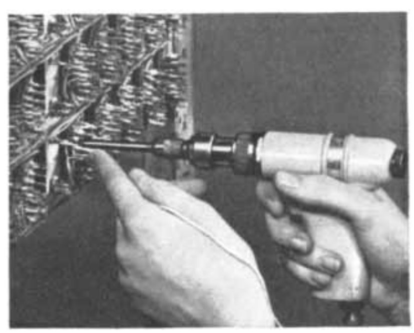
Solder, they reasoned, wouldn't be needed if wire and terminal could be kept tightly pressed together. But, for economy, this had to be done with the wire alone—without complicating screws and springs.

They found the answer in using a properly dimensioned terminal with sharp edges . . . whipping the wire around it under high tension. The terminal bites into the wire, locking it securely into position. Thereafter the squeezed edges maintain a contact pressure of at least 15,000 pounds per square inch—even under vibration that cracks soldered joints.

The new connections can be made in half the time—a big money-saver in the billion connections that Western Electric makes each year for the Bell System. It's another example of the way Bell Telephone Laboratories works continually to keep costs low.



Cross section of solderless connection. Note terminal biting into wire. In a six-turn connection there are at least 20 clean contact areas impervious to moisture and corrosive gases, offering current a low resistance path.



Power tool whips wire on terminal in fraction of a second. There is no heat which could damage miniature components . . . no dropped solder or wire clippings to cause trouble later.

BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN MECHANICAL ENGINEERING these surfaces, produces electricity, which may be the initial cause of thunderstorms."

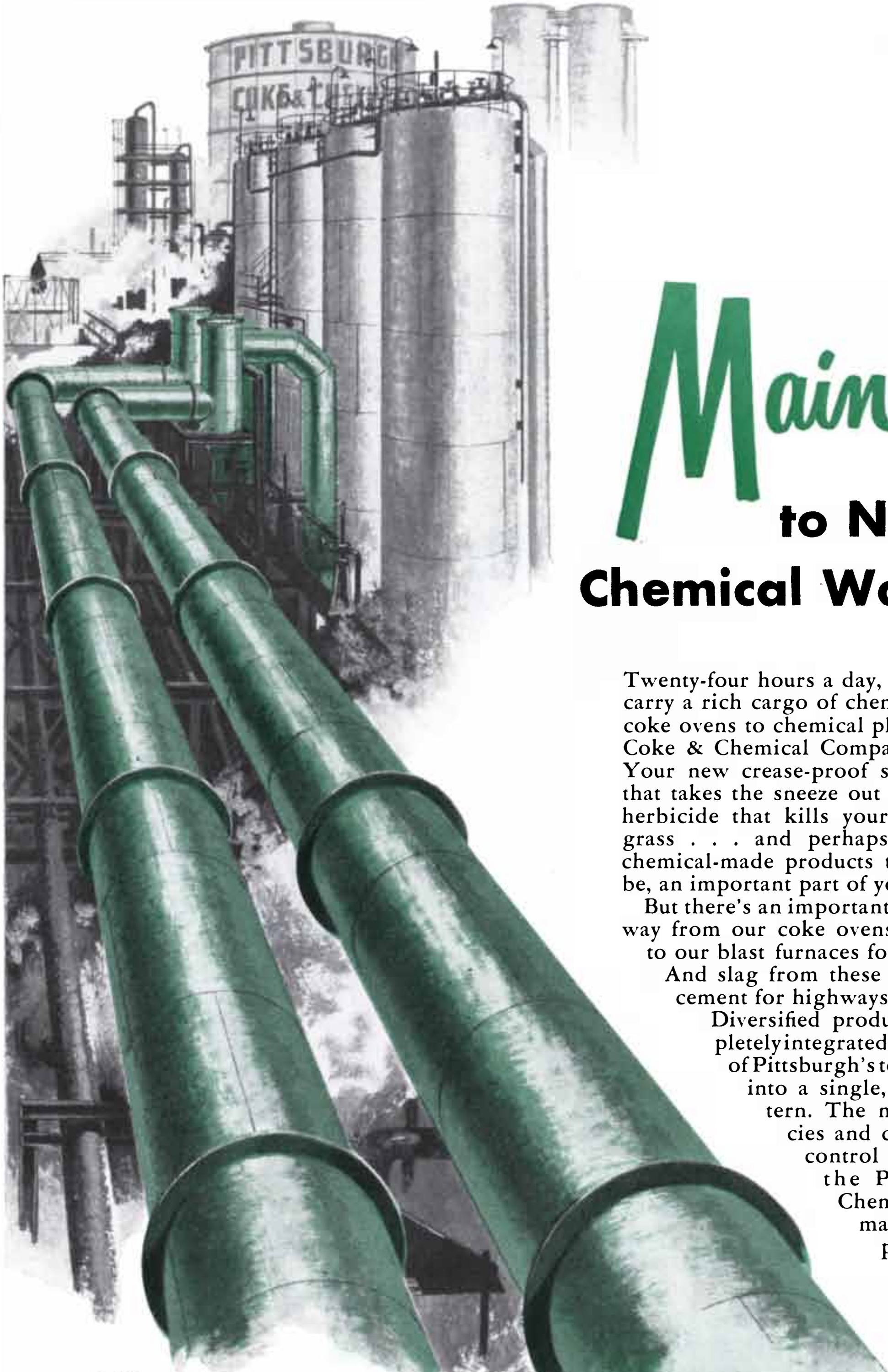
"Sir Edmund Antrobus has, through Lord Edmund Fitzmaurice, chairman of the County Council of Wiltshire, made a definite offer to sell Stonehenge and eight acres of land occupied by these magnificent Druidic ruins to the English government for $250,000, on the understanding that they will be preserved for the nation. Some years ago Sir Edmund made an offer to dispose of Stonehenge and 20 acres of the land on which the great stones stand for $750,000 to anyone who was willing to pay that price, and great alarm was expressed lest some American multimillionaire might purchase the celebrated megalithic monuments and carry them off to the United States. But this fear has not been realized."

"Amid the intense excitement of a vast crowd, consisting largely of experts, the Siemens electric train on October 23 achieved the record speed of 207 kilometers, or about 129¾ miles per hour, beating the record of the last previous trial by six kilometers. After the recent trial on the experimental Marienfelde-Zossen line, near Berlin, when a speed of 125 miles an hour was attained, the engineers declared that this would be exceeded, and that a speed of even 140 miles an hour was practicable."

SCIENTIFIC AMERICAN

OCTOBER, 1853: "There are in vogue two theories by which the phenomena of light are explained, the one that of Descartes, Huygens and Euler, commonly called the undulatory theory, the other that of Newton and Brewster, known as the theory of emanations. Both are unsatisfactory in certain respects.

"The advocates of the undulatory theory maintain that light is in all respects similar to sound, and the colors are compared to the notes of an octave. But, carrying out the parallel with sound, what would be the result if an immense multitude assembled together were each at the same time to shout with a different cry? Would a listener be able to hear distinctly the voice of any one? Most certainly not; yet gazing among the myriad orbs which spangle the starry vault, the eye can readily single out the smallest, whose light is sufficient to af-



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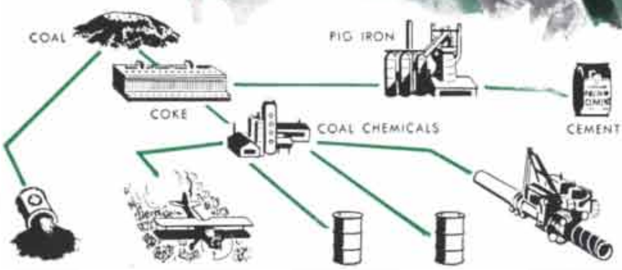
But there's an important "line" going the *other* way from our coke ovens, too. It carries coke to our blast furnaces for pig iron production. And slag from these furnaces is made into cement for highways and homes.

Diversified production? Yes, but completely integrated, too. For the operations of Pittsburgh's ten divisions are welded into a single, *basic* production pattern. The manufacturing efficiencies and coal-to-product quality control that result have made the Pittsburgh Coke & Chemical Company trademark a hallmark of dependability.



PITTSBURGH
COKE & CHEMICAL CO.
Grant Building · Pittsburgh 19, Pa.

fect it, and contemplate it, untroubled by the light of the more powerful luminaries shining in other parts of the heavens.

"In explaining color, Euler supposes that opaque bodies have each a *tone* of their own, and that when their vibrations are excited by a luminary, they are consequently uniform. According to this, a rough steel plate vibrates in harmony with the color called grey, but when polished it vibrates in harmony with all the colors of the spectrum!

"Further, there is no reason why, if light be propagated by undulations, it should always be transmitted in straight lines. Sound can move as readily in a bent tube as in any other. It has been said that light could not pass through an orifice and expand its undulations like sound, on account of the great size of the orifice compared with the extreme minuteness of the rays of light, but this is very unsatisfactory.

"The failure of the advocates of the undulatory system to explain satisfactorily the refraction of light might also be urged against it, as well as the unsatisfactory explanation of polarization.

"On the other hand, against the theory of emanations, as taught by Newton, there is one objection which, though it has been often urged, has never, and can never be answered. Newton taught that light consisted of particles of the matter of the luminous body; if so, the sun must be decreasing in mass, slowly indeed, yet nevertheless constantly, and this process must in time result in utter extinction. Priestley, casting the concentrated light of the sun upon a delicate balance, attempted to weigh it,—he even fancied he had succeeded, and from the data thus obtained, he proceeded to compute the total diminution of the sun's bulk for a period of six thousand years. But we are satisfied that our intelligent readers will, with us, reject his experiment *in toto*, as the smallest particle of dust floating in the air would weigh more than the pretended weight of the sun's rays as indicated by his balance. And from the most carefully conducted experiments, as well as from theoretical considerations, it is highly improbable that the rays of light are in the smallest degree ponderable. We regard this argument as an unanswerable one against the Newtonian system—it cannot be evaded, and is of itself, we think, sufficient to overthrow it. We are not surprised that from these considerations so many philosophers of eminence have of late been disposed to reject the Newtonian theory and adopt the only other—that of undulations."

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C-D-F unsupported and supported TAPES of TEFLON*

C-D-F tapes of Teflon offer many advantages and end-use benefits. Insulated wires and cables, with multi-layer wrappings of both unsupported and supported Teflon tapes, have increased conductor efficiency at high temperatures . . . and last longer.

Inherent characteristics of Teflon include high dielectric strength (1000 VPM or greater), low dielectric losses and high heat resistance. Teflon's effective temperature range—from –80 degrees F. to 500 degrees F.—gives permanent, trouble-free protection to all types of aircraft cables. C-D-F Teflon tapes are chemically inert, and have practically zero water absorption. Even under extremely humid conditions, Teflon tapes retain their unusually high dielectric properties.

Teflon has the required mechanical and electrical properties for heavy duty motor, generator, and conductor insulation. Unsupported Teflon tapes have a high elongation value, and a plastic memory that causes shrinkage as the conductor temperature rises. This contraction effects a tighter fit over sharp bends, corners, and other hard-to-insulate surfaces.

Supported Teflon has greater mechanical strength due to its glass fabric base . . . and is available in a greater range of widths than unsupported film. Either form may be used with mechanical wrapping machines. For complete details about this material, write for 8-page Teflon Folder T-52. Or, call in a C-D-F sales engineer for technical or engineering help . . . and learn of many new Teflon applications that are being developed daily in the C-D-F laboratories.

SPECIFICATIONS

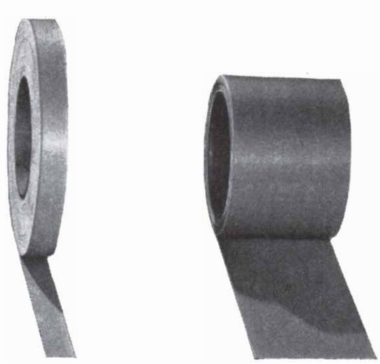
Unsupported C-D-F Teflon tapes are available in widths from ¼" to 12", and in thicknesses ranging from .002" to .060".

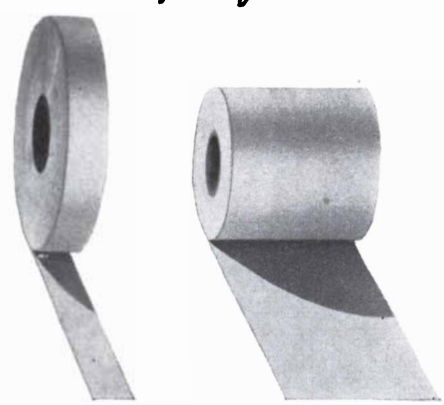
Glass fabric base Teflon tapes are available in widths from ¼" to 38", and in thicknesses from .003" to .010". C-D-F can also supply Teflon in sheets, unsupported or fiberglas cloth supported; and either copper- or aluminum-clad stock for printed circuits. Special diaphragm and gasket materials are also available.

THE NAME TO REMEMBER... CDF TAPES OF TEFLON

Continental-Diamond Fibre Company

NEWARK 24, DELAWARE

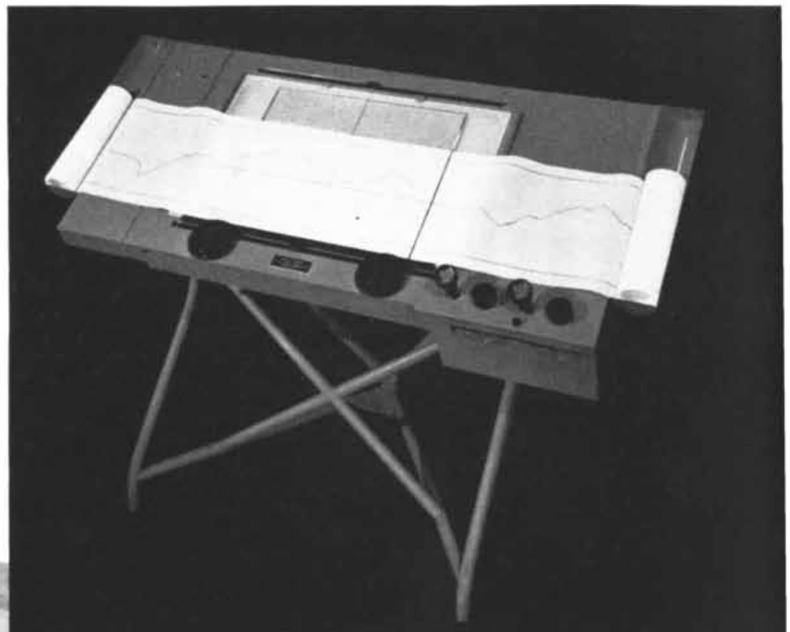


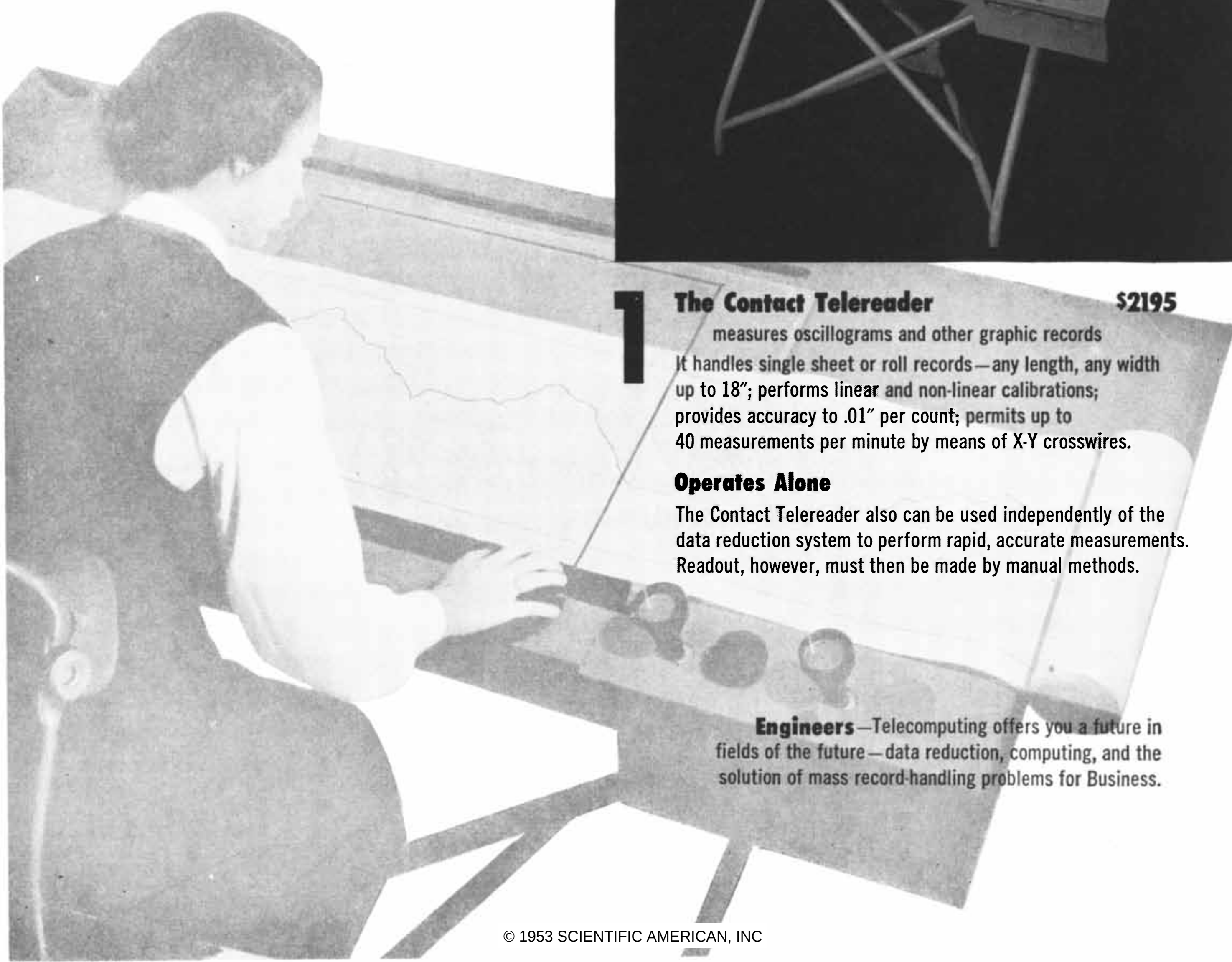


*duPont's tetrafluoroethylene resin

Telecomputing announces:

the first low-cost data reduction system





1 The Contact Telereader **$2195**

measures oscillograms and other graphic records

It handles single sheet or roll records—any length, any width up to 18″; performs linear and non-linear calibrations; provides accuracy to .01″ per count; permits up to 40 measurements per minute by means of X-Y crosswires.

Operates Alone

The Contact Telereader also can be used independently of the data reduction system to perform rapid, accurate measurements. Readout, however, must then be made by manual methods.

Engineers—Telecomputing offers you a future in fields of the future—data reduction, computing, and the solution of mass record-handling problems for Business.

Everyone concedes the value of modern data reduction instruments; but not every organization feels it can "afford" them—just yet.

A pioneer in the field of data reduction, Telecomputing has long sought a solution to this problem. It now presents the first low-cost data reduction system which offers speed, accuracy and flexibility at a price most organizations can afford: $5,555.

3

Electric Typewriter **$920**

The Program Unit **$750**
prepares parallel digital data for serial readout to the electric typewriter shown on top of the Teleducer-Program Unit cabinet.

Readout also can be in punched cards or punched tape.

2

The Teleducer **$1690**
electronically converts Contact Telereader measurements into digital form.

Other Teleducer Applications

The Teleducer can be used by itself as a laboratory digital voltmeter with an accuracy of 0.1%. It also can be used independently to digitize output of strain gauges and thermocouples without D. C. amplification. It provides for minimum full-scale input of 10 millivolts (10 microvolts per count) and maximum full scale input of 1.0 volt without external attenuation.

The Teleducer and accompanying Program Unit are housed in the same cabinet.

Computing Service

Your computing and data reduction problems, large or small, can be processed quickly, efficiently by Telecomputing's staff of engineers, physicists and mathematicians. They are fully equipped with Telecomputing and other electronic instruments to provide round-the-clock service. Representatives in Telecomputing's Burbank and Washington, D. C. offices are available to discuss your problem and prepare proposals.

Specifications on the new data reduction system, as well as detailed information showing how the Contact Telereader and Teleducer can be used independently, will be mailed you upon request. Coupon below is for your convenience.

Mr. Preston W. Simms, SA-10
Telecomputing Corporation, Burbank, California

- ☐ Please send me specifications on the data reduction system.
- ☐ Please send me specifications showing how the Contact Telereader can be used alone.
- ☐ Please send me specifications showing how the Teleducer can be used alone.

My Name ______

My Company ______

My Street Address ______

City and State ______

TELECOMPUTING CORPORATION

BURBANK, CALIFORNIA **WASHINGTON, D. C.**

THE AUTHORS

HAROLD W. MILNER ("Algae as Food") has been a staff member of the Department of Plant Biology of the Carnegie Institution of Washington since 1928. He is one of the pioneers in the studies described in his article. The interest of the Carnegie Institution in the *Chlorella* alga began with its use as an experimental subject for the study of photosynthesis. When it was learned how easily the growth and chemical composition of the algae could be influenced by changes in environment, the possibilities of large-scale culture became apparent. Milner and a colleague in 1948 wrote a preliminary report suggesting engineering researches which later were carried out at the Stanford Research Institute and at Arthur D. Little, Inc. Milner was born in Denver in 1903 and educated at Colorado College. After graduation he worked for two years as chemist in a zinc smelter before joining the Carnegie Institution. In addition to his algae investigations he has worked on the spectra of plant pigments and on the formation of starch in leaves. In his spare time he is an amateur astronomer.

WALTER T. BONNEY ("High-Speed Research Airplanes") is assistant to the executive secretary of the National Advisory Committee for Aeronautics. Born in Ludlow, Vt., in 1909, he graduated from the University of Massachusetts in 1931 and began a career as a newspaperman. For 10 years he covered politics and industry for the Springfield (Mass.) *Republican*, and wrote about aviation as a hobby. Then he was a public relations man for Bell Aircraft Corporation for eight years, except for two years of military service. In 1949 he joined the N.A.C.A. His hobbies are home repairs (at which he describes himself as "an enthusiastic incompetent") and reading and writing about aviation history. He is now at work on a book to be called *Prelude to Kitty Hawk*.

BRYCE CRAWFORD, JR. ("Chemical Analysis by Infrared") is professor of physical chemistry at the University of Minnesota. He was born in New Orleans in 1914 and was educated at Stanford University, where he took his Ph.D. in 1937. He spent two years at Harvard University as a National Research Fellow and then taught chemistry at Yale University for a year. He has been at Minnesota since 1940. During the war

Flying "taxis" that open up new roads

Miraculous rescue flights over Korean combat zones put helicopters in the spotlight. Soon, 'copters like these three leaders will open up more and more new "roads" in America's skies.

Powered by always dependable, air-cooled engines built by Lycoming, these helicopters are already used by industry as flying "taxis" to transport executives from plant to plant. Soon, major cities will get aerocab service from midtown terminals to airport flight lines. Later, every state in the union will get super "taxi" service between cities . . . and even commuter service from suburbs to hearts of business sections.

Dependable Lycoming power has helped these leading helicopters achieve outstanding safety records. This is another Lycoming contribution to America's progress in the air; another reason why we say: "For efficient, dependable, air-cooled power . . . look to Lycoming!"

Air-Cooled Engines for Aircraft and Industrial Uses
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*Wright-Cyclone engine, built by Lycoming under license from Curtiss-Wright Corporation, Wright Aeronautical Division.

Crawford did research on rocket propellants for the National Defense Research Committee and was awarded the Presidential Certificate of Merit. He has held a Guggenheim fellowship and a Fulbright grant. His research specialty is molecular structure, which he studies largely by means of the techniques described in his article. In leisure hours he devotes himself to a scholarly interest in the treatises of Dr. Watson (but has been too busy to contribute to the *Baker Street Journal*), to model railroading and to the care and feeding of two sons.

GEORGE W. GRAY ("Human Growth"), a member of the staff of the Rockefeller Foundation and a veteran science journalist, has written many articles for SCIENTIFIC AMERICAN. His most recent, "A Larger and Older Universe," appeared in the June, 1953, issue, which contained a biographical note about his career.

FRANCIS J. RYAN ("Evolution Observed") has spent almost all of his academic career at Columbia University, where he is now professor of zoology. Born in Brooklyn in 1916, he was a student at Columbia from 1933 to 1941, when he earned his Ph.D. After a year as a National Research Fellow at Stanford University he returned to Columbia to teach and has remained there since, with a year out for research, on a Guggenheim fellowship, at the Pasteur Institute in Paris. During the war he did research on gas gangrene for the Office of Scientific Research and Development. Ryan's chief work has been in the field of the genetics, growth and metabolism of microorganisms, especially bacteria. He has traveled a good deal, spending summers in Alaska and in South America. This summer he attended the sixth International Congress on Microbiology in Rome as his university's representative. He plays a first rate game of tennis and is said to be the best handball player at Columbia.

THOMAS G. BIBBY ("History in a Peat Bog") is assistant keeper of the Prehistoric Museum in Aarhus, Denmark. A British citizen, born the son of a small-town grocer in England in 1917, he got through Cambridge University on scholarships, was graduated just in time for World War II and later left the British Army "with no money and an unquenched conviction that I should really enjoy myself only as an archaeologist." He worked for an oil company in the Middle East for three years to earn enough money to obtain digging experi-

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. . . . *need*

an alloy so tough you may not yet have heard of it?

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a forged finish like plate glass?

. . . . *face*

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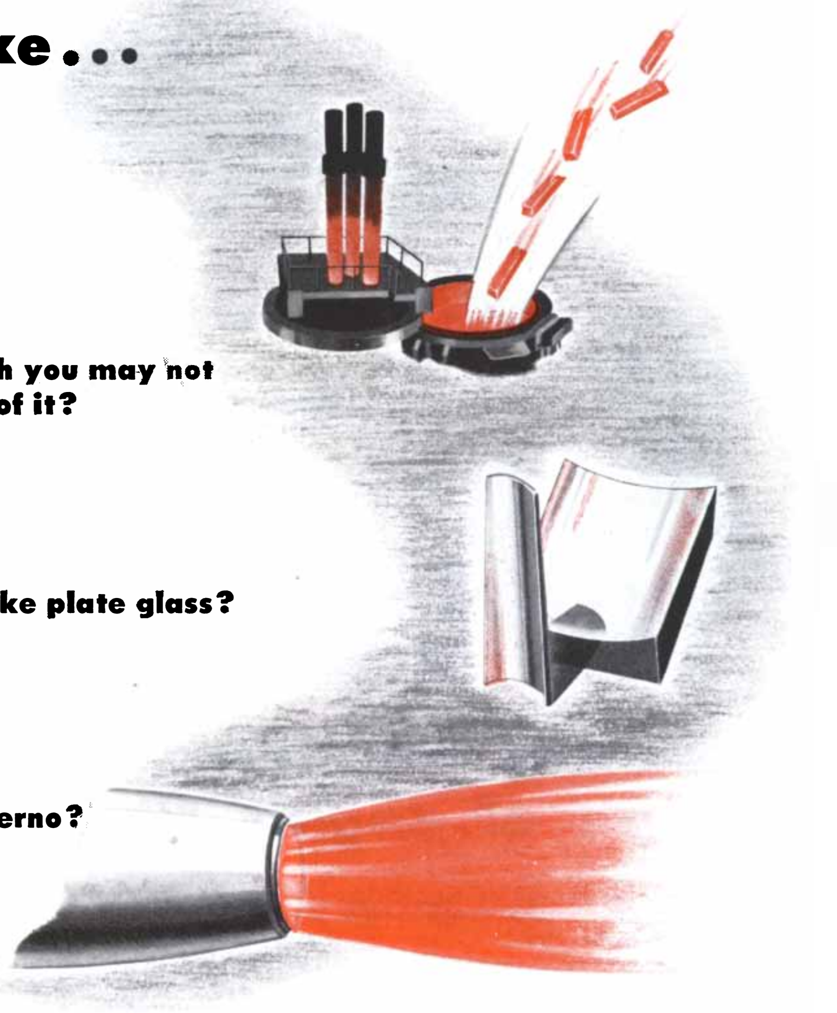

You may even have a twist or two of your own to add to the problem the Jet Division helped solve for jet aircraft engine builders . . .

The "buckets" (paddles) on the turbine rotor at the rear of a jet engine whirl around about 10,000 times a minute, pulsed by a white-hot blowtorch of flame. To withstand this roaring inferno, the bucket surfaces and curves must be forged even smoother than glass. They must be made of an alloy tougher than the toughest steel. They must "take" this red-hot ride for hours without stretching out, or "creeping", from centrifugal force and heat.

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JET DIVISION

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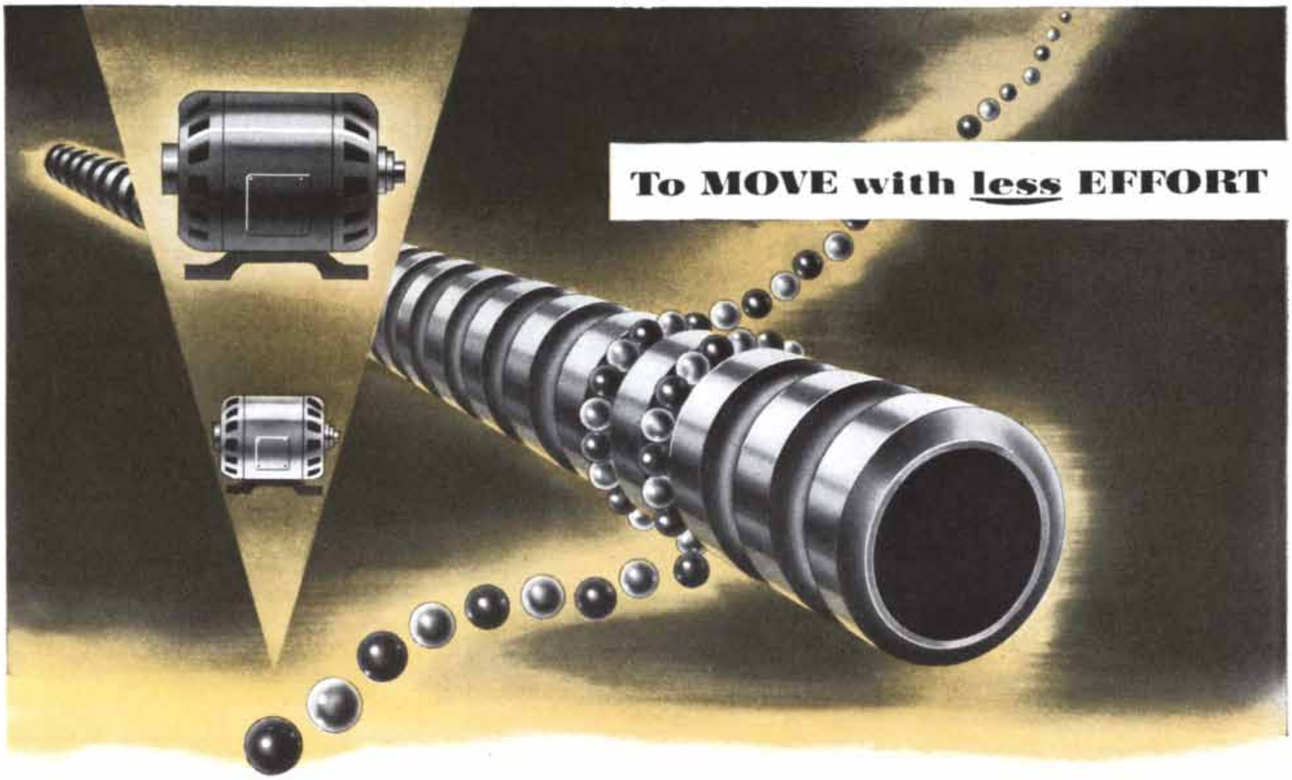
ence. Then, attracted to Denmark by a young Danish girl whom he married, he joined the staff of the Aarhus Museum. He will soon lead an expedition to Bahrein on the Persian Gulf "to try to solve the riddle of the mound-builders there."

HERBERT KONDO ("Michael Faraday") is a member of the research staff of *The American Peoples Encyclopedia* and a student of the history of physics. He was born in New York City in 1924, attended the University of Florida and received an M.A. in cultural history in 1951 at the University of Chicago. A radar technician during the war, he has also studied physics and mathematics at the Illinois Institute of Technology, and works in electronics as a hobby. He has picked up a reading knowledge of French, Spanish, German and Sanskrit. His study of Faraday grew out of an investigation of the history of the theory of relativity.

WALKER VAN RIPER ("How a Rattlesnake Strikes") is a retired investment banker, now serving as curator of spiders at the Denver Museum of Natural History at $1 a year. He approached the rattlesnake problem as a photographer rather than as a student of reptiles. Since 1939 Van Riper has been building high-speed electronic flash sets for various nature studies. His high-speed flash pictures of spiders, hummingbirds and other animals have appeared in many journals in the U. S. and abroad. He was born in 1887 and holds an A.B. from Yale University and an LL.B. from St. Louis University. He went to Colorado for his health, taught banking at Colorado College for a year, and was an investment analyst and banker in Denver from 1916 to 1943. Along the way he developed a strong interest in science. In 1943 he retired from business and joined the Denver museum.

ERNEST NAGEL, who reviews the new edition of Galileo's *Dialogue on the Great World Systems* in this issue, is professor of philosophy at Columbia University. He was born in Czechoslovakia in 1901 and came to the U. S. at the age of 10. After graduating from the College of the City of New York, he taught in the New York City public schools and at City College while doing graduate work at Columbia. He took his doctorate in 1931 and joined the Columbia faculty. Nagel has specialized in mathematical philosophy and is president of the Association for Symbolic Logic. He is the author, with Morris R. Cohen, of ***An Introduction to Logic and Scientific Method.***



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Ball-screw actuators made by Cleveland Pneumatic have an efficiency as high as 90% on most types of drives for machines. This lets you use a ½-horse-power motor instead of a 1-horse . . . a 5-horse instead of a 10 . . . with power to spare.

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These "AEROL" Ball-Screw Actuators are at work *now* . . . in the air at scores of spots on air-craft; on the ground in machine tools, in research equipment, on trucks and cars; at secret locations on difficult defense projects.

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CPT's shock absorber principle combines pneumatic and hydraulic cushioning. It can control minute vibrations or tons of impact. It is the shock absorber for the largest aircraft landing gears (CPT is the world's biggest manufacturer of landing gears), and the same principles are often adapted to finger-sized units. May we discuss with you how to take the shock out of stopping or the motion out of vibration?

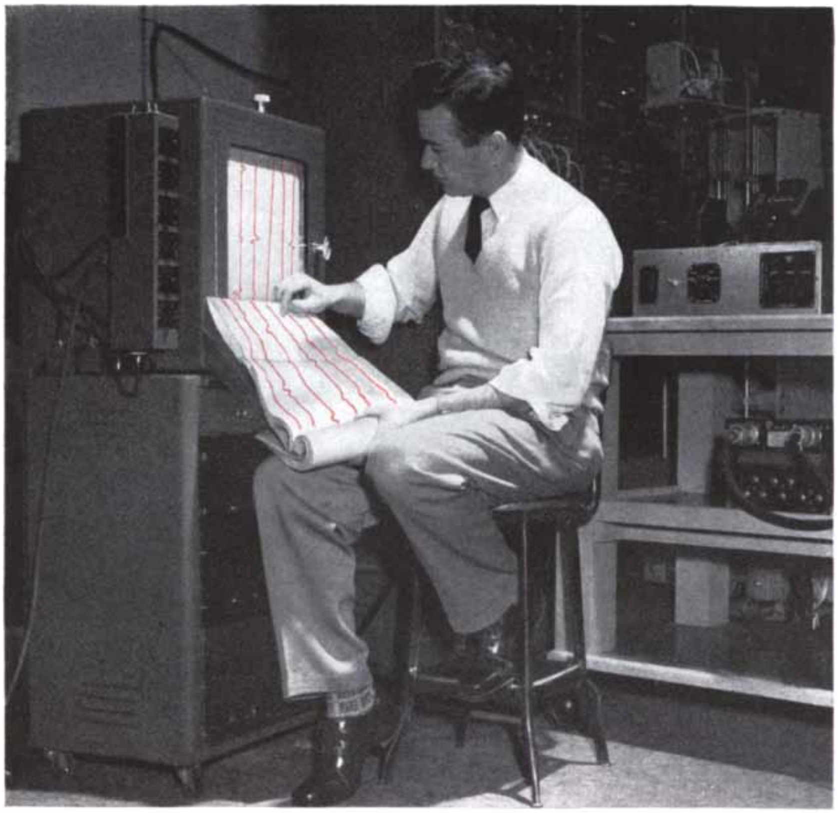
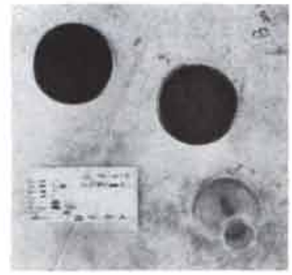


Photo courtesy Sperry Gyroscope Company



THE COVER

The photograph on the cover, made by David E. Scherman for SCIENTIFIC AMERICAN, shows the tools for the study of evolution in bacteria as described in the article beginning on page 78. They include plates of special indicator agar-gel growing beadlike colonies of the common colon bacteria, *Escherichia coli*, a pipette for transferring samples of a culture to fresh medium, and a color chart for identifying various strains of the bacteria.

THE ILLUSTRATIONS

Cover photograph by
David E. Scherman

Page	Source
32	Arthur D. Little, Inc.
33	Bunji Tagawa
34	Arthur D. Little, Inc.
35	Harold Bold (*top*), Arthur D. Little, Inc. (*bottom*)
36	Sara Love
37	Douglas Aircraft Company, Inc.
38-39	N.A.C.A., except upper right; Douglas Aircraft Company, Inc.
40	Douglas Aircraft Company, Inc.
41	Bell Aircraft Corp.
42	Engineering Societies Library
43-45	James Egleson
46	Bernard Hoffman (*top*), Bunji Tagawa (*bottom*)
47-48	Bernard Hoffman
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70-74	Child Research Council
78	E. R. Squibb & Sons
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84	T. G. Bibby
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86-88	T. G. Bibby
90-99	Burndy Library
101-102	Walker Van Riper
115	John Tremblay
116-117	Roger Hayward

When you're really "in the soup"...

In weather like this, flying is no fun.

Visibility is *zero.* Your storm-lashed plane rocks and shakes as it beats into the blackness.

You rely on the pilot. And he relies on instruments — delicate mechanisms, every one of them — to bring you in to a safe landing.

How high? How low? How fast? How slow? The answers are all on the dials. The answers are accurate, too, because modern instruments are well protected from damaging vibration by devices called "shock mounts."

Shock mounts fashioned of conventional cushioning materials are satisfactory up to a point, but they were never perfect in every way.

Under constant vibration, some have a tendency to pack down and lose resiliency. Others are at the mercy of heat and cold . . . pick up dust, oil and moisture . . . or are attacked by bacteria and fungi. Obviously, something better had to be found.

A kitchen pot cleaner of knit Monel® mesh finally put searchers on the right track. The Metal Textile Corporation knitted it with different types and thicknesses of Inco Nickel Alloy wire . . . stretched it . . . compressed it . . . subjected it to test after test.

Knit metal mesh had none of the faults of its forerunners. Even when compressed, it retained a high degree of resiliency, for the knitted loops acted like thousands of tiny springs. Here at last was the answer!

Today, knit metal mesh that traces its origin to a pot cleaner, serves on many jobs once handled not nearly so well. In addition to shock mounts, knit metal mesh is found in air filters on carburetors, and as padding on pressing machines. It's used for straining and filtering fluids and gases — and RF, Shielding of electronic components.

Just let your own imagination run. With Monel wire you have a strong, non-rusting mesh structure that resists shock and impact, heat and cold, wear and corrosion. With other Inco Nickel Alloys, you can add extra strength, if that is needed, or electrical or thermal conductivity, or other desired properties.

Have you a metal problem that's really got you "in the soup"? Then bring it to us. We're always glad to help you find a solution. All you need do is write: The International Nickel Company, Inc., 67 Wall St., New York 5, N. Y.

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Moving mountains—
with an assist from SYNTHANE

Have you a mountain to move? This big bucket, aided by parts machined from Synthane laminated plastics, does the job easily and quickly.

You can't see these parts in the picture but earth movers use Synthane for its electrical insulating properties, wear resistance, and mechanical strength. These and other properties *in combination* make Synthane an essential in industry.

Electronic manufacturers "print" circuits on foil-clad Synthane sheets; aircraft designers approve Synthane's light-weight and strength; chemical people like its resistance to moisture, corrosives, solvents.

Synthane's combination of properties may give it a place in your product. Synthane is a light-weight material that holds its shape. It's tough, resilient—yet easily machined. It has good tensile, compressive, flexural, and impact strengths.

Are you planning a new product or ways to improve your present one? Consider Synthane. Write today for the Synthane Catalog. Synthane Corporation, 2 River Road, Oaks, Pa.

There are many kinds of plastics. Synthane belongs to a group called thermosetting, that is, stable over a wide temperature range. Synthane is sometimes called the "workhorse of plastics" since its *combination* of properties is especially valuable in industrial products, equipment or processes. The three principal forms —sheets, rods and tubes—are shown above.

Synthane in Earth Movers

Insulator and insulating bolts for power shovel

Pivot bearing of a motor grader, 11.434" O.D. x $2\frac{7}{16}$" long

Name plate for tractor and bulldozer generator

Synthane-one of industry's unseen essentials

SYNTHANE

S

OAKS PENNA.

LAMINATED PLASTICS

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR OCTOBER, 1953 VOL. 189, NO. 4

ARTICLES

DEPARTMENTS

What's Happening at CRUCIBLE

about Alnico Permanent Magnets

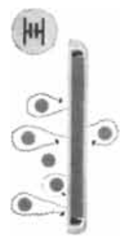
You will find Crucible Alnico Permanent Magnets in products ranging all the way from cuff links to magnatrons. Here are just a few unusual applications in which these magnets were used to simplify or improve a product.

This is Warren, age 4, a cerebral palsied youngster, using magnetic toys in therapy-play.

Magnetic Toys Cerebral palsied youngsters at the Children's Rehabilitation Institute, Cockeysville, Maryland, are unable to play with normal toys. Their lack of muscular coordination and control, causes ordinary blocks or toys to slip through their grasp and fall to the floor. Crucible helped overcome this problem by imbedding small permanent magnets in the toys. By using these magnet-equipped toys on metal topped tables, the children are able to control them much more easily.

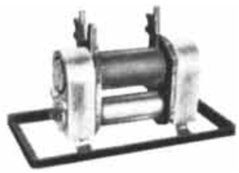
The Children's Rehabilitation Institute has pioneered techniques to help these handicapped children gain maximum muscular control and coordination. Experience at the Institute has shown that the use of magnetized toys helps develop coordination in hand and arm use, and in grasping and releasing.

Cuff Links One manufacturer of cuff links had a happy idea. He replaced the stem with a magnet assembly designed by Crucible magnet engineers. The tiny, powerful aspirin-sized magnets used, gave the finished product a holding force at the pole plate as high as 80 ounces troy.



Enlarged cross section view of one cuff link.

Telescriber-Recorder In one application, for this instrument that transmits written messages over wire, two permanent magnets were being used to match the electromagnetic fields. Assembly time and unit costs were high. Crucible magnet specialists designed one permanent Alnico magnet to replace the two. Magnet costs were cut 50% . . . and efficiency of the unit was increased.



Top bar Crucible Alnico; lower bar (replacing former 2nd magnet) provides return path.

Engineering Service Available

Perhaps your magnet problems are entirely different from these. Whatever they may be, our staff of magnet and electronic engineers will be glad to tackle them, and to work with you in meeting your magnet requirements. Don't hesitate to call us when you have an application for permanent magnets.

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SCIENTIFIC AMERICAN

OCTOBER, 1953 VOL. 189, NO. 4

Algae as Food

The one-celled plant Chlorella may become an important part of the world's food supply. An account of the first, promising attempts to grow it economically on a mass scale

by Harold W. Milner

Every bite of food that man eats can be traced back to plants. The chlorophyll-containing plant is the only form of life that can live on a strictly inorganic diet. It manufactures the organic food on which animals depend from carbon dioxide, water and mineral salts. The plant accomplishes this by using the power of sunlight. Thus the primary source of man's food really is solar energy, and whether the expanding human race will be able to feed itself will depend in the last analysis on how efficiently we can use that energy.

Our present system of agriculture is grossly inefficient in this respect. First of all, the best crop plants use barely two per cent of the sunlight that falls on them; most utilize only half of 1 per cent. Secondly, farm crops cover only part of the ground and generally for only part of the year. Thirdly, half or more of a crop plant is not edible but consists of cellulose or other indigestible material. So we have three opportunities for improvement. What we would like is a food plant that would (1) use a higher percentage of the solar energy falling on it, (2) catch more sunlight by covering all of the growing area throughout the year, and (3) produce a minimum of inedible material and a maximum of food substance—proteins, carbohydrates and fats.

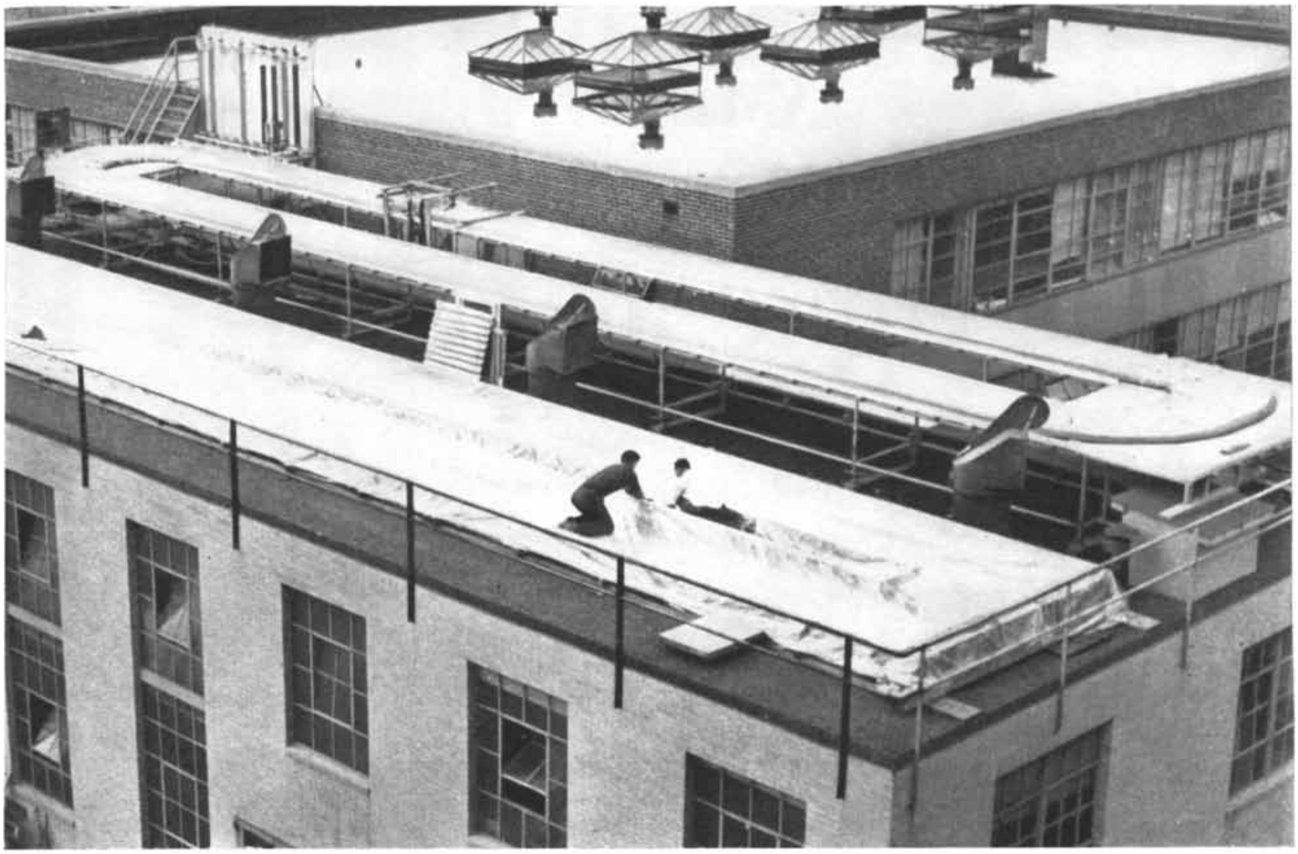
This outline of the problem explains why so many scientists all over the world are interested in the food possibilities of the water plants called algae. Here is a kind of plant that promises to combine all three of the improvements we want. Algae can be grown under controlled conditions to catch all the sunlight falling on an area and to use it far more efficiently than the ordinary crop plant can. A single-celled alga has relatively little purely structural material: most of its substance can be converted into food. In fact, under controlled conditions single-celled algae can be grown to yield almost any desired percentages of protein and fat.

The most promising alga found so far is the genus called Chlorella. It is the fastest growing of the single-celled green algae. And it responds with remarkable versatility to variations in culture conditions. H. A. Spoehr and I, experimenting with a species of Chlorella at the Department of Plant Biology of the Carnegie Institution of Washington, found that by varying the conditions we could grow batches of the organism consisting of anywhere from 7 to 88 per cent protein (dry weight), 6 to 38 per cent carbohydrate, or 1 to 75 per cent true fat.

On the basis of laboratory experiments it is estimated that each acre given to cultivation of Chlorella could produce 40 tons (dry weight) per year. Under the conditions favoring this rapid growth the composition of the plant is about 50 per cent protein and 7 per cent fat. Hence the annual yield of these scarce and highly valued foods would be 20 tons of protein and three tons of fat per acre—astronomical figures compared with present rates of production in conventional agriculture.

The palatability and nutritional value of Chlorella as human food have not yet been extensively tested, but there is no reason to suppose that it would fail in these respects. A demonstration of what can be done with this food was given at our laboratory recently by Mrs. H. Tamiya, the wife of a Japanese experimenter in growing algae, who was visiting the laboratory with her husband. Mrs. Tamiya prepared palatable breads, noodles, soups and even ice cream containing substantial proportions of Chlorella. Chlorella is rich in vitamins, seems to have all the essential amino acids and contains fats not very different from those in common use. Chlorella protein compares very favorably with other plant proteins in feeding experiments on rats and chicks. In Venezuela patients in a leprosarium were fed an algal soup for a considerable time, and it was both palatable and nutritious.

Whether algae can be an important contribution to the world food supply will depend on the cost and the yield of large-scale culture. Algal farming is water farming. The plant will have to be grown in huge tanks or tubes or other containers exposed to sunlight. The cultivation problems can be considered under two headings: first, light and tem-



PILOT PLANT for the mass culture of Chlorella was set up by Arthur D. Little, Inc., of Cambridge, Mass., on the roof of one of its buildings. Two 160-foot polyethylene tubes (*see opposite*), which were employed in experimental test, are shown, one in operation.

perature conditions; second, the raw materials.

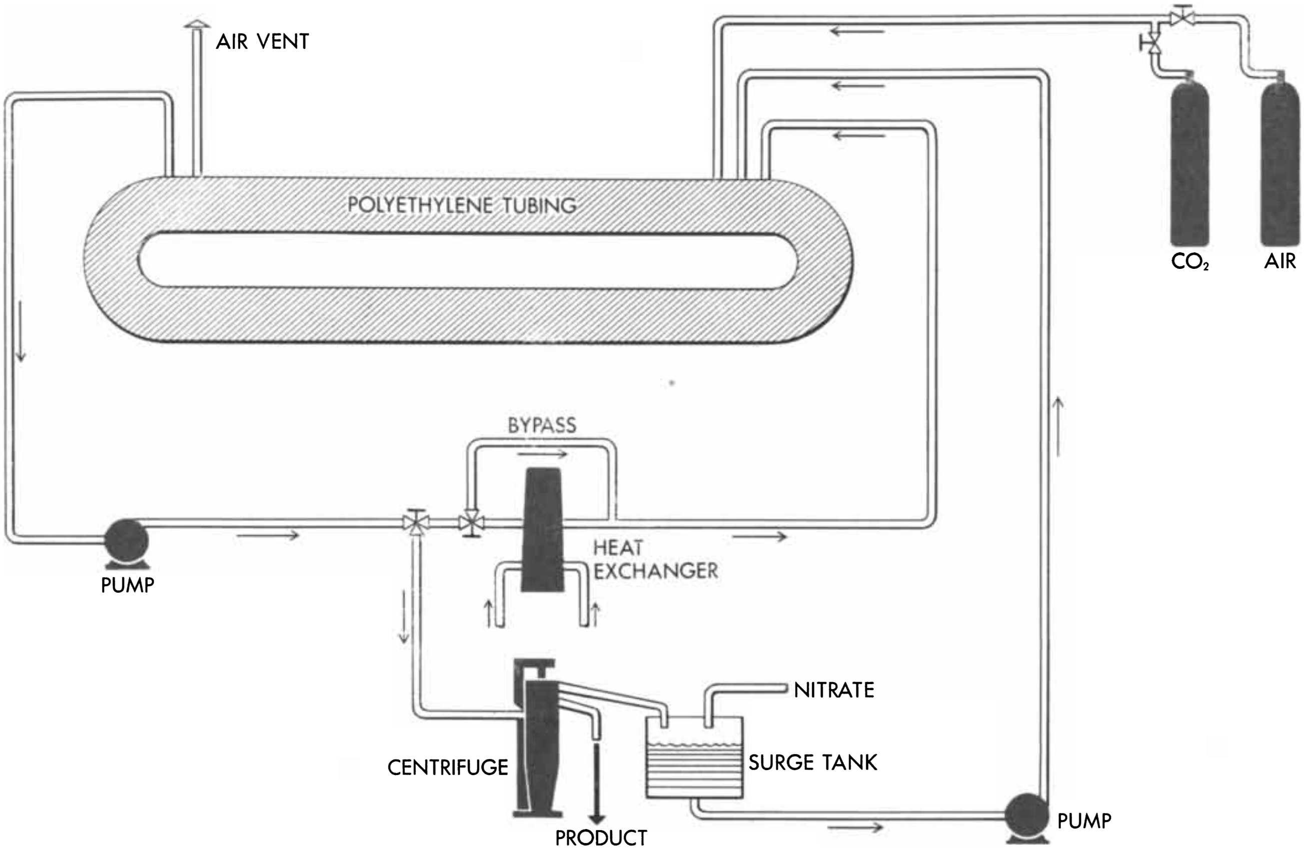
The question of efficient utilization of light is of paramount importance. Efficiency demands that all the light be absorbed. However, the plant uses only part of the absorbed sunlight for growth; since the rest is converted into heat, provision must be made for cooling the culture. The culture must also be so arranged that its cells will receive the optimum intensity of sunlight. This is not a simple problem, because the algal cell responds to different intensities of light in conflicting fashion, from our point of view. Its use of light for manufacturing organic material is most efficient when the light is dim; at low intensities the cell can convert as much as 25 per cent of the light energy into chemical energy stored as organic matter. But in dim light the growth of the plant is relatively slow. It grows fastest in brighter light; yet here the efficiency of energy conversion diminishes. At around 500 to 1,000 foot-candles there is a saturation point beyond which more light will not increase growth and will still further reduce the efficiency of energy utilization. Hence we want the cells within the culture illuminated at some compromise intensity. The maximum yield is produced by a culture which is dense enough to grow efficiently and rapidly but not so dense or deep that it shuts off light from many cells.

Key factors in the mass culture of Chlorella were studied in the laboratories of Tamiya and his co-workers at the University of Tokyo, of J. E. Myers and associates at the University of Texas, of the Stanford Research Institute and elsewhere. This background of information was used in the design of outdoor units to test the feasibility of large-scale culture of algae. Such tests are being made not only in the U. S. but also in England, Germany, the Netherlands, Israel, Japan and Venezuela.

One of the main problems in the engineering of these units is the critical relation between the density and the depth of the culture. We can maintain the density at any desired level by continuously harvesting the grown algae. For a good yield the density should be kept fairly high. But this means that cells deep in the culture get too little light while those near the surface get too much. This state of affairs can be improved by stirring the culture. Stirring not only gives the cells more uniform illumination but also makes the nutrient materials in the culture more accessible to them. At our laboratory in the Carnegie Institution Department of Plant Biology we have experimented with various devices. E. A. Davis and C. S. French were able to increase the yield of Chlorella 70 per cent by using a stirring apparatus. As for the question of density *v.* depth, our experiments showed that a dense, shallow culture gave a better yield, per liter, than a sparse, deep one. Davis pumped a dense culture through coils of plastic and glass tubing with a 7.5-millimeter bore. I experimented with a dense culture 17 millimeters deep in a shallow, rocking tray. These devices yielded more growth of Chlorella per liter of culture than did low-density cultures 30 centimeters deep in five-gallon bottles.

In these experiments the temperature control was poor. With more accurate temperature control I was later able to increase the yield threefold. The best results were obtained when the temperature was kept at 86 degrees Fahrenheit by day and 68 degrees at night.

The cooling problem would be serious in a hot climate or where water is scarce.



SCHEMATIC DRAWING of pilot plant shows the complete culture system. Polyethylene tubing, through which the algae were exposed to sunlight, held 1,200 gallons of solution in a layer three inches thick. Carbon dioxide and nitrates are food for the plants.

But it may be overcome by cultivating strains of Chlorella that thrive on heat. Myers and his Texas colleagues have found a strain which grows best at a temperature of 102 degrees.

Incidentally, this suggests a means for solving other problems. By producing mutations of algae artificially, it may be possible to create forms of algae to fit various cultural conditions.

Let us turn now to the question of raw materials. The three chief requirements are water, carbon dioxide and fixed nitrogen. Among the great attractions of algal farming is that it requires no soil, no rain, no spraying with insecticides, no laborious cultivation. No great amount of water is needed, because the water can be used again and again. Thus algae can be farmed in semi-arid regions and other places where conventional farming is impossible. Moreover, this is a crop that can be harvested continuously all year round.

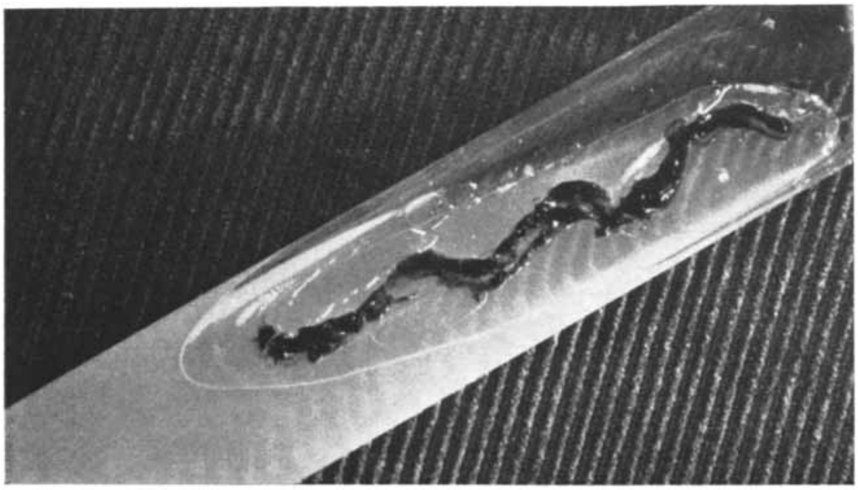
The culture of algae will require a concentrated source of carbon dioxide. About two tons of carbon dioxide are needed to produce each ton of dried algae. It seems impracticable to try to get the carbon dioxide from the air, because the atmosphere contains so little (.03 per cent) that enormous volumes of air would have to be pumped through the culture. F. Gummert in Germany has studied the possibility of culturing algae in open ditches charged with carbon dioxide from the waste gases of the industrial Ruhr. But there was some trouble from bacterial contamination of the product, and both the efficiency of light absorption and the yields were low. While these disadvantages might be more than offset by the low investment required, closed systems for the culture of algae seem more promising.

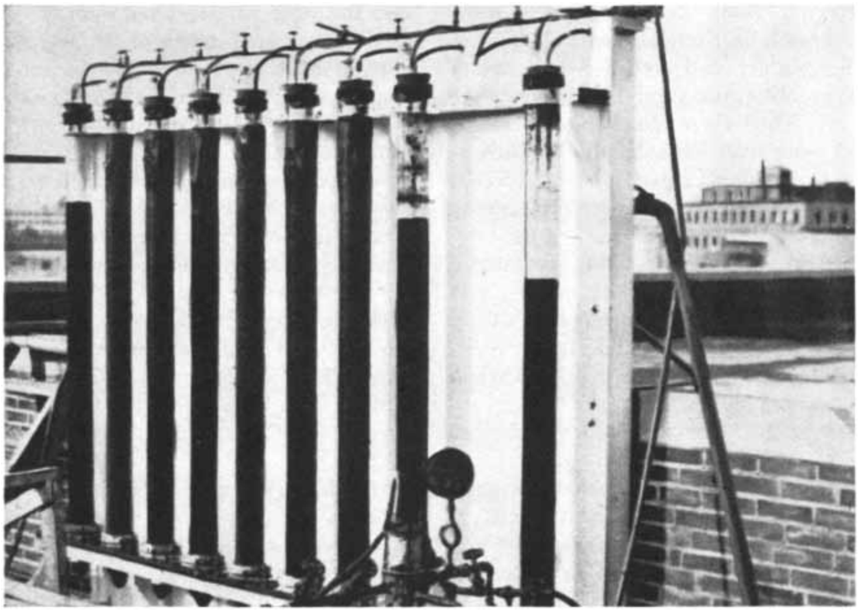
In most of the experiments I have described, a supply of air containing about 5 per cent carbon dioxide was bubbled through the culture. M. J. Geoghegan in England has experimented with concentrations of carbon dioxide as high as 20 per cent. This concentration, and perhaps even higher ones, can be used with good results provided the carbon dioxide is supplied no faster than the algae consume it.

Fixed nitrogen would be supplied to the algae in a form such as is used in fertilizers. The production of each ton of algal protein requires about 1.1 tons of potassium nitrate, .75 ton of ammonium sulfate or .2 ton of ammonia. There is a voluminous literature on the mineral requirements of algae, and the proper "diet" for each type of alga would have to be carefully worked out. To conserve minerals, as well as water, the culture medium should be recycled after the algae are harvested from it.

Of the several trials of large-scale cultivation of algae made so far, the simplest was carried out by J. Jorgensen and J. Convit in Venezuela. They grew a mixture of algae in a solution of commercial fertilizer in open, unglazed clay bowls, each holding about 15 quarts. Evaporation of water from the porous bowls kept the culture temperature below 80 degrees F., even under the tropical sun. Every day the evaporated water was replaced and the cultures were stirred. The harvest was a "soup" containing about 10 per cent by volume of algae.

In the U. S. the most extensive investigation of algal mass culture was made in a pilot plant operated by Arthur D. Little, Inc. at Cambridge, Mass., for the Carnegie Institution of Washington. Chlorella was grown outdoors in types of equipment suitable for expansion to



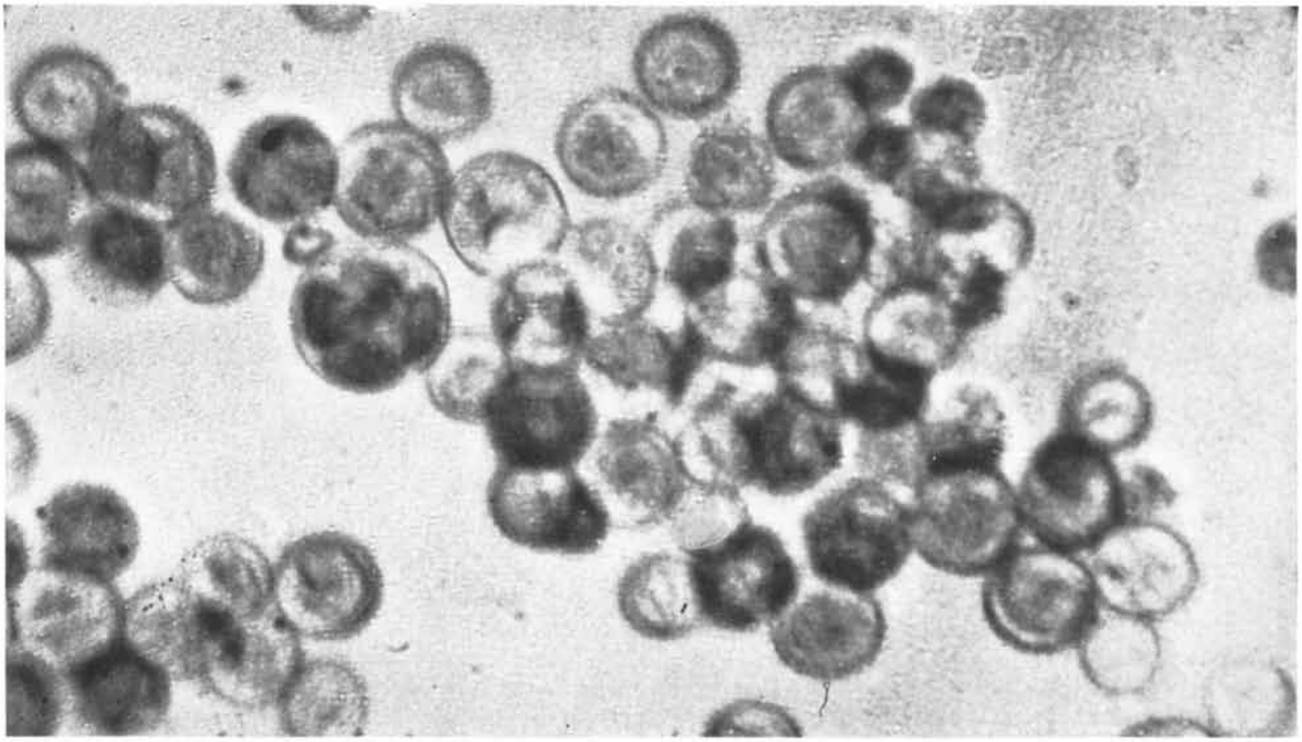


STEPS IN PREPARING ALGAE for pilot plant are shown above. Original culture in agar (*top*) was transferred to rocking flasks (*center*) and then outdoors to pyrex tubes (*bottom*).

large-scale commercial methods. The first culture unit was a broad, flat, thin-walled tube made of polyethylene. It was four feet wide and a few inches high. A 160-foot length of the tubing held 1,200 gallons of culture in a layer two to three inches deep. This arrangement exposed about 600 square feet of surface to the sun. Air containing 5 per cent carbon dioxide was pumped through the tube over the culture. A centrifugal pump circulated the culture through the tube and by-passed part of it through a heat exchanger to control the temperature. The Chlorella was harvested in a centrifuge. During the three months of operation of this unit the yield averaged about one third of an ounce per square yard per day—roughly equivalent to 16 tons per acre per year.

Thus the best large-scale yields so far are about half the estimated potential of 40 tons per acre per year. Even so, the production of protein and fat and the efficiency of light utilization are well above those of conventional crops. Current estimates are that algae could be mass-produced at 25 to 30 cents a pound. On the basis of cost per pound of protein, this is not far out of line with the cost of present high-protein feeds. If the yield could be doubled and the cost cut in half, algae would immediately become highly competitive with farm produce in a free-economy market. Even at 25 to 30 cents a pound, they could have tremendous survival value to people in those areas of the world where the specter of famine is ever present.

It seems unlikely that algae farming will ever be a back-yard enterprise. The technical skill and the equipment required seem to put it in the mass-production class. Tests on a larger scale are needed to work out improvements in the mass-culture process. If they are successful, within a few years algae may begin to be an important supplement to mankind's food supply. As experience brings further improvements, algal culture may take over an ever larger part of the task of feeding the world. The algae offer possibilities not only as food but as industrial raw materials. Moreover, we must bear in mind that almost all the energy man uses is solar energy, converted into chemical energy by plants. In a century or two our planet's supply of fossil sunshine stored as oil and coal will be nearing exhaustion. Perhaps by that time man will be able to turn to algae to convert the sun's energy into the food and materials he needs to keep his civilization running.



CHLORELLA COLONY is shown magnified about 800 diameters. A little to the left of the center of the picture can be seen a cell which contains "autospores," or daughter cells. This photograph was made by Professor Harold C. Bold, of Vanderbilt University.

POLYETHYLENE TUBE in pilot plant is pictured in close-up. The space above the foaming culture is filled with a circulating mixture of air and carbon dioxide. The culture is about three inches deep and flows at the rate of three-tenths of a foot per second.

HIGH-SPEED RESEARCH AIRPLANES

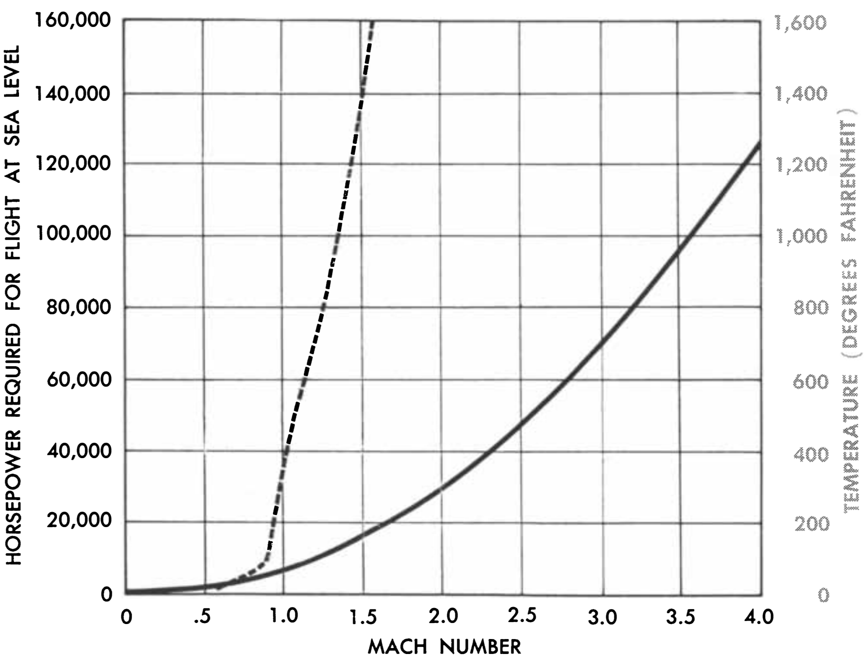
An account of what can be told in public about the investigation of flight at speeds beyond "the sound barrier" now being conducted by NACA in partnership with the military services and industry

by Walter T. Bonney

In 1936 a British aerodynamicist named W. F. Hilton gave a paper in which he discussed, among other things, the enormous power that would be needed to propel an airplane at supersonic speeds. He showed a graph plotting plane speed against the horsepower required. The curve rose very sharply at the speed of sound: to push a plane faster than this, it showed, 20,000 horsepower or more would be needed. Hilton observed that the power requirement looked "like a barrier against future progress" in the speed of flight.

This remark of Hilton, picked up by the press, may have been the origin of the phrase "the sound barrier." Test pilots, and fighter pilots in the early years of World War II, were soon to learn that there were other barriers, more frightening than the power requirement, near the speed of sound. Approaching this speed in dives, pilots found themselves buffeted by disastrous shock waves that sometimes tore the plane apart or froze the controls so that they could not pull out of the dive. The compressibility effects were at that time, hardly 10 years ago, very little understood.

Since then a whole series of fast research airplanes has been built, and at least two have flown faster than sound. Already aircraft manufacturers of the U. S. are busy constructing prototypes of the "hundred series" of fighter aircraft. At least one of this series, North American Aviation's F-100, has repeatedly attained supersonic speeds. The story of how man has broken through the sound barrier in the past 10 years is a story not only of daring pilots but of long, intensive laboratory research, carried on by U. S. industry, the military services and the National Advisory Committee for Aeronautics. Much of the story is still a military secret, but this article will give a brief account of the facts which are not secret. It will concentrate mainly on the high-speed experimental airplanes, the "research" planes, that have tested the power and aerodynamic devices by which science and technology have overcome the sound barrier.



"THE SOUND BARRIER," represented by dotted line, is the enormous increase in horsepower (*see scale at left*) required to drive airplanes above the speed of sound (Mach 1.0). Heating of airplanes at still higher speeds (*scale at right*) presents a barrier beyond.

The speed of sound varies with temperature, but it is usually given in terms of altitude because temperature varies with altitude. At sea level (59 degrees Fahrenheit) sound travels at about 760 miles per hour; at 40,000 feet (70 degrees below zero F.) its speed is about 660 m.p.h. An airplane flying at less than the speed of sound sends tiny signals ahead which in effect warn the air molecules of the oncoming object. But the signals travel only at the speed of sound, and an airplane which flies at this or greater speed piles up the unprepared air into shock waves and other disturbances. The most troublesome speed zone is the transonic—the range between 600 and 800 m.p.h.—where part of the airflow around the plane is slower than sound, part faster.

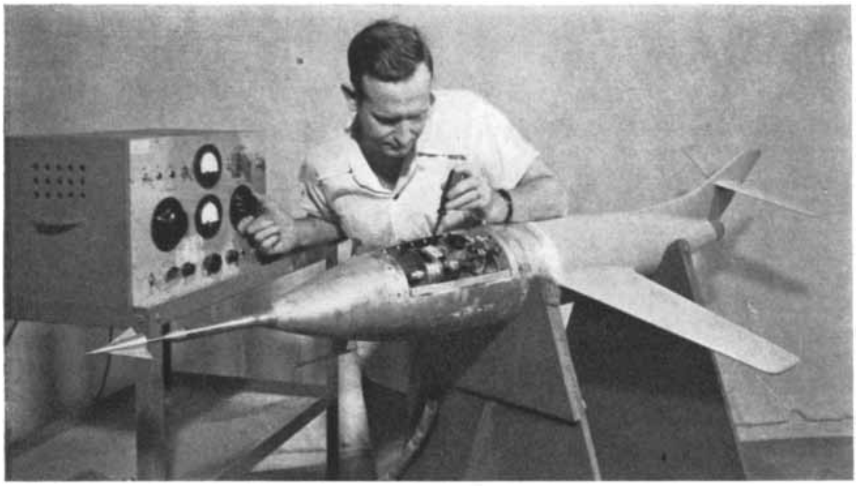
The problem of supersonic flight was twofold: power and aerodynamics. As everyone knows, the power problem was solved by turbojet and rocket engines. The best piston engine produces less than 5,000 horsepower, and the fastest piston-engine, propeller-driven plane can do little better than 450 m.p.h. The turbojet and rocket engines, in contrast, not only can produce more power but become more effective as the plane speed increases. The output of such an engine is rated in pounds of thrust: *viz.*, at 375 m.p.h. one pound of thrust is the equivalent of one horsepower, at 750 m.p.h. a pound of thrust equals two horsepower, at 1,025 m.p.h. it equals three horsepower.

The working out of the aerodynamic problem has been in many ways more difficult. For one thing, there were at first no adequate laboratory techniques for studying the effects of motion faster than sound. Wind tunnels suffered a "choking effect" at speeds approaching that of sound. Fighter planes were sent up with small airplane models mounted near the leading edge of the wing to record turbulence effects during a dive, but the information was only small-scale and the flights were dangerous. Falling bodies and rocket-propelled bodies were studied, but the electronic equipment required to obtain information during their flight was not then available. (Recording instruments developed in recent years have now made rocket-propelled models a valuable research tool.)

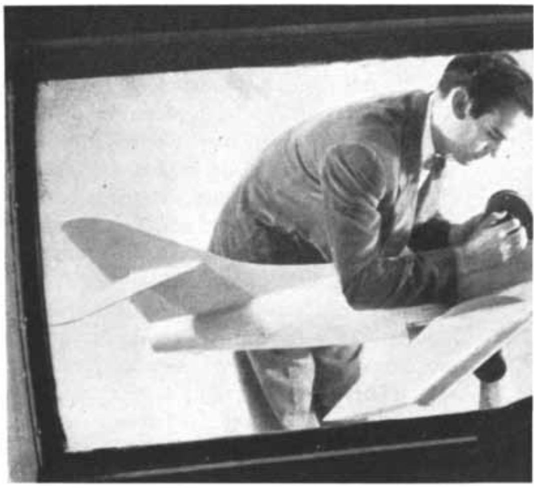
The wartime development of jet-propulsion and rocket engines suggested a new approach. During 1943 and 1944 representatives of the Navy, the Air Force and the N.A.C.A. discussed and finally decided upon a daring project: the building of full-scale research airplanes to study transonic and supersonic effects by flying at those speeds. The planes would be built as strong as necessary to resist shock waves, would go through the transonic range in level or climbing flight instead of in a dangerous dive and would fly at very high altitudes.

The Air Force awarded a contract to the Bell Aircraft Corporation to build a plane, originally designated XS-1, which became famous as the X-1. Its fuselage was shaped like a .50-caliber bullet, and it had very thin, straight wings to minimize compressibility effects. To power this craft the Navy made available a rocket engine designed and built by Reaction Motors, Inc. It burned liquid oxygen and an alcohol-water mixture,

SKYROCKET holds announced speed and altitude records in N.A.C.A. research program. Note vertical fins, "fences," on wings, added to cure plane's tendency to roll at high speeds.



MODEL OF SKYROCKET is here being instrumented for flight. Such models, powered by rocket or dropped from airplanes, provided data for speeds beyond range of wind tunnels.



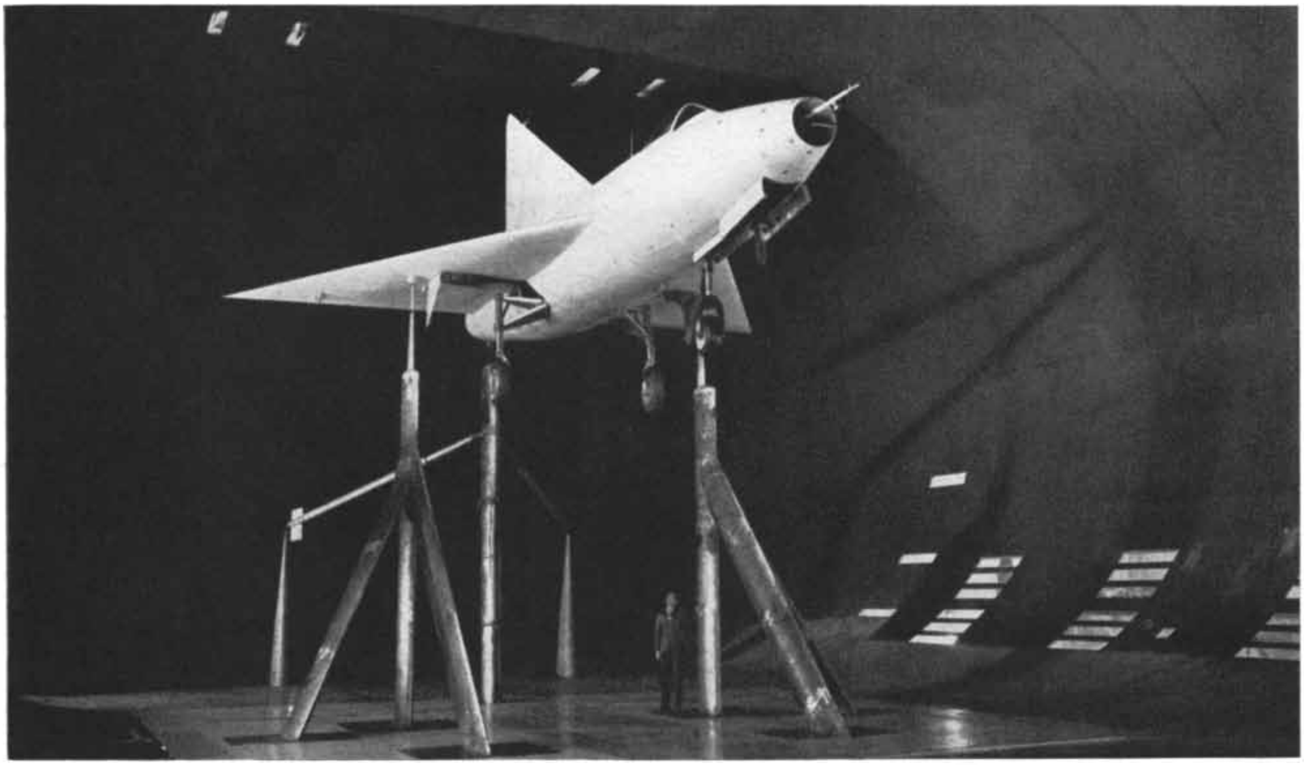
WIND TUNNEL MODEL of Skyrocket is fitted with "slats" on leading edge of wing.

and produced 6,000 pounds of thrust. The Air Force announced two versions of the X-1—one, with a design speed of 1,000 m.p.h., used a heavy-nitrogen pressure fuel system; the other, to be equipped with a turbopump enabling carriage of more fuel, was designed to reach 1,700 m.p.h. at 80,000 feet.

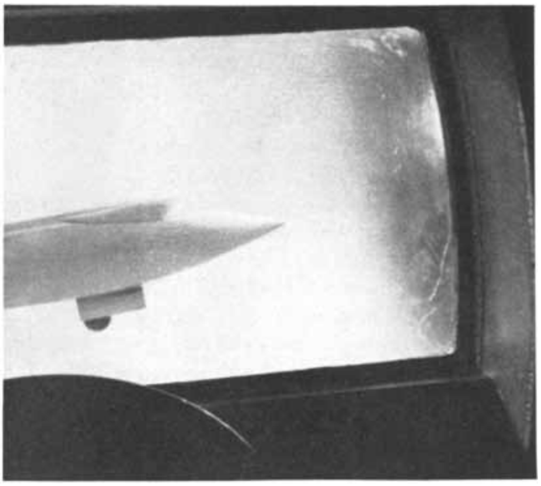
At the same time the Douglas Aircraft Company received an assignment to build two aircraft. The first was the Skystreak, or D-558-I. Powered by a General Electric turbojet engine, it was designed to fly a little short of the speed of sound—in 1947 it reached 650 m.p.h. Its wings were straight and of conventional thickness. The second airplane was the Skyrocket, D-558-II, powered both by a Reaction Motors rocket engine similar to that used in the X-1 and by a Westinghouse turbojet. It had swept-back wings, testing this design as an alternate solution of compressibility troubles.

The series of high-speed research aircraft was later expanded to include the Bell X-2, the Douglas X-3, the Northrop X-4, the Bell X-5 and the Consolidated XF-92-A. Recently a Boeing B-47 bomber has been specially instrumented for similar use.

Some of the design and construction problems were difficult indeed. For example, the X-1 was required to withstand forces 18 times that of gravity, compared to the 12 G required of conventional fighter craft. Its wings were fabricated out of plates about half an inch thick at the wing root. A power-operated, "all-movable" stabilizer was specified for use in the event that elevator forces became too great for the pilot



AMES WIND TUNNEL at Moffett Field, California, is big enough at throat to handle a full-size airplane for low-speed performance tests. This is the delta-wing Convair XF-92-A. Motion of plane in air stream is transmitted via tripod mount to instruments outside.



These were tested and added to airplane, after it had been flown, to improve stability.

TEST FLIGHT of Skyrocket at low altitude over Muroc desert is monitored by battery of instruments (*right*). Airplane is formally designated D-558 II, and was built by Douglas.

to handle. Because the first version carried so little fuel that it flew for less than three minutes, a Boeing-29 "mother ship" took it aloft and launched it at 30,000 feet or so. This procedure of air launching was later adopted for the Skyrocket.

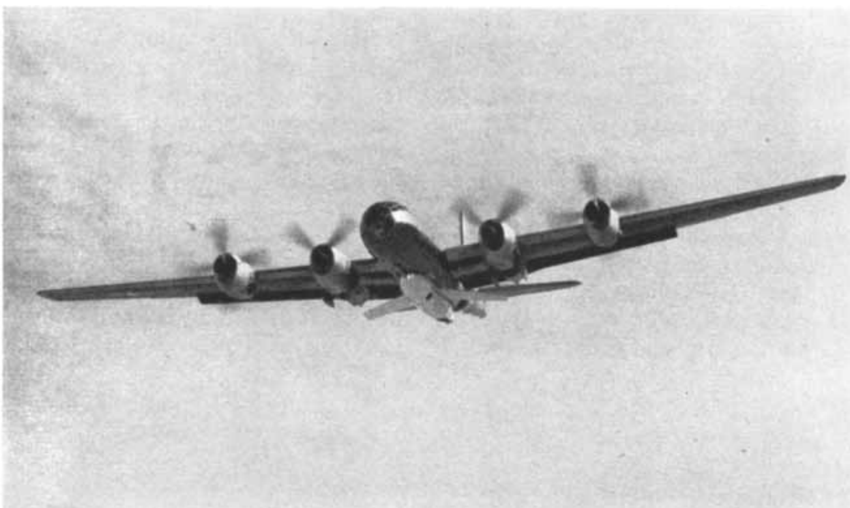
The Northrop X-4 tested a tailless design, especially with respect to stability and control troubles encountered by high-speed fighters. The Convair XF-92-A was a delta wing design, originally conceived for Air Force use but transferred to the research airplane program when the Air Force decided to wait a little before putting so radical a plane into service. Fitted with an Allison turbojet engine, it has been used to explore the possible aerodynamic as well as structural advantages of a triangular-shaped wing.

The Bell X-5 was fitted with an adjustable wing whose sweep could be varied in flight from 20 to 60 degrees. The idea of changing wing-sweep in flight isn't, by itself, especially new. The theory is that a straight-edge wing is desirable during the slow speeds of take-off and landing and at very high speeds beyond Mach 2 (twice the speed of sound).

Relatively little may be said about the Bell X-2 and the Douglas X-3. The former, financed by the Air Force, is of stainless steel construction, with sharp-edge swept wings. It is powered by a rocket engine constructed by Curtiss-Wright. Last spring an X-2 was taken over Lake Ontario by its mother ship for fuel-system tests. There was an explosion. The pilot, "Skip" Ziegler, and a member of the B-29 crew were killed. Construction of a second X-2 is continu-

N.A.C.A. RESEARCH AIRPLANES are assembled at Moffett Field for a family portrait. From left to right, they are the Douglas Skyrocket, D-558-II, and Skystreak, D-558-I; Convair XF-92-A (*center, rear*); Northrop X-4 (*center, forward*); and Bell X-1 and X-5.

MOTHER SHIP, a modified B-29 bomber, is lifted high on jacks and the Skyrocket is wheeled underneath for pickup preparatory to a high altitude launching on a research flight.



ALOFT, the Skyrocket is carried in belly of mother ship. Skyrocket's gas turbine, with jet assistance, can get it off ground; rocket engine then takes over to attain maximum speed.

SKY LAUNCHING permits maximum utilization of Skyrocket's brief flight range in research flying. With fuel exhausted the airplane can come down at reasonable landing speed.

ing. The X-3, financed jointly by the Air Force and Navy, has made initial flights at Edwards Air Force Base, Muroc, California.

The Boeing B-47 Stratojet, which joined the research airplane group only this year, is being used to investigate the interrelated aerodynamic and structural problems associated with high-speed flight of large aircraft.

Use of the research airplanes has followed a definite pattern. First the new craft is put through a series of flights by its builder to satisfy minimum performance guarantees. In the case of the X-1, Bell Aircraft had only to demonstrate it could be flown at eight tenths of the speed of sound (Mach .8). Next come maximum performance flights, with either service or company pilots at the controls. Finally the aircraft is turned over to the N.A.C.A. for methodical, unspectacular investigation of the specific aerodynamic problems for which the airplane was principally intended.

On October 14, 1947, Captain Charles Yeager of the Air Force flew the X-1 supersonically. This was the first time such speed had been reached. Later the Air Force said that the X-1 had flown "hundreds of miles" faster than the speed of sound, but its top speed has never been divulged. In August, 1951, the Skyrocket, with Douglas Aircraft's William Bridgeman as pilot, reached a speed of 1,238 miles per hour, according to a Navy announcement. Bridgeman was also credited with having flown higher than man had ever gone—almost 80,000 feet. This summer Marine Colonel Marion E. Carl reached 83,235 feet in the D-558-II. These are the maximum performances of the research airplanes announced to date.

Yeager's historic flight was of immense psychological value: he demonstrated not only that the "sonic barrier" could be hurdled but that there was no special trick or danger involved in attaining supersonic flight.

But it is as information collectors that the research airplanes are most useful. Each research plane carries a quarter of a ton or more of instruments. Much of this equipment was specially devised by the N.A.C.A.'s instrument-makers over the years. It includes telemeters to radio back data to ground receiving stations, pressure-measuring devices and load-recording machines. The raw statistical information gained during a flight is later reduced to useful form for interpretation by aerodynamicists.

Paradoxically some of the ground-laboratory facilities which could not themselves provide the needed data on transonic problems proved useful in suggesting answers to questions arising during the design of the research airplanes. At the N.A.C.A.'s Langley Laboratory, for example, small models of the X-1 were studied in wind tunnels and in a spin tunnel. A wing-flow model was used, and still another model was built and instrumented for dropping. From such studies as these came valuable, if tentative, answers to design and construction problems.

At the Ames Aeronautical Laboratory a model of the XF-92-A was mounted in the world's largest wind tunnel, with a test section measuring 40 by 80 feet, for study of its landing and take-off characteristics. The X-3 was studied in a supersonic tunnel there. The Lewis Flight Propulsion Laboratory has investigated new power-plant problems, such as how to handle the great quantities of air required by a turbojet engine flying at supersonic speeds. The air must be taken into the induction system with minimum shock disturbance and must pass through the engine and out of the tail pipe in such fashion as to be used most efficiently.

The research planes of course are used to flight-test improvements designed to overcome faults demonstrated by their own performance. For example, when the Skyrocket reached its highest speeds it became laterally unstable. Bridgeman has graphically reported some of these control problems, mentioning violent rolls with the wings dipping as much as 75 degrees on a side at a rate of 86 degrees per second. These were difficulties which had been anticipated from theoretical and wind-tunnel research, but they could be thoroughly evaluated only in flight. Devices to alleviate these troubles are now being tried on the Skyrocket. One such modification is the "fence," a metal strip, attached to the upper side of the wing, which retards the tendency of air moving close to the wing surface to flow outward.

Another such design modification, on a different aerodynamic principle, is extension of the wings' leading edge. Wind-tunnel tests indicate that such extensions will improve stability, and the idea is being flight-tested by the Skyrocket. The same ship is trying out a third device for improving stability: a long slat mounted over the leading edge of the wing, permitting air to flow freely through the space between.

In recent years the N.A.C.A. has developed new wind tunnels with "ventilated throats" which permit transonic research under precise laboratory conditions. Despite improvements in the accuracy and versatility of this and other laboratory techniques, however, the information gained can be verified ultimately only by the actual flight of full-scale airplanes. Moreover, many problems related to loads, dynamics and operation are best investigated in flight.

FOG OF LIQUID OXYGEN surrounds Bell X-1 during fueling. Oxidizers needed in rocket airplanes, added to explosive fuels, multiply the accustomed ground hazards of aviation.

The research-plane program has cost millions of dollars and years of work by some of the nation's best aeronautical brains. Has it been worth the cost? The answer, without qualification, is yes. Unfortunately security prevents even the most casual outline of the valuable aeronautical information obtained. About a year ago Rear Admiral Theodore C. Lonnquest, then deputy and assistant chief of the Navy's Bureau of Aeronautics, disclosed that design information from the program had "already been used in Navy fighter models now flying, and will increasingly affect the design of newer and more advanced models. . . . The Navy, in partnership with other members of the National Defense team, is convinced of the value, indeed the absolute necessity, of a vigorous program in the development and exploration of research aircraft as minimum insurance to keep the U. S. in the forefront of aviation progress." Similar comments have been forthcoming from the Air Force and from the aircraft industry.

Although the barrier of which Hilton spoke 17 years ago has been destroyed, a critical new problem has now arisen. Airplanes are flying at speeds which raise the danger of cooking their occupants because of the heat of friction. At Mach 4, the speed of some of the rocket missiles today, the skin temperature of a craft in sustained flight at 40,000 feet can rise to 900 degrees F. It gets seriously hot at speeds much slower than that—speeds at which planes have already flown for brief periods. Here may be a problem much more serious than that of breaking through the sound "barrier."

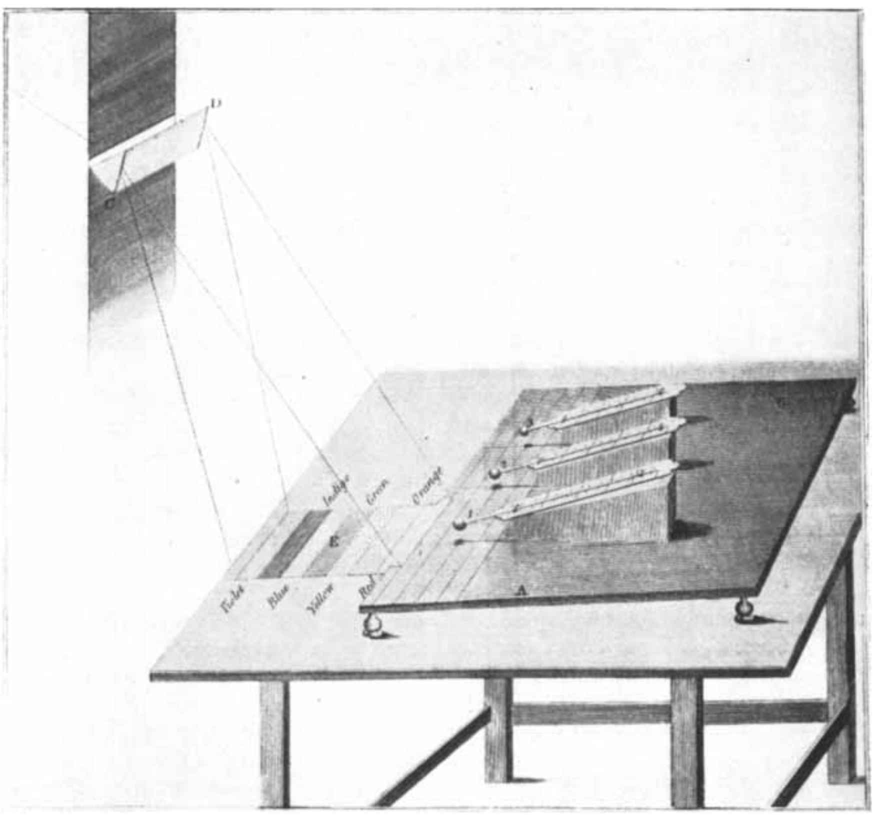
Chemical Analysis by Infrared

Electromagnetic waves make the atoms in a compound vibrate. The frequencies to which a substance responds can tell much about its structure and about the nature of chemical bonds

by Bryce Crawford, Jr.

Infrared spectroscopy has grown like a mushroom in the past 10 years. Before the war it was employed by only a few chemists and physicists, using home-built or custom-built infrared spectrometers. Now the instrument is a standard commercial item supplied by a competitive industry to chemical and medical researchers all over the country. More than 1,300 commercial infrared spectrometers, each representing an investment of two to six Cadillacs, are earning their way in scientific laboratories and industrial plants.

To an old-timer in the field—"old-timer" by virtue of having studied infrared as long as, say, 15 years—this burgeoning use of infrared by his colleagues is most gratifying, but hardly surprising. The power of infrared as a tool for chemical characterization and analysis has been known for some 20 years. The infrared spectrum of a substance is related to its chemical structure in a uniquely convenient way, and organic chemists have been heard to say that the infrared spectrum of an organic compound is its most important physical property.



FIRST INFRARED SPECTROMETER, improvised by Sir William Herschel in 1800, was the means by which he discovered infrared radiation. Thermometers placed in successive bands of solar spectrum registered more heat outside and beyond red region than within.

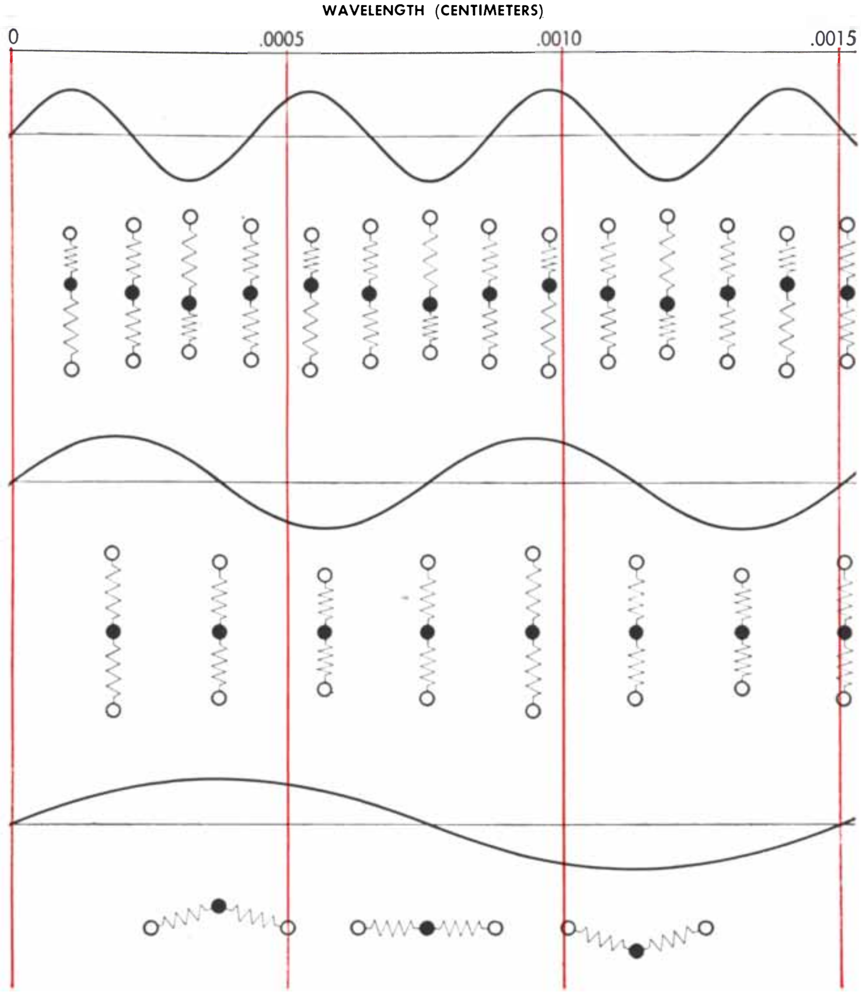
Infrared radiation itself was discovered more than 150 years ago, long before scientists had any clear understanding of radiation. Sir William Herschel, who started life as an organist at Bath and became an astronomer, made the discovery. In 1800 he reported to the Royal Society certain experiments in heat radiation. He resolved sunlight into its spectrum with a glass prism and placed a thermometer at successive positions in the spectrum. He found heat radiation not only in the visible spectrum but in the longer wavelengths beyond the red. Herschel even crudely measured the absorption of this radiation by various substances, including tap water, distilled water, sea water, gin and brandy. He could not know, could not even suspect, how revealing the absorption could be about chemical structure. Before anyone could appreciate the significance of infrared absorption, light radiation itself had to be understood. A century passed before the theory of the nature of light was worked out and the necessary techniques and instruments for infrared analysis were developed.

Sir William had found that the most intense heat radiations were outside the visible part of the spectrum. Consequently for many years it was believed that heat and light were two quite different radiations. But some 35 years later Sir William's son, Sir John Herschel, and other investigators advanced the idea that heat and light might merely be different manifestations of the same radiation—that is, light waves of different wavelengths. Before the end of the century James Clerk Maxwell had shown theoretically and Heinrich Hertz had proved experimentally the essential identity of light, heat and other electromagnetic radiation.

The infrared region, as spectroscopists usually define it, lies between the visible and the radio portions of the spectrum—that is, the wavelengths between one thousandth of a millimeter and one millimeter. (Infrared of course is not synonymous with the common meaning of the word "heat," for, as we have seen, there are heat radiations in the visible part of the spectrum.) The region most useful to the chemist is the range of wavelengths from 2 to 20 microns (thousandths of a millimeter). This is sometimes called the vibrational region.

We shall confine ourselves to this region and to considering how absorption spectra in it give information about matter. The other infrared regions, and the physics of the radiation itself, are just as interesting: it was in the near infrared that Max Planck, by instinct and gentle nature one of the most classical of physicists, was led to the disturbing idea of the quantum, which upset the whole beautiful pattern of 19th-century physics. But we cannot cover the whole subject of infrared in one article.

The chemically useful study of infrared absorption spectra was really begun in 1903 at Cornell University. A graduate student named William W. Coblentz, under the physics professor Edward Nichols, had undertaken research on infrared absorption. After improving the available experimental techniques, he received an appointment as a research associate of the Carnegie Institution of Washington, which enabled him to set about measuring absorption spectra of pure substances. He mapped spectra for two years and in 1905 published a collection of accurate infrared absorption spectra for 131 substances. Even today, after 48 years of improvements in infrared technique (to which Coblentz himself contributed much until his retirement from the National Bureau of Standards in 1945) the monumental work that he did at Cornell still stands worthy of study. Subsequent studies have confirmed more than they have corrected Coblentz's observations.



VIBRATION OF MOLECULAR BONDS accounts for selective absorption of infrared energy by various compounds. Each of three modes of vibration of carbon dioxide bonds shown here is resonant to infrared at wavelength indicated. Energy is absorbed, however, only by modes at top and bottom, which disturb geometric and electric symmetry of atom.

When sunlight falls upon a green leaf of a tree, the leaf absorbs the red wavelengths of the light and reflects the green wavelengths: this is what gives the leaf its color. The absorption tells something about the leaf's molecular composition. Essentially the same principle is involved in studying infrared absorption, except that the radiation is not visible; if our eyes were attuned to the infrared, we could recognize a compound by its characteristic color. Instead we measure its absorption of heat. Infrared radiation is passed through a solution of a compound, and the compound characterizes itself by the wavelengths it absorbs and those it transmits. Each compound has its own absorption spectrum.

The absorption of infrared is due to some disturbance within the molecule; this Coblentz established by observing that he got different spectra from isomers—molecules which are composed of the same atoms but in different arrangements. Coblentz found further that certain subgroupings of atoms within molecules identified themselves by absorbing characteristic wavelengths: for example, phenyl compounds, containing the benzene ring, absorbed at 3.25 and 6.75 microns, while mustard oils, containing the thiocyanate group, absorbed at 4.78 microns. These absorptions were additive: in phenyl mustard oil Coblentz found "the characteristic vibration of the mustard oils superposed upon the vibration of the benzene nucleus." He concluded that "there is a something—call it 'particle,' 'group of atoms,' 'ion' or 'nucleus'—in common, with many of the compounds studied, which causes absorption bands that are characteristic of the great groups of organic compounds, but we do not know what that 'something' is."

With half a century's progress since Coblentz, we now have a clear idea of the "something." It lies in the bonds between the atoms in a molecule. These bonds are written in chemical formulas as single, double and triple lines connecting the atoms. As the Danish chemist Niels Bjerrum once said, they "summarize, in a very compact form, chemistry's knowledge of the creation and destruction of compounds. Nowhere in science has a shorthand notation been developed which summarizes such an abundance of exact knowledge in so small a space." In 1914 Bjerrum showed that, if we think of the atoms as small masses and the bonds as springs holding the atoms together, we can account correctly for the vibrational behavior of molecules, as observed in their infrared spectra and in their heat capacities.

The bonds hold the atoms in position fairly tightly, but not rigidly. The response of the atoms to a light wave is much like the response of cork balls, floating on a lake, to waves on the lake. As waves move past the ball, they push the ball alternately up and down. So a light wave moving past an atom sweeps an oscillating electric field over it, and if the atom carries an electrical charge it will be pushed first one way and then the other. Atoms in general do carry a charge, greater or lesser according to the molecule; thus in the hydrogen chloride molecule the hydrogen atom carries a small positive charge, the chlorine atom a corresponding negative one. Because of these opposite charges, the electric field of the light wave will push the two atoms in opposite directions, and will tend to set them into vibration, stretching and compressing the H-Cl bond alternately.

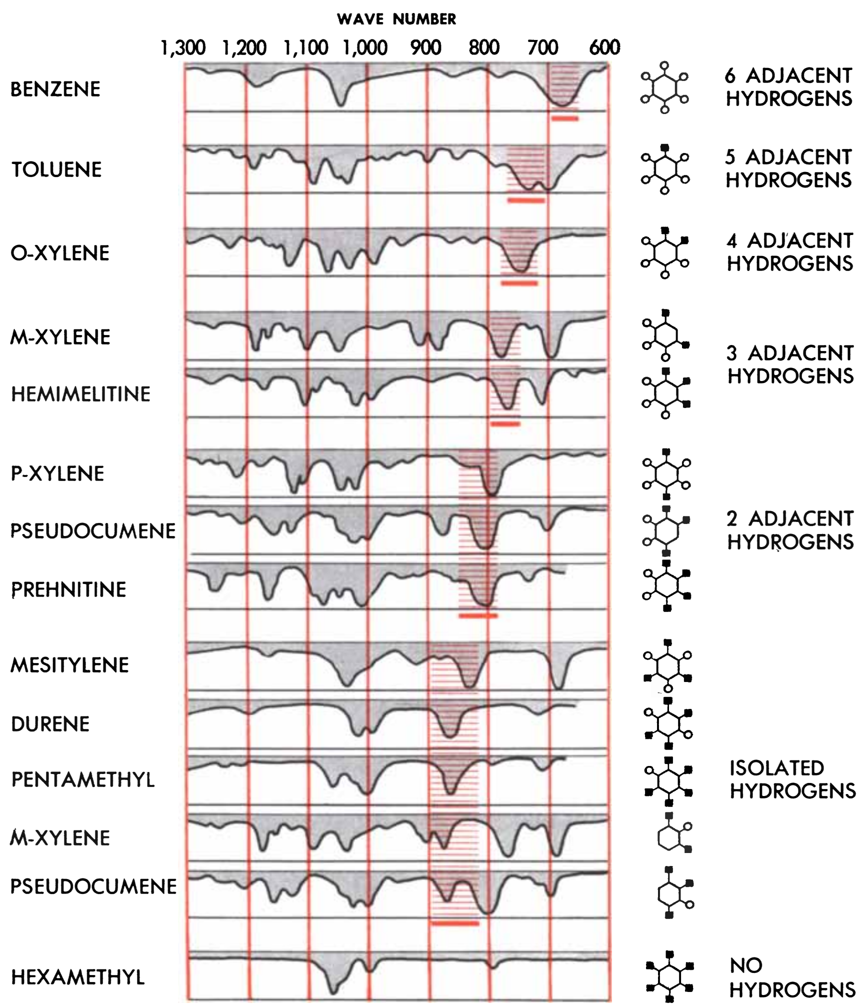
The bond has a natural frequency of vibration, determined by the masses of the two atoms and the restoring force of the bonds. A light wave with this frequency of oscillation will have most effect on the bond: its energy will greatly increase the natural vibrations of the atoms. The molecule will absorb part of the energy of the light at this resonant frequency, and an absorption detector will show an absorption peak for that wavelength.

To obtain the infrared spectrum of a sample, we illuminate the sample with infrared radiation of successive wavelengths from 2.5 to 25 microns and measure with the spectrometer the amount of light transmitted by the sample at each wavelength. A modern spectrometer automatically computes the percentage of the light transmitted at each wavelength and in 10 or 15 minutes produces a curve of transmittance against wavelength, or, more commonly nowadays, transmittance against frequency. Frequency, meaning the number of waves that sweep past per second, is easily computed from the wavelength and the speed of light. The measure of frequency is called the "wave number"—it is actually the number of waves in one centimeter of light beam. In the range of infrared that we are considering the wave numbers run from 400 to 4,000 per centimeter.

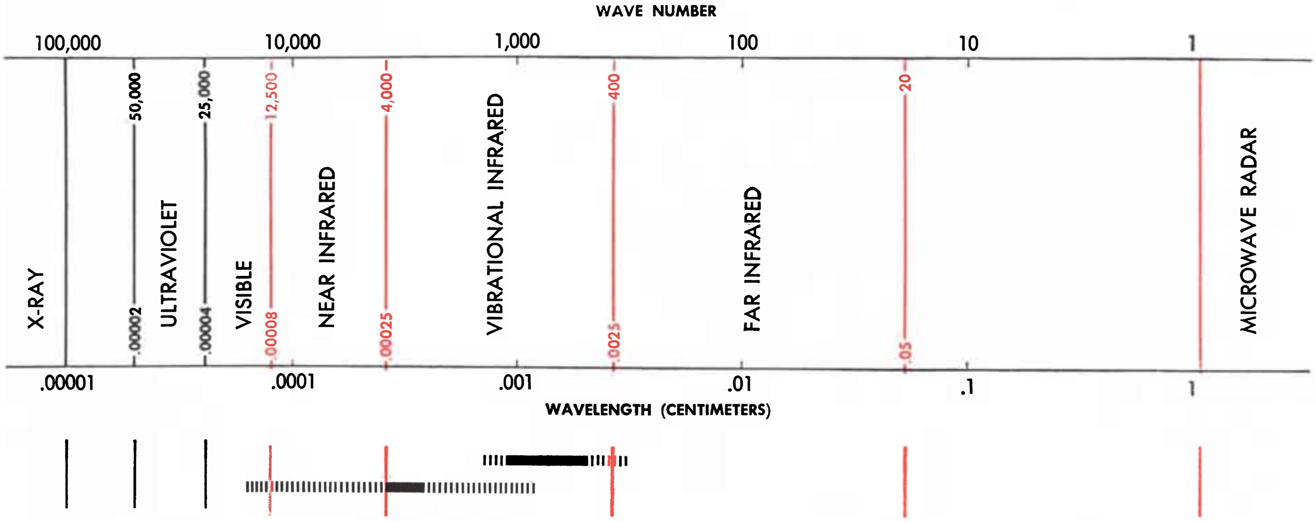
Modern atomic theory at once shows the chemical importance of the frequency of absorption. Atoms and molecules absorb light in quanta, the energy in each quantum being proportional to the frequency of the light. The absorbed energy is in fact Planck's constant h times the frequency, or hc times the wave number. Einstein enunciated the principle that, when molecules absorb light, each quantum is wholly absorbed by one molecule.

Now a molecule can safely absorb only so much energy: chemical bonds are not unbreakable—and a good thing, or there'd be no chemistry! The energy required to break the bonds is known fairly accurately; it is comparable to the energy of a quantum of ultraviolet or visible light. When a molecule absorbs such light, the bonds are either broken or profoundly altered, and the "excited" molecule is a very different entity from the original. The deduction of atomic structure from ultraviolet spectra has been compared to deducing the structure of a piano from the sounds emitted as it falls down a flight of stairs.

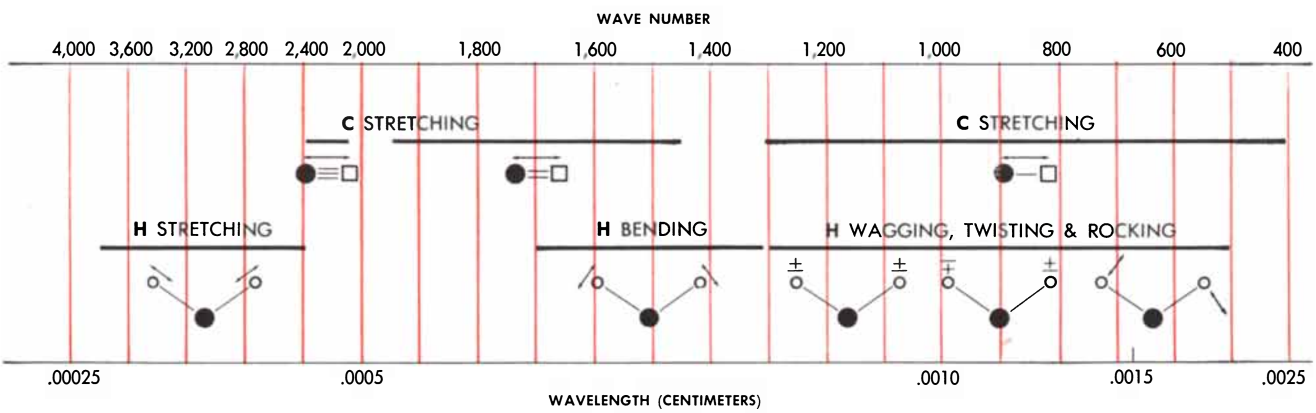
The absorption of a quantum in the infrared, on the other hand, is not so rough a process. At these wavelengths a quantum of energy is only about one twentieth that in the ultraviolet. Hence the radiation merely sets the bond into vibration. In infrared spectroscopy we don't push the piano down the stairs,



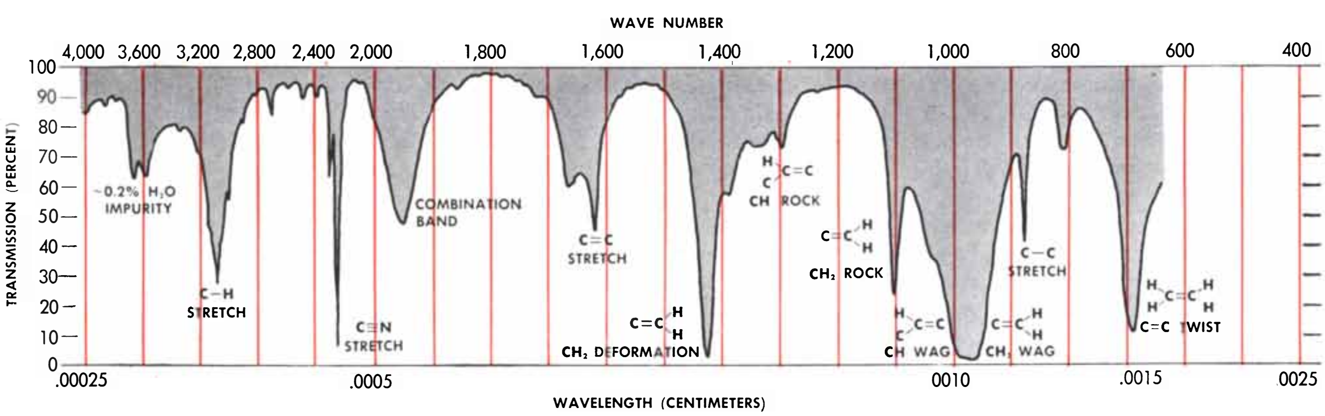
RELATED FAMILY of compounds, the methyl benzenes, exhibit both an over-all similarity and distinctive differences in their infrared spectra. The absorption dips which are marked in red are due to hydrogen wagging (see middle diagram on the facing page). The hydrogen atoms are vibrating in and out of, in a direction perpendicular to, the page surface.

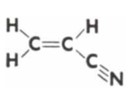


ELECTROMAGNETIC SPECTRUM is diagrammed above. Wave number means the number of wavelengths per centimeter and is proportional to frequency. Wave numbers from 400 to 4,000 have the right frequency to excite molecular vibrations. Bars below locate concentrations of heat radiation from a black body at 80 degrees F. (*upper bar*) and 1,800 degrees (*lower*). In each bar 50 per cent of the total heat energy is in the black sections, 40 per cent in the broken section, and the rest tapers off from the ends.

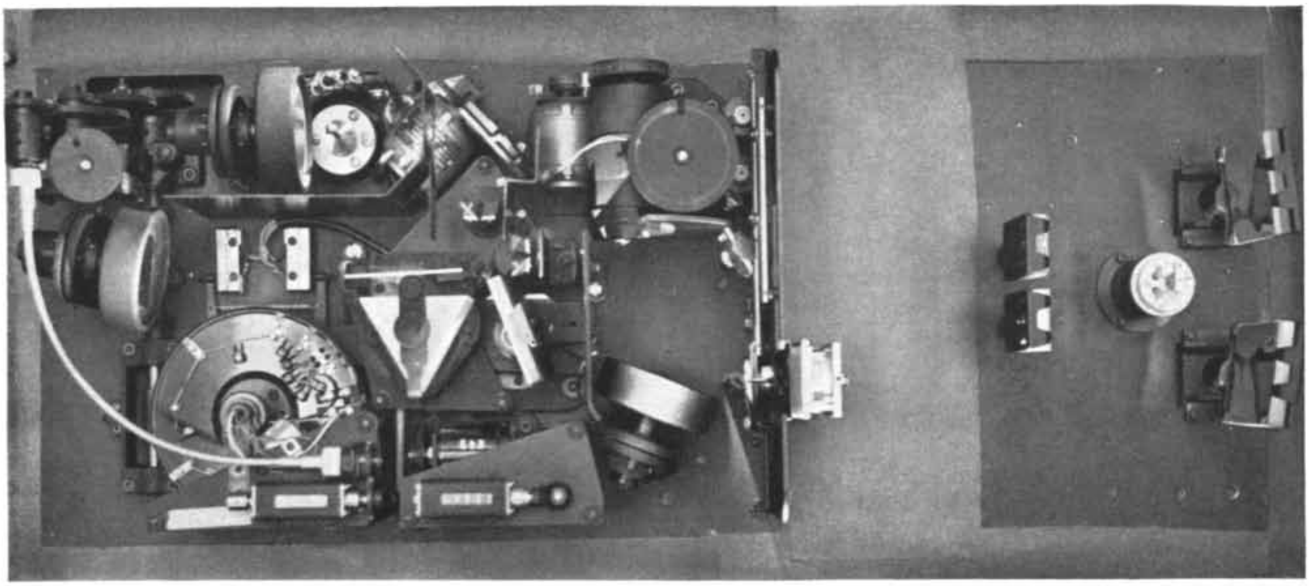


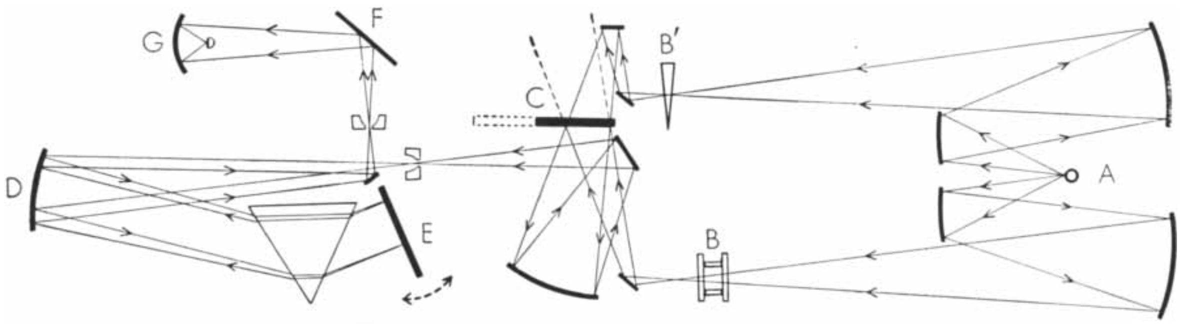
TYPES OF VIBRATION that cause most common absorption bands are here located in spectrum. Carbon atoms are represented by solid black circles, hydrogen atoms by small open circles, other atoms by squares. Carbon bonds stretch at the indicated frequencies whether running between two carbon atoms or between carbon and a different atom. Hydrogen wagging, twisting and rocking cover the 500 to 1,300 region jointly. Plus and minus signs for wagging and twisting indicate motion in and out of plane of page.





ACRYLONITRILE, whose molecular formula appears at left, gives the infrared spectrum shown above. The curve represents the amount of energy transmitted by a sample of the material as the wavelength increases (*from left to right*). Dips indicate frequencies at which energy is strongly absorbed, showing that a natural frequency of molecular vibration has been reached. Vibrations causing dips are indicated for comparison with chart above.





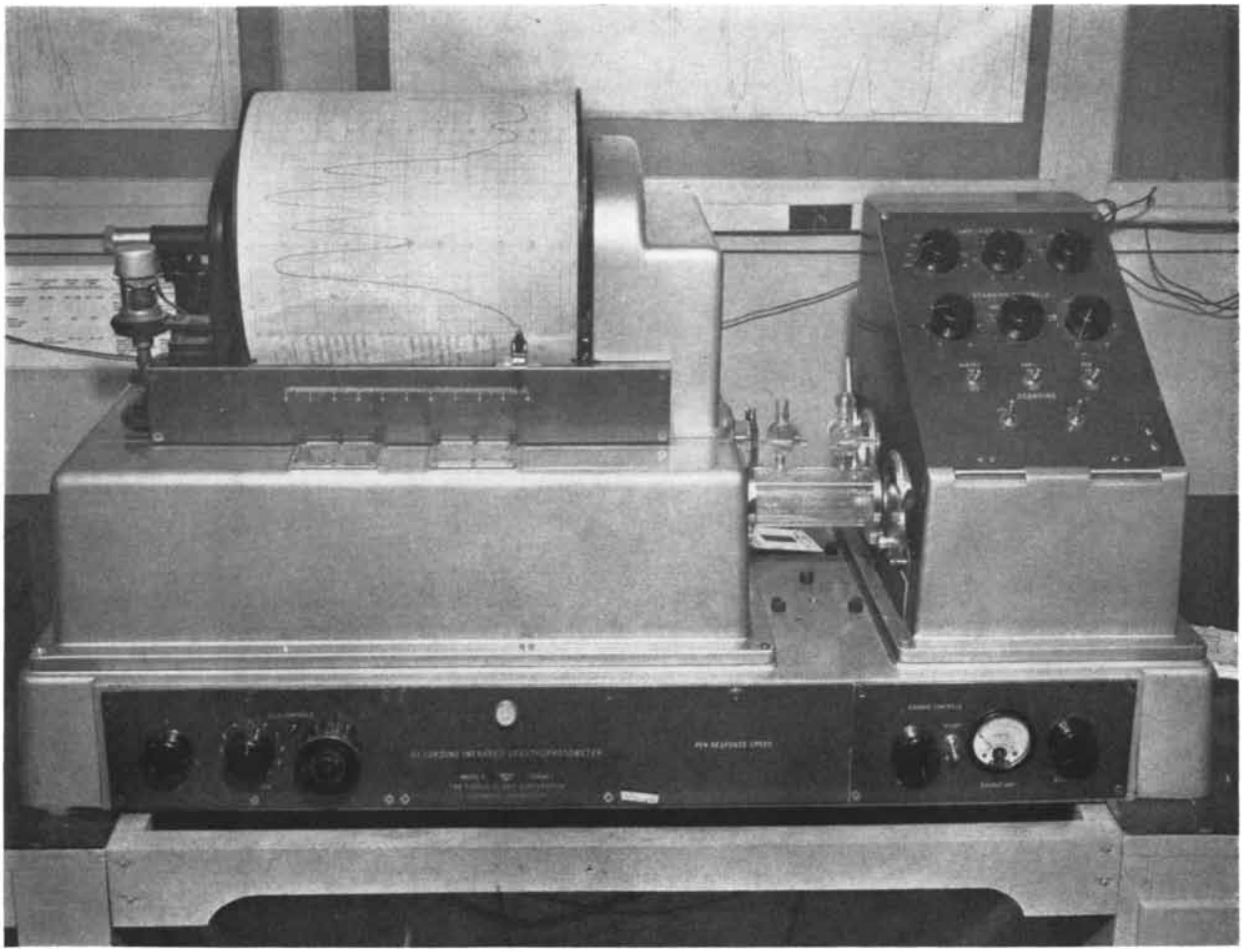
INFRARED SPECTROPHOTOMETER made by the Perkin-Elmer Corporation is shown on opposite page. Above are a photograph and diagram of its optical system. Infrared rays from a heated carbide rod (A) are split into two beams, one passing through the sample to be analyzed (B) and the other through a wedge whose transparency can be adjusted. A rotating mirror and diaphragm (C) alternately passes the two beams, by way of a pair of mirrors, to the curved mirror (D). This reflects the beams through a prism

we just plunk the keyboard a bit, and the sounds are a bit easier to relate to the piano.

We can carry this image further. The infrared spectrum of a two-atom molecule such as HCl shows absorption not only at the single natural frequency of the bond, but also at the overtones of that frequency. A molecule containing several atoms has several bonds and several natural frequencies. Here we cannot match up the frequencies with the individual bonds. We may think of such a molecule as a mechanical system of several masses connected by springs, and the resonant frequencies will be those of such a set of coupled oscillators. When one bond is set into vibration, the rest of the molecule also is involved through the interconnecting bonds. Hence the resonant frequencies are characteristic of the *whole molecule*. They are determined by (1) the masses, which means the specific atoms involved, (2) the spring forces, which means the bonds in the molecule, and (3) the way in which these are coupled, which means the specific geometrical arrangement of the bonds. If any of these changes, the set of resonant frequencies will change.

The infrared spectrum is simply a display of the resonant frequencies of the sample. Actually not all resonant frequencies give rise to absorption. Only those which, like the simple H-Cl vibration, cause some net change in the separation between positive and negative charges will interact with the oscillating electric field. Thus a molecule like Cl_2, which can have no charge separation no matter how the bond length changes (one Cl is like another!), does not absorb anywhere in the infrared. One of the resonant frequencies of CO_2, in which the two oxygen atoms move symmetrically, causes no charge displacement and hence does not appear in the infrared spectrum. But in general there are enough active resonant frequencies in a molecule so that the infrared spectrum is characteristic of the atoms, the bonds and the geometrical arrangement.

And here we see one reason for the great value of infrared: its *specificity*. The infrared spectrum is the most nearly unique property of a substance. Even geometrical isomers, which have the same atoms and the same bonds but differ in arrangement, can be distinguished by infrared. Such isomers are very hard to distinguish by ordinary chemical methods, yet their "slight" structural differences can give rise to profound differences in biological activity. Many, perhaps most, biological phenomena are highly sensitive to such differences in compounds. Consequently medical investigators need a sensitive analytical method. The infrared spectrometer was a key tool for the late cancer researcher Konrad Dobriner at Memorial Hospital in New York City in his



which separates their wavelengths. A rocking mirror (E) sweeps the dispersed beams across the detector, by way of (D), the small plane mirror, (F), and (G). The strengths of the alternately received beams are compared at successive wavelengths. When the detector senses a difference between the sample and the reference beams, an alternating current is generated which adjusts the movable wedge to equalize the signals. The motion of the wedge in turn is transmitted to pen that traces the absorption curve on drum.

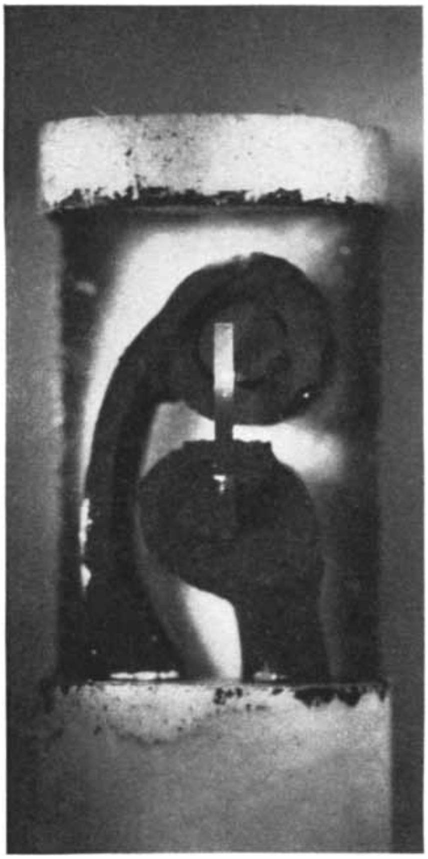
work of unraveling the metabolism of steroids in the body.

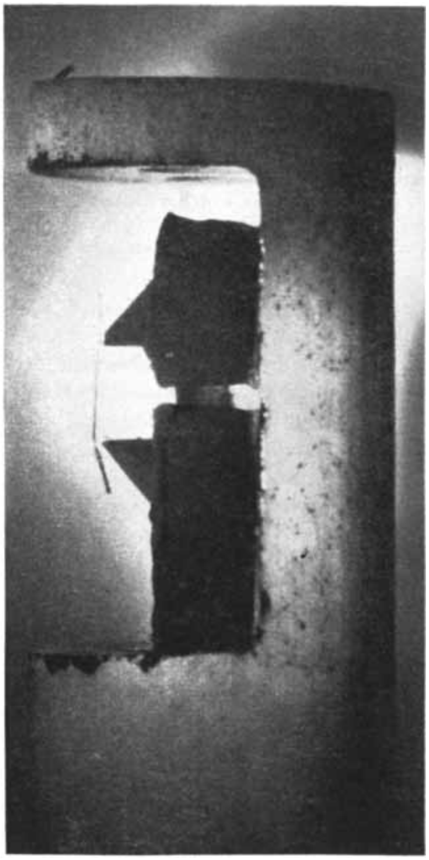
Inanimate objects—if internal-combustion engines can be so classified—also are sometimes sensitive to isomeric differences. The difference between "knock" and "anti-knock" gasoline components is a problem nicely suited to the infrared spectrometer. Indeed, the need in the petroleum industry for a fast, reliable and convenient method of distinguishing isomeric hydrocarbons and analyzing mixtures of them has played a large part in the recent upsurge of infrared. The war gave rise to pressing demands for high-test gasoline and for synthetic-rubber intermediates; both of these involved analysis of isomeric hydrocarbons. Infrared had been used in a few industrial laboratories in the late 1930s. Under the wartime challenge it was soon shown that infrared spectra offered the rapid and accurate analytical method so badly needed. And to meet the need for instruments the first commercial infrared spectrometer appeared in 1943.

The infrared also has unusual sensitivity to atomic mass; it can distinguish not only isomers but also isotopes. Practically the only methods for analyzing the stable isotopes used in tracer work are infrared and mass spectroscopy. Which is the better method in a given case will depend on many factors; in cases calling for a fast, nondestructive analytical method applicable *in situ*, the specificity of infrared can be very useful.

Yet all this is not the whole story. The greatest advantage of infrared as a research tool is that an infrared spectrum can be interpreted in terms of the same concepts chemists use in studying chemical properties—bonds and bond groupings. In classifying compounds and thinking about them and working with them, chemists have long spoken of "functional groups"—of olefins, of acid chlorides and so on. The functional groups provide a broad chemical description and a clue to the specific chemical properties of a compound—and they can be related to its infrared spectrum.

Let us consider for a moment the mechanical model. When two or more high-frequency springs are coupled together tightly, the vibrations of the resulting system form a new pattern in general quite distinct from that of the uncoupled springs; but when two high-frequency springs are coupled by means of a low-frequency spring, the resulting vibration pattern will include the frequencies of the high-frequency springs with only small shifts. Now chemical bonds fall approximately into two classes: (1) "high-frequency," which includes all multiple bonds and the single bonds involving hydrogen, and (2) "low-frequency," which includes all other single bonds, such as C-C, C-O, C-N. In





DETECTOR for spectrophotometer is shown in front view (*top*) and side view (*bottom*) about 16 times actual size. Beam of radiation is focused on thermocouple, the fine gold ribbon mounted on the contacts.

studying infrared spectra we may therefore try out the idea of a "vibrational functional group"—any set of high-frequency bonds directly connected. According to this, all molecules with the group —N=C=S, for example, should have some frequencies in common, but they should differ from those with the —N=C— or C=S groups. Here indeed we find the "something" for which Coblentz was groping!

Now we find a piece of good fortune—one of the rare presents Nature bestows on investigators. Chemical functional groups and vibrational functional groups run parallel. Therefore certain characteristic absorption bands in an infrared spectrum give direct and strong evidence on the chemical nature of the sample. It is not really conclusive evidence, for the functional group idea is an approximation, and the parallelism of chemical and vibrational functional groups is not too strict. The infrared spectrum is not a magic crystal ball in which one reads the structural formula of an unknown sample. But its clues, when wisely used, can shorten by weeks the time required to complete the job. And the direct applicability of the chemical-bond concept and the functional-group concept means that the chemist can understand infrared spectra without having to learn a new language. He *does* have to learn a new dialect of his chemical language—and incautious chemists who have overlooked this have made some serious blunders. But the dialect can be picked up relatively quickly.

The knowledge of molecular structure required to make use of infrared spectroscopy had been achieved by about 1930 or 1935. Why, then, did the blossoming of chemical infrared start only in 1943? Some pioneer applications of infrared *had* been made in the chemical industry as early as 1936. But the technique is difficult. The cost of the modern commercial instruments and their need of maintenance still remind the user that the infrared spectrometer is doing a basically harder job than its ultraviolet counterpart. It has been well said that "no other spectrometric region of the electromagnetic range is so beset with experimental difficulties." Basically these arise from the very fact that infrared radiation is resonant with atomic vibrations. We have seen the advantages stemming from this; let us glance at the price we must pay.

As a source of infrared, we must use vibrating atoms, and the only practical way to set atoms vibrating is through heat. To get a reasonable intensity of infrared, we must heat our source to a high temperature; a common source is an electrically heated rod of carborundum at 2,200 degrees Fahrenheit. Refractory materials able to withstand such temperatures are brittle, which can be a nuisance! Moreover, the laws of physics worked out by Planck show that most of the energy goes into the near-infrared and even the visible region, wasting our power and filling our instruments with a lot of unwanted wavelengths which must be filtered out or shunted off.

The same basic trouble arises in the measurement of infrared intensity—detection, as it is appropriately called. The infrared quanta do not disturb molecules enough even to affect a photographic plate! All we can measure is a slight rise in the temperature of the absorber, and we measure it today as Herschel did—by the effect on a blackened thermometer. The "thermometer," however, is a very sensitive thermocouple.

We must find prisms to disperse the infrared spectrum and optics to focus it, windows to let the radiation through the cells holding our samples and solvents in which to dissolve materials we want to study. Since all atoms can vibrate, it is not easy to find substances transparent to the infrared. Glass and water are completely opaque to it; ordinary organic solvents have so many absorption bands themselves that they obscure the spectrum of the substance dissolved in them. So we use mirrors instead of lenses, make our prisms and cell windows of rock salt, and think hard about the choice of solvents.

For infrared, the wartime need was a blessing in disguise—a very perfect disguise, to quote Mark Twain—because urgent necessity stimulated great improvements in instrumentation. The availability of better instruments today is a great blessing not only to analytical chemists and workers in the chemical industry but also to infrared spectroscopists interested in fundamental chemistry. Infrared spectroscopy has helped us win our present understanding of molecular structure, notably the geometry and dynamics summarized in the ball-and-spring model. Nowadays more people than ever before are at work on this fundamental use of infrared, studying the nature of those springs and the distribution of electronic charges in the bonds. Without depreciating the more widespread use of infrared for the analysis of compounds, we may well feel that in the long run the fundamental use will be more exciting. For the nature of the chemical bond is the problem at the heart of all chemistry.

Kodak reports to laboratories on:

how to learn the fundamentals of radiography . . . why and how we produced a phosphor for scintillation counters . . . a laboratory instrument you can have fun with

Radiography

Suppose you desire to find out a little more about the practical aspects of working with x-rays than what you have been able to observe as a medical or dental patient and rank layman. One way to inform yourself painlessly and withcut nuisance to acquaintances who are professional in the field is through our 100-page book, "The Fundamentals of Radiography." Just issued is the rewritten eighth edition of this work, which has introduced many thousands of practicing x-ray technicians to their careers.

The typical reader the author has in mind is an intelligent and earnest young person who has never previously given much thought to the difference between an anode and a cathode but is willing to learn. Certain of the earlier pages you can probably afford to pass over rather quickly to get to the parts where we review the geometry of x-ray image formation, the effect of kilovoltage on what is shown, scattered radiation and its control, intensifying screens and how to use them, the selection of film and processing procedures, calculation of exposures, how to get more contrast, how to get more detail, how in general to run a radiographic operation for consistently good results and maximum personal safety. The viewpoint is essentially that of the medical x-ray clinic, but the content can be useful elsewhere—to you yourself or to a newcomer you'd like to interest in the topic.

To get a copy of "*The Fundamentals of Radiography,*" *one simply drops a note to Eastman Kodak Company, X-ray Division, Rochester 4, N. Y. If, however indirectly, it results in an increment to the ranks of the radiographers, we shall feel amply rewarded.*

To scintillate

"If it's conjugation you want, then conjugation you shall have," we synthetic organic chemists said to the physicists, who seem to be set these days on finding new and better scintillation phosphors for their counters. One very highly conjugated molecule we could see a chance of producing and isolating with reasonable success was *p-Quaterphenyl.* We didn't worry too much about its ability to form sizable crystals because the physicists have been telling us lately that they can work with solutions instead of single crystals, if need be. To the future we left the problem of finding a suitable solvent for *p-Quaterphenyl.*

First we had to capture our *p-Quaterphenyl.* We knew there was some present in the residue from the manufacture of biphenyl, but in that coal-like conglomerate it was bound to prove elusive. Instead, we put our heads together with a friend who teaches chemistry at a college an hour's drive away, and is always looking for worthy projects to throw at his students. From our discussion, two routes to purified *p-Quaterphenyl* emerged. We selected one, and two young men then embarked on an instructive experience that began with an Ullmann reaction of iodobiphenyl with copper powder and concluded as 600 grams of Eastman 6866. With scintillation so warm a topic, we expect the initial batch will not dwell long on our shelves, but we wouldn't want to bet one way or the other.

In addition to p-Quaterphenyl, *there are over 3500 other Eastman Organic Chemicals we can ship from stock. They're all in our List No. 38, a copy of which you may have by writing to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

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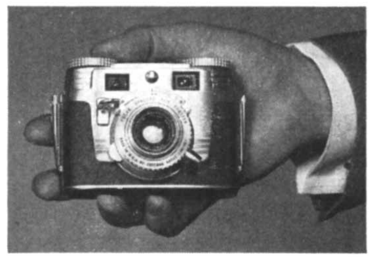

But, since neither man nor camera can work all the time, we'd like to point out that the *Signet* also makes an all-remembering companion when it's time to enjoy yourself with family and friends. There's no extra charge, and what you spend on film you'll never miss.

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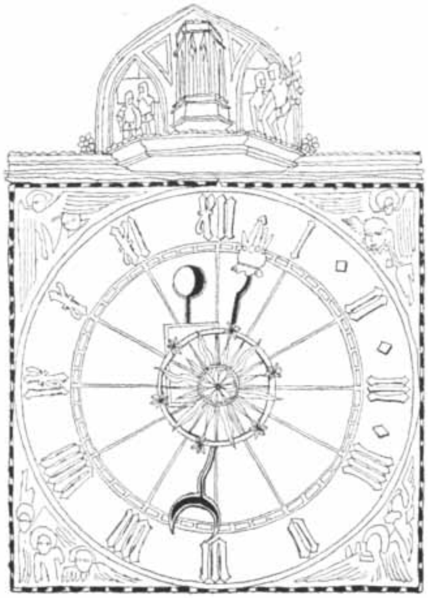


On Hydrogen Explosions

That both the U. S. and the U.S.S.R. have now produced hydrogen fusion explosions was officially confirmed last month. On August 8 Premier Georgi M. Malenkov told the Supreme Soviet that "the U. S. no longer has a monopoly of the hydrogen bomb"; four days later Russian scientists exploded a thermonuclear device. Although the explosion was detected in the U. S. and Great Britain, no announcement was made until the Soviet Union broadcast the news nearly two weeks later. Lewis L. Strauss, chairman of the Atomic Energy Commission, then confirmed the explosion, saying it "involved both fission and thermonuclear reactions." He said that the U. S. had achieved "similar reactions" in tests at Eniwetok in 1951 and 1952.

Pravda described the Russian explosion as "one of a variety of hydrogen bombs." It said "the test showed that the power of the hydrogen bomb is many times greater than the power of the atomic bomb." But whether the thermonuclear reactions have as yet actually been incorporated in a deliverable bomb is not clear. W. Sterling Cole, chairman of the Joint Congressional Committee on Atomic Energy, pointed out that A.E.C. announcements have not used the word "weapon" or "bomb" in connection with the U. S. thermonuclear experiments.

The Russians followed up their thermonuclear test with an unannounced fission explosion 11 days later. The A.E.C. said that this explosion was "in the same range of energy release as our recent Nevada tests," and it added that the Russians seemed to be embarked upon a new series of atomic weapon tests. The A.E.C. said it would make no further announcements of nuclear explosions that took place in the Soviet Union "unless intelligence indicates information of greater interest."

Alexander Wiley, chairman of the Senate Foreign Relations Committee, called for a new attempt in Washington and Moscow to reach an agreement on international control of atomic energy. Commissioner Strauss remarked that "it is a fallacy to assume that a stockpile of atomic weapons in our hands is in itself any longer a complete deterrent to aggressive action." The United Nations Disarmament Commission, which has been inactive since October, 1952, is expected to take up the problem of international control again this fall.

New Probe of the Nucleus

A new picture of the nucleus of the atom is coming out of experiments with the big linear accelerator at Stanford University. It appears that nuclei are not uniformly packed with matter, as had been generally supposed, but are dense in the center and grow diffuse toward the edges. This is the conclusion of Robert Hofstadter, who has penetrated the nucleus to a record depth with a 135-million-volt beam of electrons.

The electrons pass through a thin sheet of the material being studied and are scattered by the particles in its nuclei. A magnetic spectrometer measures the number scattered at various angles, thus showing the disposition of the nuclear particles. Two unique advantages of the apparatus are that it can analyze the nuclear properties of chemical compounds without separating them into their elements and can distinguish between unseparated isotopes.

Electrons are better suited to probing intact nuclei than are heavier particles such as protons. The latter interact with the components of the nucleus in a very complex way, whereas electrons are influenced by comparatively simple electric forces. At the energy now being used, the electron wavelength is about half the diameter of a nucleus. This is just about short enough to "see" into it. At higher energies the wavelength will be shorter and the detail correspondingly finer. The Stanford accelerator is designed for an eventual energy of a billion electron volts. Hofstadter is now building a magnetic analyzer to operate with 500-million-volt electrons and is designing one for the billion-volt beam.

Who Owns Atomic Energy?

The Atomic Energy Commission is by law the owner of all patents in its field. But recently it had to buy one—a basic invention which has been in use ever since the first atomic pile went into operation. The method of making radioactive isotopes by bombarding elements with neutrons slowed by a moderator was patented by a group of Italian scientists in 1940, and they have now claimed their rights. The A.E.C. paid them $300,000 for infringement and for partial revocation of their patent. (The Atomic Energy Act of 1946 revoked all patents on processes used in making fissionable material.)

The patentees are Enrico Fermi, now of the University of Chicago; Bruno Pontecorvo, who disappeared from England in 1950, presumably into the U.S.S.R.; Franco Rasetti, now at The Johns Hopkins University; Emilio Segre, now at the University of California, and Edoardo Amaldi, Oscar D'Agostino and Guilio Trabacchi, who are still in Italy. Pontecorvo's share was deposited in the U. S. Treasury according to a regulation which "governs the payment of funds to individuals in certain countries."

A California company, to which the scientists had assigned the patent, had filed two claims for compensation with the Commission, one of $1.9 million and another for $2.1 million. It had also filed a court action for $10 million, which it withdrew before the settlement.

The A.E.C. has paid off another private atomic inventor—Nicholas Christofilos. He received an undisclosed sum for his patent on the strong-focusing synchrotron, whose principle he discovered three years before it was announced by physicists at the Brookhaven National Laboratory (see "Science and the Citizen," SCIENTIFIC AMERICAN, June, 1953). Christofilos is now working at Brookhaven.

Astin Wins His A

Secretary of Commerce Sinclair Weeks last month asked Allen V. Astin to stay on indefinitely as director of the National Bureau of Standards "in the best interests of the Bureau and the public." Weeks had fired Astin in March in the AD-X2 battery additive controversy. When the Bureau staff threatened to resign, Astin was reinstated on a temporary basis pending a review of the Bureau's work. Now, Weeks announced, "no further need exists to seek a successor, as Dr. Astin has expressed his willingness and desire to continue as a key official of this Administration and as such he is from here on a member of my team."

Weeks indicated that there will be changes in the Bureau's procedures, especially in regard to the testing of commercial products. From now on the Secretary of Commerce, and not the director of the Bureau, will decide whether such products shall be tested and whether adverse reports are to be published. Weeks said that the new procedure is in line with recommendations of the evaluating committee, headed by Mervin J. Kelly. The committee's report has not yet been made public.

Out of the Fog

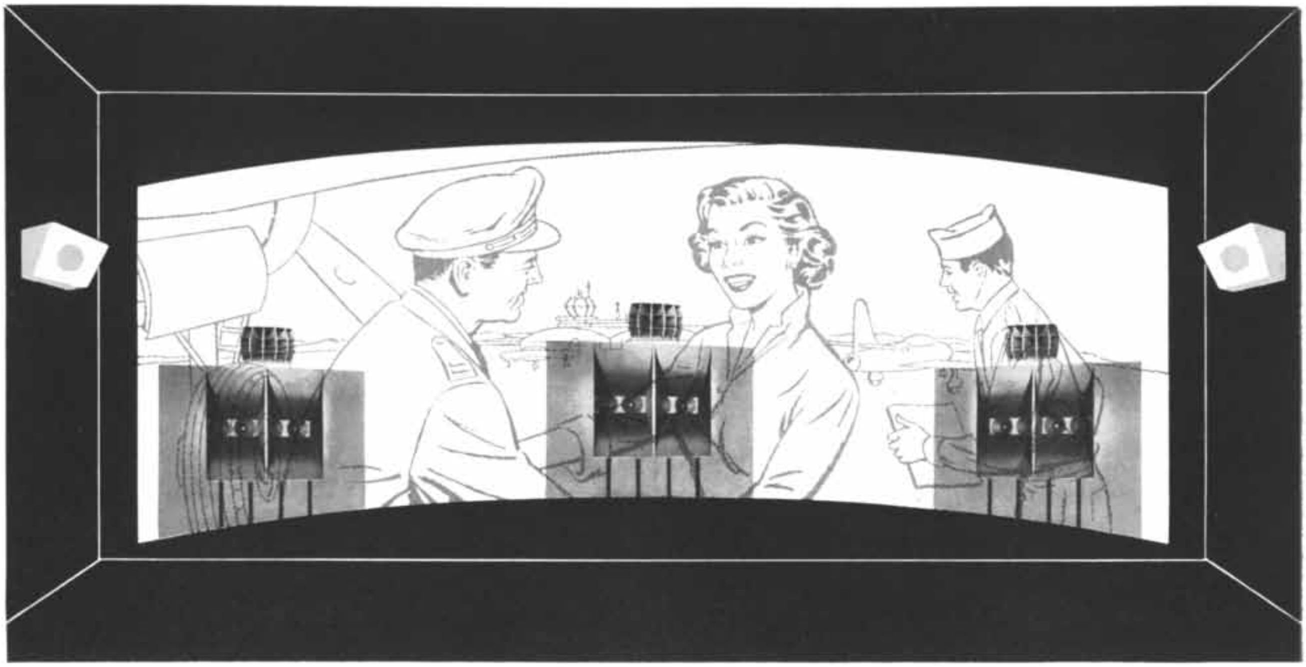
Astronomers at the Greenwich Observatory, who tell the world how to set its clocks, often have to consult their watches to find the time. The pall of smoke and fog that hangs over London obscures the night sky and prevents the Astronomer Royal and his colleagues from watching the stars cross the prime meridian. Early next year they will be looking through the clearer air of a Sussex village 60 miles southwest of their old location. After 278 years at its present location, the venerable observatory is moving to the ancient Hurstmonceux castle, built in 1440.

Though it will still be called the Royal Greenwich Observatory, the prime meridian will no longer pass through it. The famous Airy transit will be left in Greenwich as a public exhibit. All observations will be made at Hurstmonceux, and the time will be corrected to Greenwich Time by subtracting about a minute and a quarter.

Hunger Atlas

Although the world produces enough food to nourish all its inhabitants, two-thirds of the human race is starving. These are conclusions of the American Geographical Society, which has just completed a "Study in Human Starvation."

The Society's maps show that in the Western Hemisphere only the U. S., Canada, Uruguay and Paraguay have



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Working closely with the motion picture industry, the Altec Companies pioneered the perfection of stereophonic sound, a system of multiple microphone pick up, multiple track recording and multiple loudspeaker system reproduction that provides sound that moves.

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Dealers everywhere

adequate diets as a national average. In Europe four nations—Portugal, Spain, Italy and East Germany—are below the subsistence level. In the rest of the world the only countries whose average inhabitant gets enough to eat are Turkey, Kashmir, Nepal, Tibet, Thailand, Cambodia, Formosa, Somaliland, Portuguese Guinea, Australia and New Zealand.

Jacques M. May, who directed the study, discusses some of the reasons for world-wide malnutrition in *The Geographical Review*. The chief difficulty of course is low income, or inability to buy enough food. But malnutrition is common in rural areas. Farmers are chronic borrowers (paying interest as high as 200 per cent in some parts of the world) and are forced into unsound agricultural practices to support their burden of debt. Exhaustion of the soil in certain areas contributes to local starvation.

May hopes that his sad and dramatic maps will inspire an increased "determination to do something about" starvation in the hunger-ridden areas of the world.

The Calculus of ESP

Extra-sensory perception is a subject that makes many scientists uncomfortable: they are sure there must be something wrong about the experiments, but the fallacy is tantalizingly elusive. In a recent issue of *Nature* an Oxford University scientist named G. Spencer Brown supplies the skeptics with some apparently well-reasoned ammunition. He finds "little evidence for telepathy, clairvoyance, precognition, psychokinesis, *etc*." and thinks he has found the basic flaw in the interpretation of the experiments.

Brown attacks the heart of the matter: "statistical significance." The main argument for ESP is that the experimental results would be extremely unlikely to occur by chance. Brown points out that psychic research, unlike other statistically-based investigations, suffers from two important limitations. First, its "significant" results are not highly reproducible. Identical experiments often come out differently. Second, there are no satisfactory controls, because control series "cannot be relied upon to give results which are any the less curious and 'significant' than those of the main series."

Brown cites a famous card-guessing experiment which was conducted to test telepathy. Half the cards were known to the experimenter; the rest, serving as controls, were unknown. Since there was no appreciable difference between the results for the two groups, the experi-

menter "rightly concluded that he had found no evidence for telepathy." Later other students, noting that the cards, both known and unknown, had been guessed much more frequently than would be expected from chance, concluded that the experiment demonstrated clairvoyance.

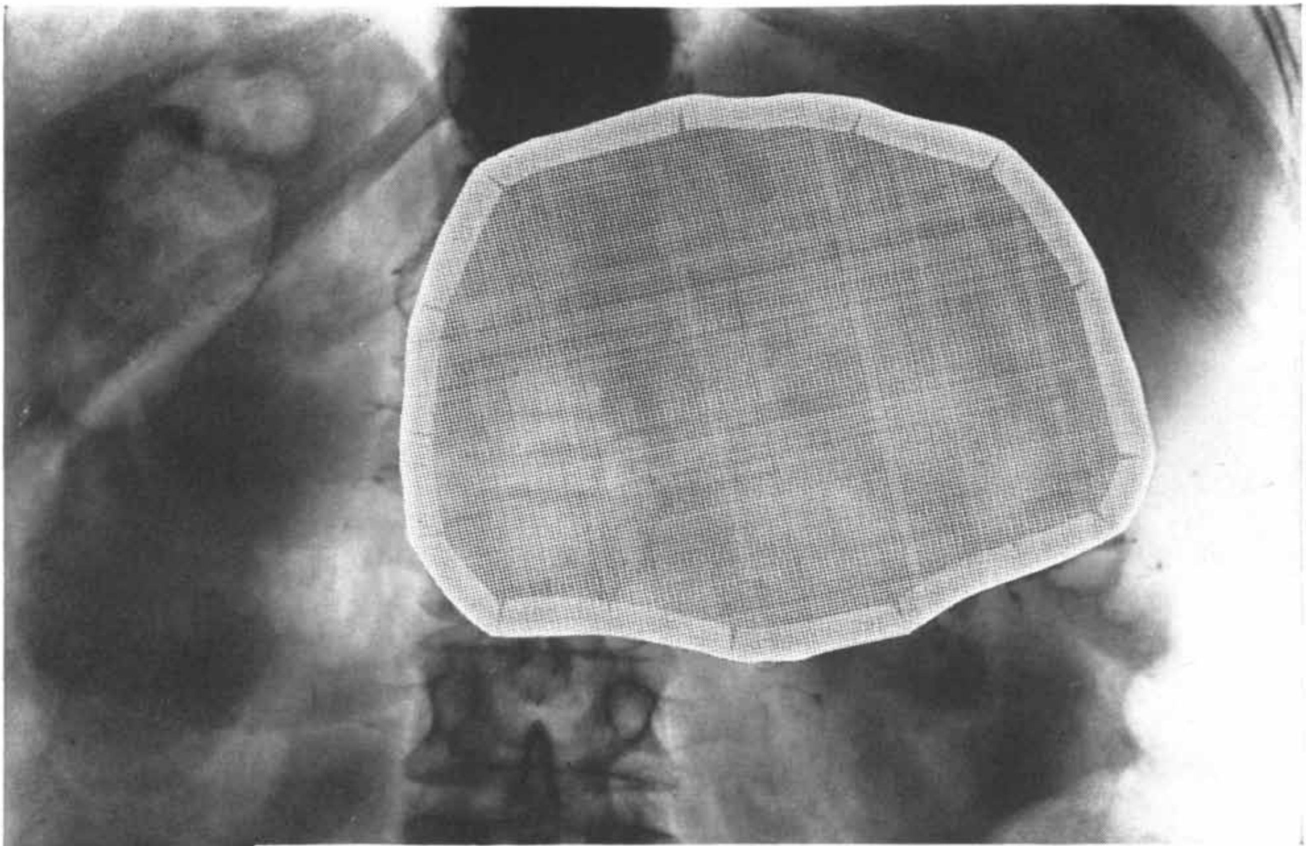
Thus an unsatisfactory control, Brown observes, becomes a new psychic phenomenon. This progression has culminated in "psychokinesis"—the idea that an experimenter can influence the fall of a die or the turn of a card by thinking about it. Here, he says, we have come to the end of the line. Any test of statistical significance depends on the "randomization of the set of observations." The cards must be truly "randomized" by shuffling beforehand if the results of an experiment are to be significant. But if the shufflers affect the cards through psychokinesis, then they have destroyed their experiments before they start. They are left to "depend solely on a test of significance which is valid only if the results they claim do not in fact occur. . . . The claim for psychokinesis has thus made nonsense of the claims for telepathy, besides being itself, on the evidence, a nonsensical claim."

How, then, is one to explain the "curious" results? "The simplest explanation left open to us is that the calculus which leads us to interpret these results as significant is itself misleading. . . . It is incumbent on us to try the hypothesis . . . that the concept of chance can cover a wider natural field than we previously suspected." Brown matched digits between arbitrarily-chosen columns of a random number table, scoring each successful match as if it were a guess of a card. The "pure chance" results "differed from the mean expectation by more than three standard deviations"!

Brown expects to prove that statistical significance has been "systematically misleading in certain zoological experiments in much the same way as . . . in psychical research." The problem, he concludes, lies in our "extremely arbitrary" and "necessarily vague" concept of what physical randomness is. Perhaps it should be "a matter of some surprise" that present probability theory works in science as well as it does. "If we could discover how it is that it does work so well, we might . . . see how it is that it does not . . . work quite well enough."

More Oil

Two new developments in petroleum processing, which promise to extend oil reserves substantially, were an-



The stainless steel screen is so fine (50 x 50 mesh from 18-8 wire 0.003" diameter) it had to be emphasized by photographic technique for this picture.

Inside Her Tummy is a Mesh of Stainless

This photo of an X-ray shows a fine screen of stainless steel permanently imbedded in abdominal muscles. Surgeons insert this mesh to reinforce hernia or other persistent openings.

Stainless is used because it doesn't corrode, nor set up electrolysis with the body chemistry.

Stainless steel is certainly one of the most versatile, if not *the* most versatile of metals.

Probably more tons of stainless go for trimming automobiles than for anything else. Here the beauty of its gleaming all-the-way-through surface is the valued feature. But as atomic energy and radioactive materials become more widely used, an unmeasured, tremendous new frontier is opening before stainless. It's vital to the production of atomic energy. It has become the standard material used for "hot labs." Even a small laboratory for a private company, using radioactive materials, takes several hundred square feet of stainless.

Republic is the largest manufacturer of stainless and alloy steels. It makes so many types of ENDURO Stainless because stainless is so versatile. You may need stainless that is magnetic or non-magnetic. Republic has it for you. Perhaps you want ductility. Or machinability; corrosion resistance; heat resistance; or high strength-to-weight ratio. Republic can provide you with an ENDURO Stainless Steel emphasizing whichever quality you need.

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REPUBLIC STEEL

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REPUBLIC STEEL

WORLD'S WIDEST RANGE OF STEELS AND STEEL PRODUCTS nounced last month. The Socony-Vacuum Oil Company has worked out a means of recovering very heavy crude oil which is too thick to be pumped out of the ground by present methods. The oil sands are ignited, a blast of air is forced through them, and the air drives the unburned oil, made less viscous by the heat of combustion, into a well from which it can be pumped. "In-situ combustion," as the process is called, has been tried successfully in an Oklahoma oil field. Laboratory tests have shown that 60 to 90 per cent of a deposit could be recovered, and that less than 15 per cent is lost through burning. About four billion barrels of heavy, "unrecoverable crude" are estimated to underlie U. S. fields.

The Standard Oil Development Company has invented a process called fluid coking which will get gasoline and light fuel oil out of the heavy residue left from conventional crude-oil treatment. The low-grade crude stock is mixed with hot, finely divided coke particles. On the hot surfaces of the particles the heavy oil molecules break down into lighter fractions. In the process, part of the oil turns into more coke.

Better Cotton

A chemical treatment of cotton that produces an improved fiber has been announced by the Institute of Textile Technology, a cooperative research center of the textile industry. Called T-7, the fiber is said to be permanently resistant to mildew and bacteria, to resist heat better and to be easier to dye than ordinary cotton. It is made by treating cotton fiber, yarn or cloth with acrylonitrile in a process known as cyanoethylation. The new fiber can be further altered to be made stronger and more resistant to stretching and abrasion than either the original cotton or T-7.

The process has been tested in commercial-scale runs at a Tennessee mill. Other firms are setting up pilot plants to produce the fiber. The Institute points out that it can be handled on the same machinery used for spinning and weaving cotton, while yielding "many product qualities attainable to date only with synthetics."

Deep Sleep for Epilepsy

A drastic new treatment in which patients are kept in a deep coma for several days helps many epileptics for whom standard therapy is ineffective, according to the neurologists Tracy J. Putnam and Sanford F. Rothenberg. At

the Cedars of Lebanon Hospital in Los Angeles they treated a series of 25 cases, and 64 per cent were completely relieved of seizures (for periods of from one to several years), while the others showed substantial improvement. There were no serious reactions or deaths from the treatment, although Putnam and Rothenberg concede that it involves "some potential risk."

To induce the coma the physicians use large doses of the anti-convulsant drug diphenylhydantoin. If necessary they also give other soporifics. During the sleep, which usually lasts four days, the patient may be starved, given inhalations of carbon dioxide and injected with glutamic acid—all measures effective in reducing seizures or suppressing abnormal brain waves. Sometimes stimulating drugs are necessary to arouse the patient from his sleep. The entire treatment lasts about two weeks.

The chief danger is from pneumonia. Daily injections of penicillin are given to ward off infection, and a nurse is in constant attendance during the sleep.

Describing their treatment in *The Journal of the American Medical Association*, Putnam and Rothenberg point out that the need for hospitalization and continuous nursing makes it expensive. They suggest that its cost could be reduced if one or two nurses took care of a group of patients simultaneously.

No Brain-Cutting

Prefrontal lobotomy is outlawed in the U.S.S.R., the Soviet psychiatrist N. I. Oserezki told the World Federation for Mental Health at a recent meeting in Vienna. Oserezki, a member of the Pavlov Institute of Medicine in Leningrad, described the operation as "an anti-physiological method that violates the principles of humanity," makes the patient an "intellectual invalid" and deprives him forever of any hope from future discoveries or from proper use of less drastic available methods. He quoted a Soviet colleague as saying that, through lobotomy, "an insane person is changed into an idiot." Oserezki accused psychiatrists of using the operation because it offers a quick and simple way to get mental patients out of hospitals.

The *New York Times* reported that many of the psychiatrists at the meeting agreed with the Russian. H. C. Ruemke of the Netherlands, president of the World Federation, said the operation was advisable only in rare instances and was being performed much too frequently in the U. S.

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

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

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

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CVC's experience in high vacuum metallizing and associated lacquering operations is available to help solve your problems. And *CVC* is ready to help you get started in this rapidly growing business with the most efficient vacuum metallization equipment available. For information on this or any other application of high vacuum, write to ***Consolidated Vacuum Corporation, Rochester 3, N. Y.*** (A subsidiary of Consolidated Engineering Corporation, Pasadena, Calif.) Sales offices: Menlo Park, Calif. • Chicago, Ill. • Camden, N. J. • New York, N. Y.

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Imagineering

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Help came in the form of an engineer from our Development Division. He knew the refrigeration industry and the importance of what Warren was trying to do. Solving their problem was a matter of adapting a technique he had learned from other such projects. The answer: To make a tight fit between aluminum fins and aluminum tubes, the tube was inserted through holes in the fins and expanded with a mandrel.

The aluminum-finned tubes worked so efficiently that Warren looked for other places to use aluminum. A special extrusion was made to replace a casting of another metal. A special fastener was designed to space the walls of a light fixture. A new welding technique was suggested to solve a difficult joining problem. There were many others.

In each case, Warren drew from experience of men in our Development Division. And in each case, aluminum gave their commercial coolers a little boost above competition.

This, then, is the moral of the story. You may wish, like The Warren Company, to institute a regular program of step-by-step product improvement with the help of our development people who can show you short cuts. Or you may have in mind a use of aluminum so different, so radical, that it can revolutionize your industry. We can provide basic research, testing, even pilot models to prove its practicality. Our Development Division is ready to help.

The newest member of the Warren line is this apartment-size freezer. It takes full advantage of aluminum's fast cooling in the liner, the shelves, the coils, even the freezer doors.

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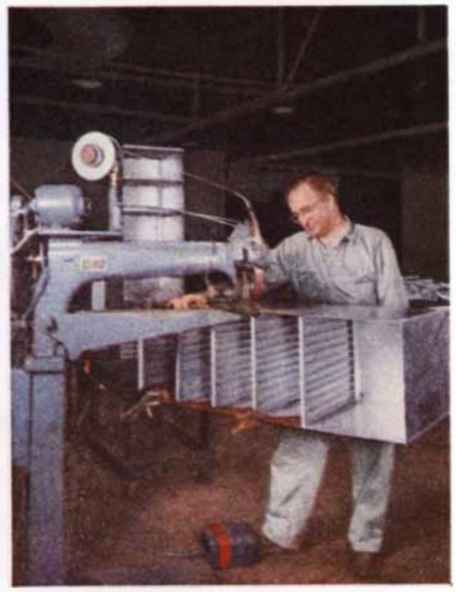
Giving the inside of the freezer a hard, easy-to-clean finish required special anodizing techniques. Alcoa technical men suggested methods—Alcoa mills supplied aluminum sheet with a special pattern rolled on it.

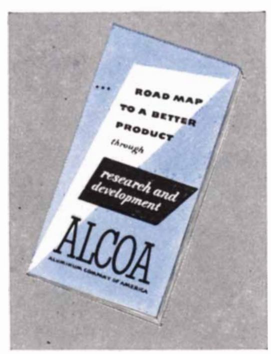
Fastening the cooling coils to the shelves required special joining techniques. Alcoa technical men suggested resin bonding and assisted in finding a suitable resin. Alcoa mills supplied tubing in 1,000-foot lengths to reduce scrap.



Joining the shelves to the sidewalls was a problem until Alcoa technical men suggested metal stitching. Now the shelves are assembled with staples—saving greatly in production time and capital investment.

Your next step . . .

is to write for the free booklet, "*Road Map to a Better Product*." It describes in detail the facilities available to you for immediate application to your problems. Aluminum Company of America, 2182-K Alcoa Building, Pittsburgh 19, Pa.



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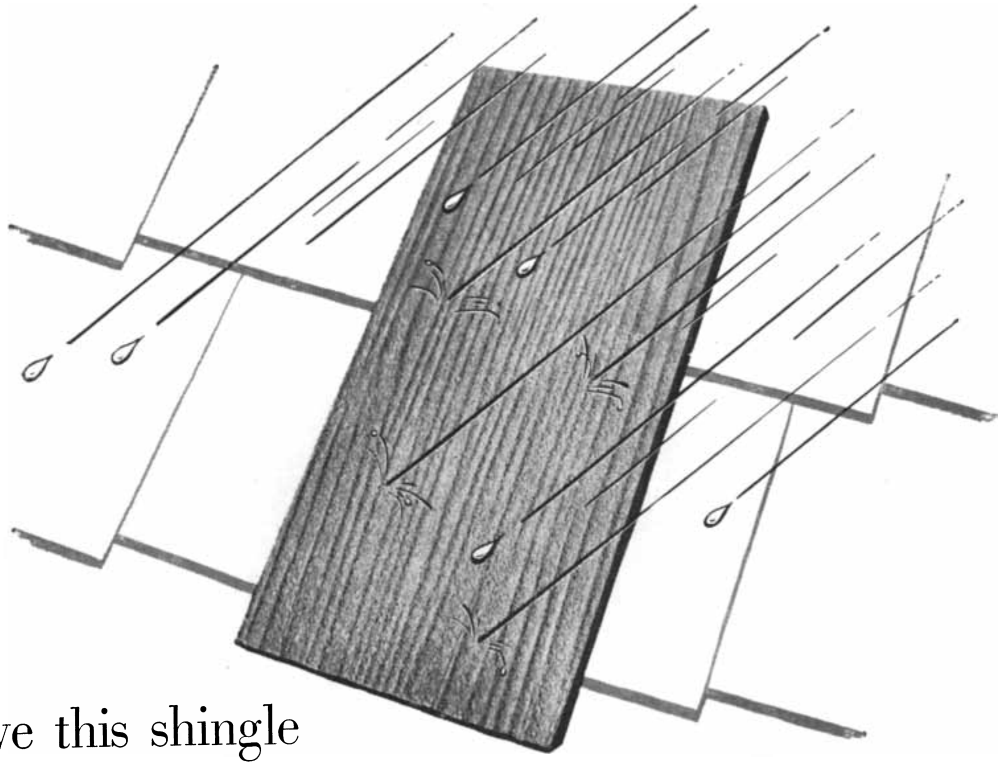

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NORELCO X-ray Diffraction helps eliminate the "misfits"

The durability of many materials can often be accurately determined by atomic structure analysis. At Johns-Manville, NORELCO X-ray Diffraction equipment aids immeasurably in establishing the wearing characteristics of various combinations of materials and in eliminating those formulations which are undesirable long before final outdoor weathering tests.

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NORELCO serves science and industry

This example of ingenious application by Johns-Manville is typical of the many uses found for products of North American Philips throughout science and industry. It characterizes the imaginative research, creative engineering and extreme precision in manufacture behind every product that bears the NORELCO name. Non-destructive NORELCO X-ray Diffraction can provide invaluable aid to your organization. The Technical Staff of North American Philips Application Laboratories is available for free consultation. Write also for booklet "Three Powerful X-ray Tools."

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Human Growth

The complete physical, physiological and psychological histories of 160 boys and girls recorded by the Denver Child Research Council are yielding a clear picture of how a normal individual grows up

by George W. Gray

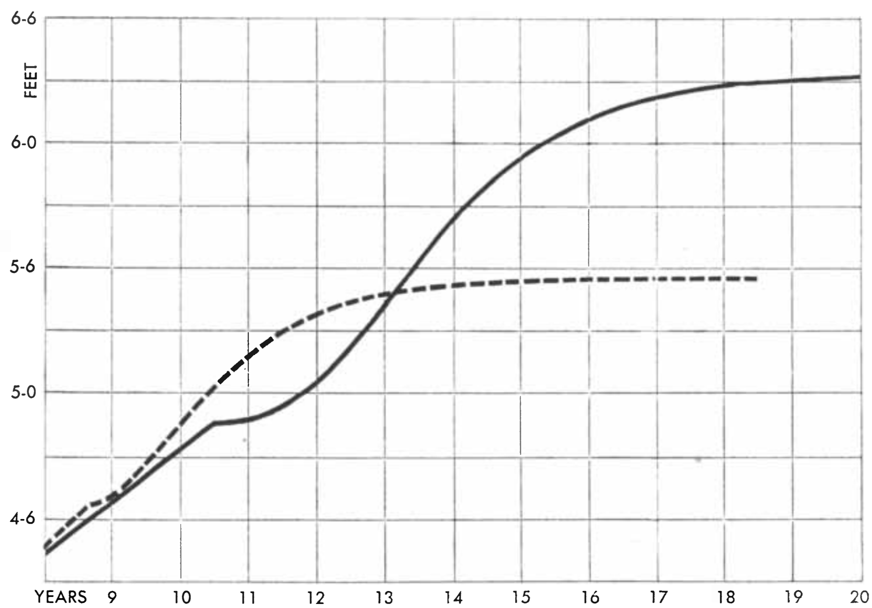
Among the 160 children of various ages whose development is being followed in the remarkable study of human growth by the Child Research Council in Denver, Col., is a boy whom we shall call Tommy Smith. In nursery school he was a top member of his class—a happy, normal, healthy, highly intelligent youngster. But as he approached the age of five, the records began to show a flattening of his growth curve: he lost weight and stopped gaining in height. The staff nutritionist, calling at his home for a check-up, found that the boy's appetite had fallen off sharply. He was not eating enough, particularly not enough milk, and the result was a shortage in his intake of proteins and minerals. Actually, the whole staff for some time had been noticing symptoms of retardation in this apparently healthy boy. The psychologists had reported that Tommy had regressed in mind as well as in body. His I.Q. rating had dropped. He seemed tense, anxious, uncertain. His inner strains were reflected in his responses to the Rorschach inkspot test, the thematic apperception test and other psychological techniques.

A clue to his trouble was disclosed by one of these techniques: doll play. Three dolls, representing a man, a woman and a small boy, were placed on the floor, together with an assortment of doll furniture and other household accessories. Tommy proceeded to "play house," and in his play he sent the mother doll off "to the office," put the father doll in the kitchen getting the next meal and wondered aloud whether the little boy doll would grow up into a man. Maybe, he speculated, the boy would become a woman and go off to the office "like mamma."

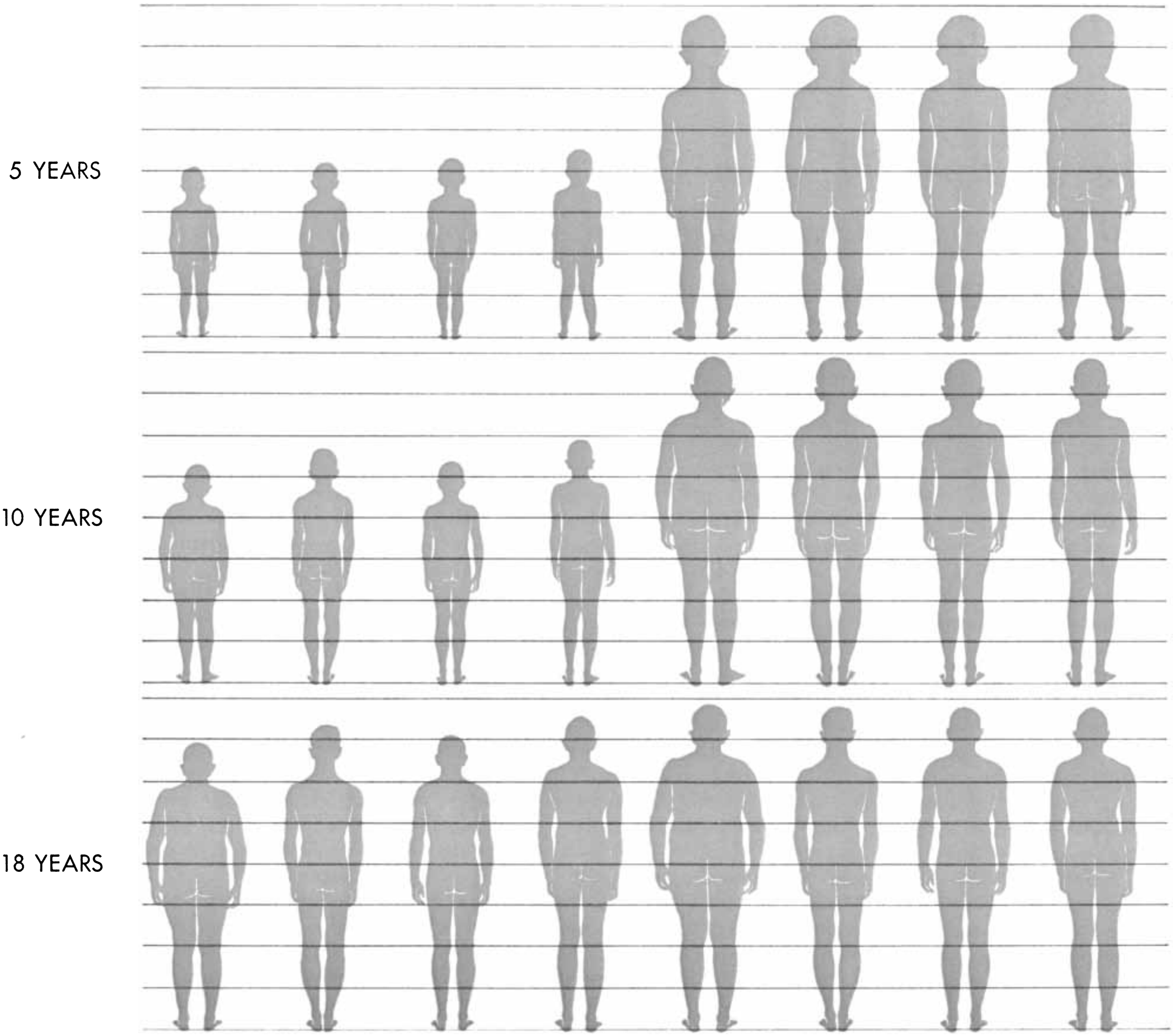
Here was the anxiety that underlay Tommy's loss of interest in food, his interrupted growth and his lapses in I.Q. It turned out that the doll drama reenacted his actual home situation. Tommy's mother had a job which kept her away from home from early morning until late afternoon. The father, whose business hours were not exacting, did many of the housekeeping chores, fed and dressed the boy and took him to and from school. Because the mother frequently came home exhausted, the father often put the child to bed. It was all very confusing to Tommy. He was at the stage in which a normal boy wants to identify himself with a male figure, but his family setup was such that he was not certain what the figure stood for—and anyway, he was not sure that he wanted to be that kind of man.

The Child Research Council is not a clinic: it does not treat diseases or disorders. But when symptoms come to light in the course of its research, it calls them to the attention of the parents and their family physician. In this case the parents finally recognized that their son's disturbance stemmed from themselves, and they immediately made adjustments to correct the situation. The mother went on half time at her business and made it her main job to love and care for Tommy. The father relinquished many of his mothering services. Within a few months after this realignment of the parental roles, Tommy was a much happier and better adjusted boy. He was eating so voraciously that the family doctor had to advise cutting down on his carbohydrates; his height and weight resumed their growth, and again he stood head and shoulders above his classmates in intelligence tests.

"This is not an unusual case," says Alfred H. Washburn, director of the Child Research Council. "I'm quite sure that other people working in guidance centers with play techniques could tell similar stories. But the episode does illustrate



RATES OF GROWTH of a boy (solid line) and a girl (broken line) are contrasted by these curves. Girls enter and complete the adolescent phase of rapid growth earlier than boys.



CHANGES IN PROPORTIONS OF THE BODY that come with growth are illustrated by profiles of changing figures of four boys and four girls. The drawings are based upon photographic records kept by Child Research Council. In each panel, four figures are pic-

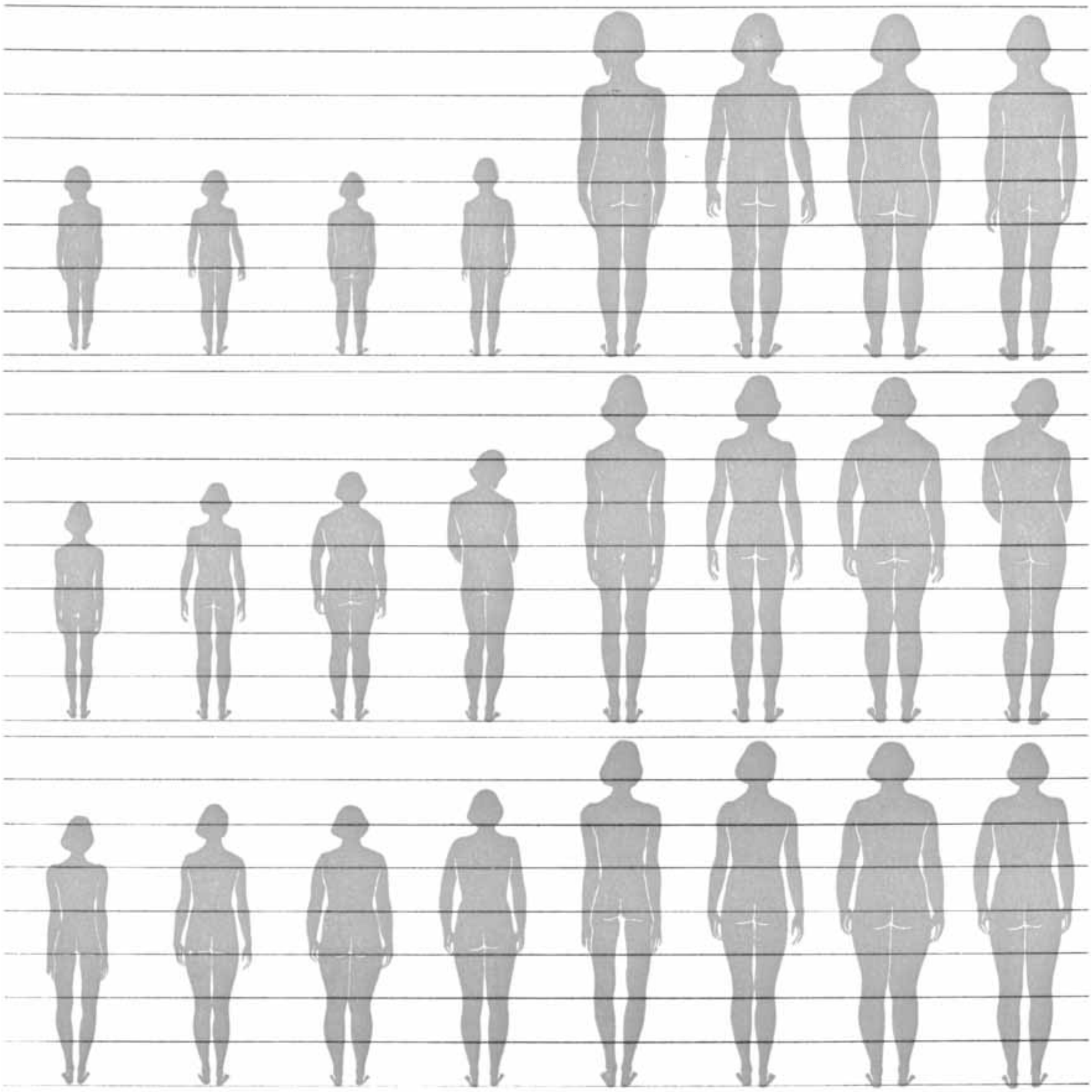
the three-fold nature of growth, and the interdependence of the growth factors. Human growth is a sensitively balanced complex of processes in which body structure, physiological function and emotion each plays its indispensable part—and a disturbance or deficiency of one factor can seriously affect the others. Here in Denver we are endeavoring to follow the course of each of these factors through the entire life spans of our children. We are keeping records of each individual from infancy into childhood and from childhood into adulthood. We intend to continue the study of each life until accident or old age eventually writes its finis."

Washburn, a tall, rangy man now in his late fifties, is a native of Boston who was graduated from Amherst College in 1916 and from the Harvard Medical School in 1921. Classmates recall that as a student he was not bashful about challenging medical dogma. During his internship something that he read in a book prompted Washburn to scribble this query in the margin: *Why hasn't medicine been more concerned with the problem of understanding the whole life cycle of a human being during healthy growth?*

Why not, indeed? There was a vast file of assorted information on the anatomy, physiology, psychology, behavior and diseases of the human system. There were multitudinous tomes on man-in-the-abstract. But never had a satisfactory study been made of the life cycle of even *one* human individual. "We know more about how a garden pea or a hog or a laboratory rat grows and adapts to varying environmental conditions," reflected Washburn, "than we do about how a person grows up and becomes the kind of adult he is."

With such ideas stewing in his brain, the young medical graduate went West to start the private practice of pediatrics in Portland, Ore. While there he held an instructorship at the University of Oregon. The following year the University of California called him to Berkeley, and soon Washburn was the gadfly of its faculty with his persistent questions about the life cycle, about what is normal in human growth and about the importance of making a beginning toward a science of man.

Meanwhile an interest in these same questions was fermenting among physi-



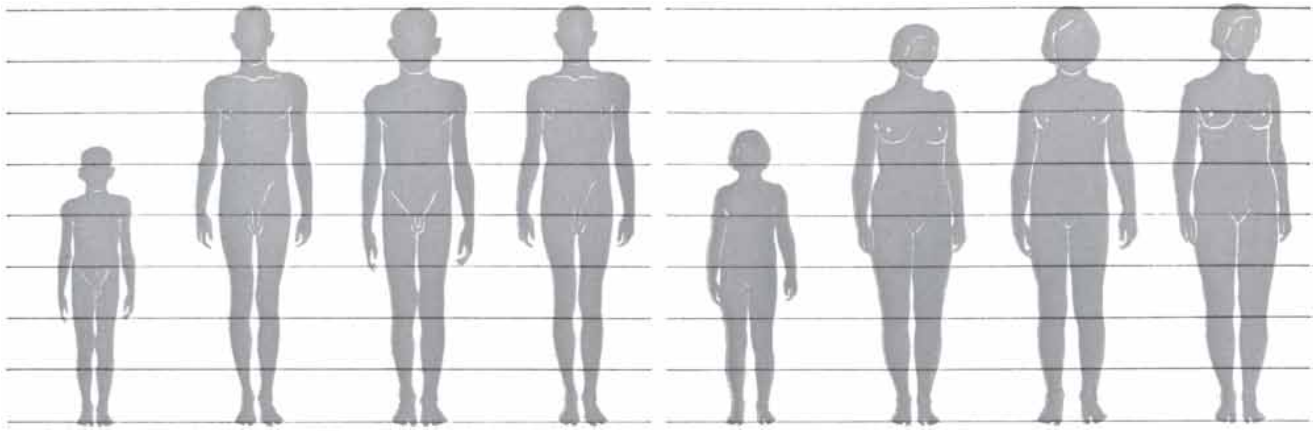
tured at relative actual height at left and, at right, all of the figures are blown up to the same arbitrary height to bring out contrasts in proportion. Major change in both sexes is relative increase of height to breadth of body as long bones achieve growth.

cians and public-spirited citizens in Colorado. In the early 1920s a group in Denver had set up a project in preventive medicine to examine children periodically for early signs of tuberculosis and respiratory disease. But after five years of operation its financial support had failed, and the project would have lapsed but for the intervention of a few local physicians and scientists. They had caught the vision of a larger objective. Instead of limiting the examinations to tests for disease, they asked, why not consider the child as a whole, study each as an individual and follow his pattern of growth and adaptation continuously?

The proponents of this idea enlisted the interest of the president of the University of Colorado, and the project had a new birth. It was incorporated by the State as the Child Research Council. The University of Colorado School of Medicine offered laboratory and administrative quarters in its building, and the Council agreed to make its findings available to the school. But a leader was needed, and at this stage the Council discovered Washburn, then an associate professor at California. It invited the transplanted New Englander to Denver, bombarded him with questions on his favorite theme, and hired him on the spot to become director of its research. That was in 1930. Washburn gathered an extraordinary team of investigators which has now been working together closely for more than two decades.

The oldest of the 160 persons whose life cycles are being followed by Dr. Washburn and his 26 associates is now 32 years of age, and the youngest was born last month. Occasionally the group loses a subject: a family moves to another city, a girl grows up and marries an outsider, a boy goes away to a distant job. But such losses are kept at a minimum by selecting the subjects from stable families. By adding three to five new babies annually, the Council has steadily increased its roster. The current enrollment is about as large as the present staff can keep track of, but the staff may eventually be increased to where it can enroll a maximum of 200 subjects.

"We have to realize that most of the children we are studying now will outlive every member of our present staff," Washburn observes. "Other investigators will complete the observations that we begin, and reap the harvest of what



HOW BOY AND GIRL CHANGE in build between the age of five and completion of growth (boy at 18, girl at 15) is shown here. In each panel the figures are paired at the same relative age. The figures at right in each panel are blown up to same height.

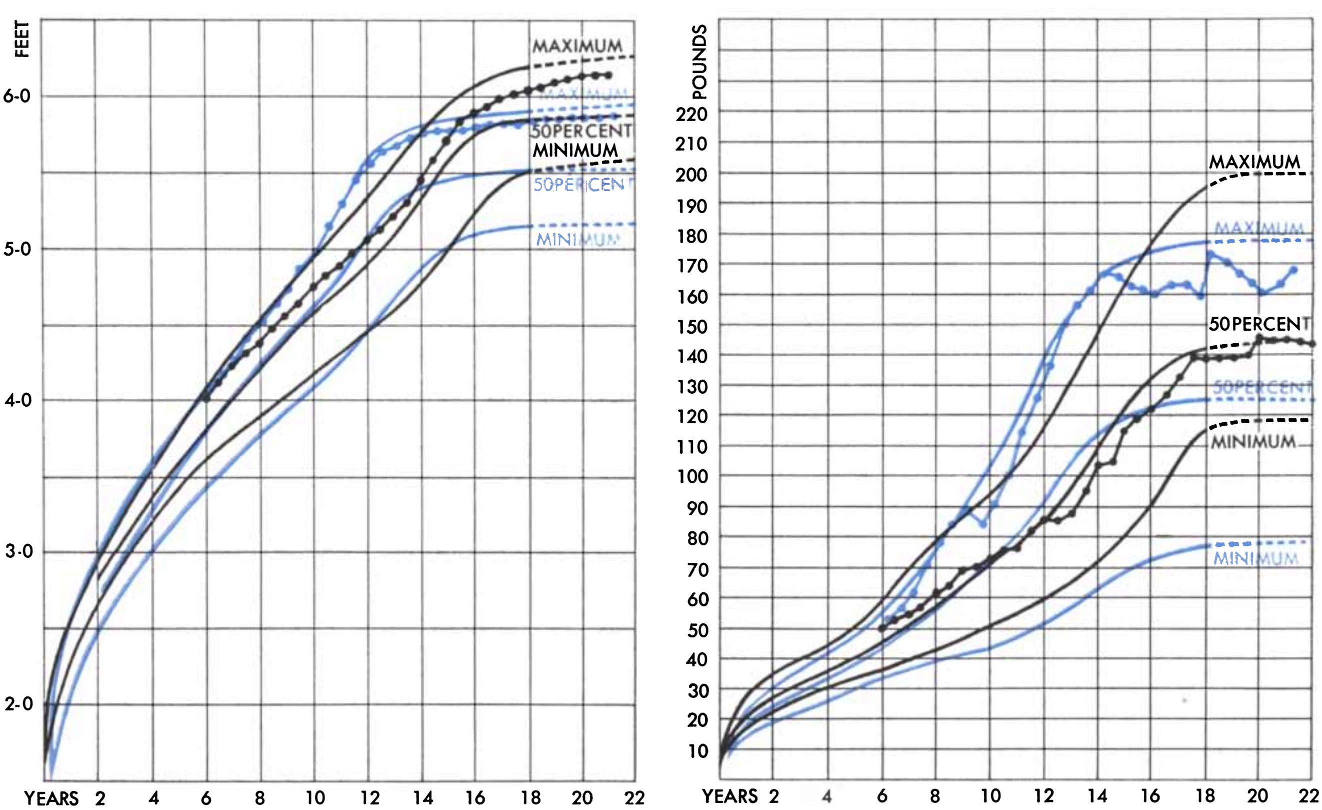
we have sown. All the more important, then, is our obligation to plan the program on an adequate scale, to start each study with a full realization of what it may mean for the future and to record the findings with thoroughness and a scrupulous care for accuracy and relevance.

"Our effort is based on the theory that the adult is what he is, and behaves as he does, as a result of his total transactions of living—and that means the sum of his experiences from conception on to his present age. We proceed on the hypothesis that this continual interplay between the individual and his environment is susceptible of observation, measurement and interpretation at three levels of organization—physical, physiological and psychological. Those three categories define our study: *physical* growth and adaptation as shown by structure, *physiological* growth and adaptation as shown by functioning, and *psychological* growth and adaptation as shown by mental ability, emotional attitudes, social behavior and other ingredients of personality.

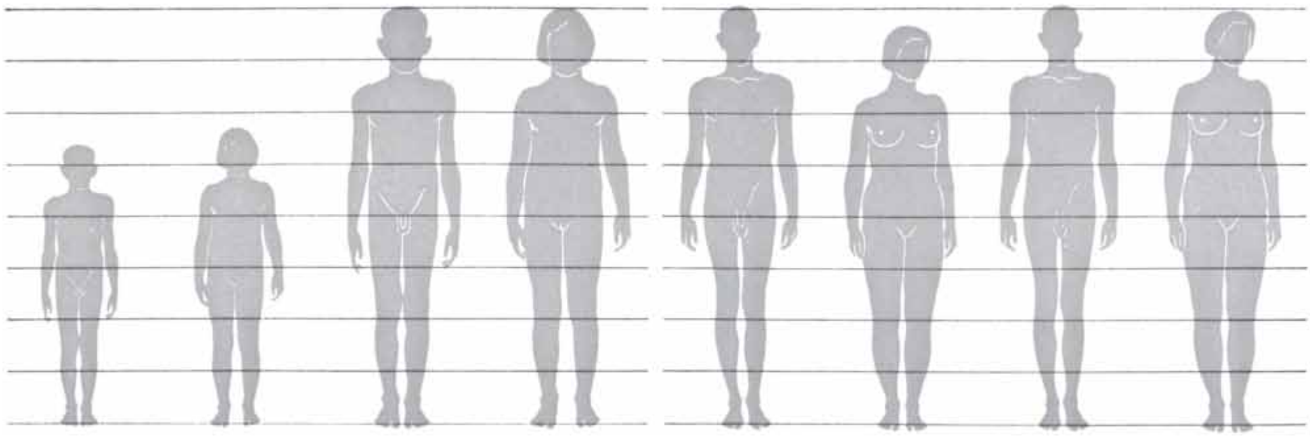
"We have tackled this many-sided, long-range and difficult research on the assumption that, from learning how people succeed or fail in adjusting to their world, we can obtain information which will guide children toward becoming happier, healthier and more useful members of society."

Physical Growth

Photography is an indispensable tool for studying growth. With X-ray photography the Council measures the



BOY GIRL **CONTRASTING GROWTH PATTERNS** of the boy and girl whose figures are profiled above are shown in charts which compare the curves of these individuals (beaded lines) with maximum, minimum and median curves for

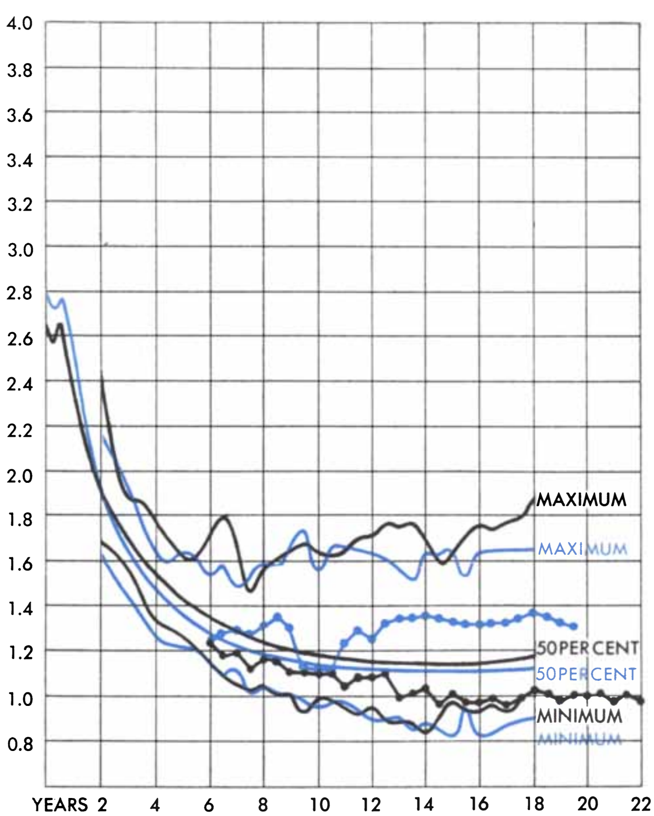


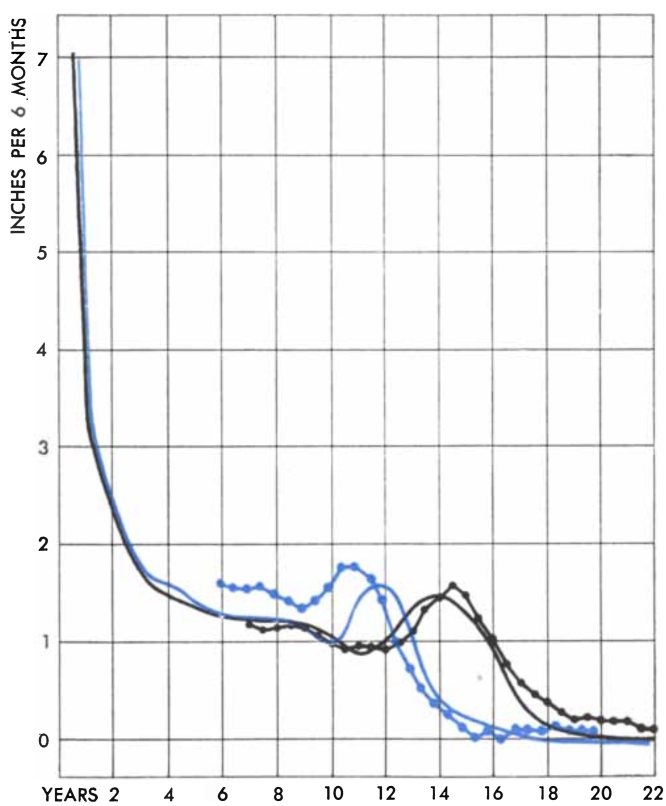
HOW BOY AND GIRL CONTRAST at the same stages of growth is shown in these two panels. In panel at left their figures are compared at the age of five; at right, at the completion of growth, with the figures blown up to same height at right in each panel.

growth of leg bones, arm bones, the head, chest, spine, heart, lungs, teeth and other internal organs and tissues; with direct photography it records the shape of bodily development. Nothing shows so plainly where and at what rate physical growth is taking place as a series of photographs of the same individual, taken at regular intervals over a period of years.

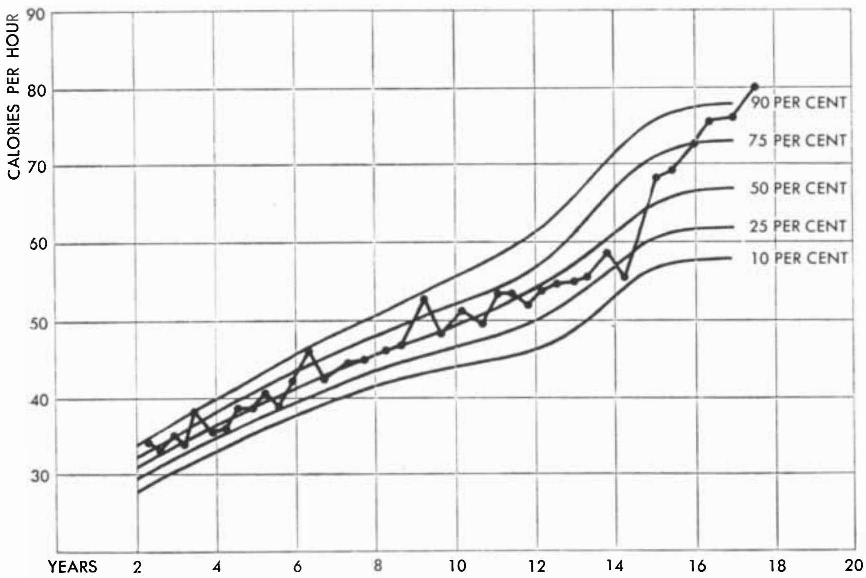
Edith Boyd, a pediatrician who specializes in anatomy, devised a simple technique which has enormously increased the value of the photographic records. "I took an enlarger," explained Dr. Boyd, "and projected all the photographs of a subject at various ages to the same height; for example, using the height of the subject at his current age, say 16, the images of the child at one year, at five years, at 10 and at 12 were all blown up to this height. Then I could see at a glance what changes had taken place in his body form.

"One of the biggest differences among people is their distribution of mass—whether they are long-legged or short-legged, how wide they are for their height, whether the hips or the shoulders are wider. In the series of pictures blown up to the same height, I found that I could measure how much of the child's mass was made up of his foot, how much of his leg, his thigh and so on up the body. I could follow and trace changes in the relative masses of these structural features. In a baby or small child, the shoulders may be wide compared to the hips; as a boy approaches school age, his shoulders and hips may come about even; as he goes into his puberty growth, his hips broaden out. While the boy's





healthy children of the Denver group. Charts from left to right are height, weight, ratio of increase in height and weight, and rate of growth. The girl is shown to be relatively heavy for her height, the boy relatively light. Girl's rate of growth peaks earlier than boy's.



BASAL METABOLISM is a sensitive indicator of the demands of growth. X-ray pictures at the bottom of spread explain why this boy's metabolism ascends so sharply at 15 years.

hip mass is growing, the shoulder mass is standing still, so the ratio changes."

Dr. Boyd showed a series of photographs of a girl from infancy to her eleventh year. "Her shoulders will broaden, but her hips will grow still wider," she commented. "For a boy the probability is that as he grows into adolescence, his hips will not grow proportionately wider, but his shoulders will—and that, of course, is one of the major sex differences in physique.

"When a person reaches adulthood, growth is completed only in the sense that the body has reached its maximum stature. There will be further changes in the structure, but they will be more gradual, and a photograph every five years instead of every year should be sufficient. The oldest photograph in our present file was taken at age 28. I don't see why we shouldn't attempt to trace the structural changes of aging just as we trace the structural changes of growing up. Every period of life is significant in a life-cycle study. And so I hope my successor will follow these subjects through to the end."

Another pediatrician on the staff, Jean Deming, specializes in biometrics. Dr. Deming has subjected the growth data collected by Dr. Boyd to mathematical analysis and plotted the results in a curve for•each individual. Actually two curves are necessary: one, known as the Rachel Jens curve, represents growth from birth to the beginning of adolescence; the other, an elongated S called the Gompertz curve, covers the period of adolescence. The Rachel Jens curve is fairly uniform for both boys and girls. But the Gompertz curve of adolescent growth is markedly different for the two sexes. In girls, the curve begins to bend upward into the first arm of the S at an earlier age and at a more rapid rate of ascent than in boys. But while the typical boy's curve starts later, and turns upward more slowly, it keeps ascending long after the typical girl's curve has leveled off.

"Plotting the growth of children brings out at a glance facts which, though obvious and well known, are apt to be ignored until they are shown graphically," said Dr. Deming. "One of these differences is the earlier maturing of the girl. You can see it dramatized in these two curves," and she picked up a sheet comparing a boy's and a girl's growth in height. "Note how almost parallel the two curves are up to the start of the girl's adolescence, which in this case occurred at 8½ years. The boy's adolescent growth spurt did not begin until he was 10½, when the girl's height was far above his, and she kept above him until about 13. Thereafter the boy kept on growing at a rapid rate, while the girl leveled off.

"We are all familiar with the fact that in junior high school the typical girl is much larger and more grown up than the typical boy of the same age. She's not interested in dates with these small boys; she wants to go with older boys. It is interesting also to see how the curve follows the personality pattern. The growth curve of a feminine type of boy—with a soft rounded body and a greater interest in dolls than in baseball, for example—usually follows the typical girl's pattern. Similarly girls of the tomboy type usually have a growth pattern conforming to that of boys."

Internal Structure

The staff member primarily responsible for measuring the growth of the internal structure of the body is Marian Maresh. She also is a pediatrician with a specialty: X-ray. Some of the most exciting discoveries of physical growth have come through roentgenology. Dr. Maresh works in close collaboration with Dr. Deming and Dr. Boyd in interpreting the X-ray pictures. The Council's collection of X-ray photographs of the chest is the largest on healthy children in the world.

"This collection of films," said Dr. Maresh, "has helped us to define the range of normality and to understand the variations that an individual child may have and still remain healthy. We had been taught in medical school that a child's chest film must look a certain way. Now we know that each child has his own standard and carries it through life, as far as we have gone. As he grows up, he may have a severe pneumonia or any of a number of other acute infections, but as soon as he has recovered, he will swing back to his own pattern of normality. He will not carry with him the so-called scars of repeated infections, unless he is chronically ill.

"As for sinuses, we have found that their appearance in a child has very little relation to his health. He may have small

ELBOW JOINT is site of one of the principal milestones in the process of growth. This is the fusion of

sinuses or large sinuses, occasionally cloudy sinuses, and still be a healthy child. This, of course, is quite contrary to what one finds in grown-ups. An adult with a cloudy sinus is apt to be sick."

The Council's chest X-rays have shown that the range of variability in the size and shape of the normal heart is greater than anatomists had believed. "Heart size is related to body size," declared Dr. Maresh. "A child who has been growing fast and is overweight is going to have a large heart. A child of medium body build, whose height-weight relationship is about average, will usually have a heart of average size. He will seldom have a small heart such as we find in the thin child. When it comes to shape, the hearts of healthy children have differences so great that some of them suggest textbook pictures of congenital heart disease—and yet nothing is wrong. The shape of a child's heart is his own business. After he gets that shape, he is going to keep it, barring affliction with a serious disease."

The growth spurt that marks the entrance to adolescence is revealed with a wealth of minutiae by the X-ray photographs. Within a few months the bones, lungs, heart and other organs may grow at a speed double or even treble the previous rate. As the general growth of the body slows down after adolescence, the heart actually decreases in size. This is not strange when you remember that the heart is a muscle. Muscles grow with use and diminish as the use grows less—and the heart is no exception.

Every child is an individual. Each has a unique structural pattern, which may or may not conform to what has been regarded as normal. In her X-ray study of the growth of bones, for example, Dr. Maresh has found a wide variation in the age at which the junctions between the long bones mature. Most boys are born with no wrist bones, only a soft cartilage, and girls rarely have more than one bone in the wrist at birth. The cartilage progressively calcifies into eight small bones. The rate at which they form has been taken as an index to bone development. But the Denver records show that at the age of five a healthy child may have anywhere from two to seven bony centers in the wrist; only 20 per cent of the children have the number heretofore regarded as normal for that age.

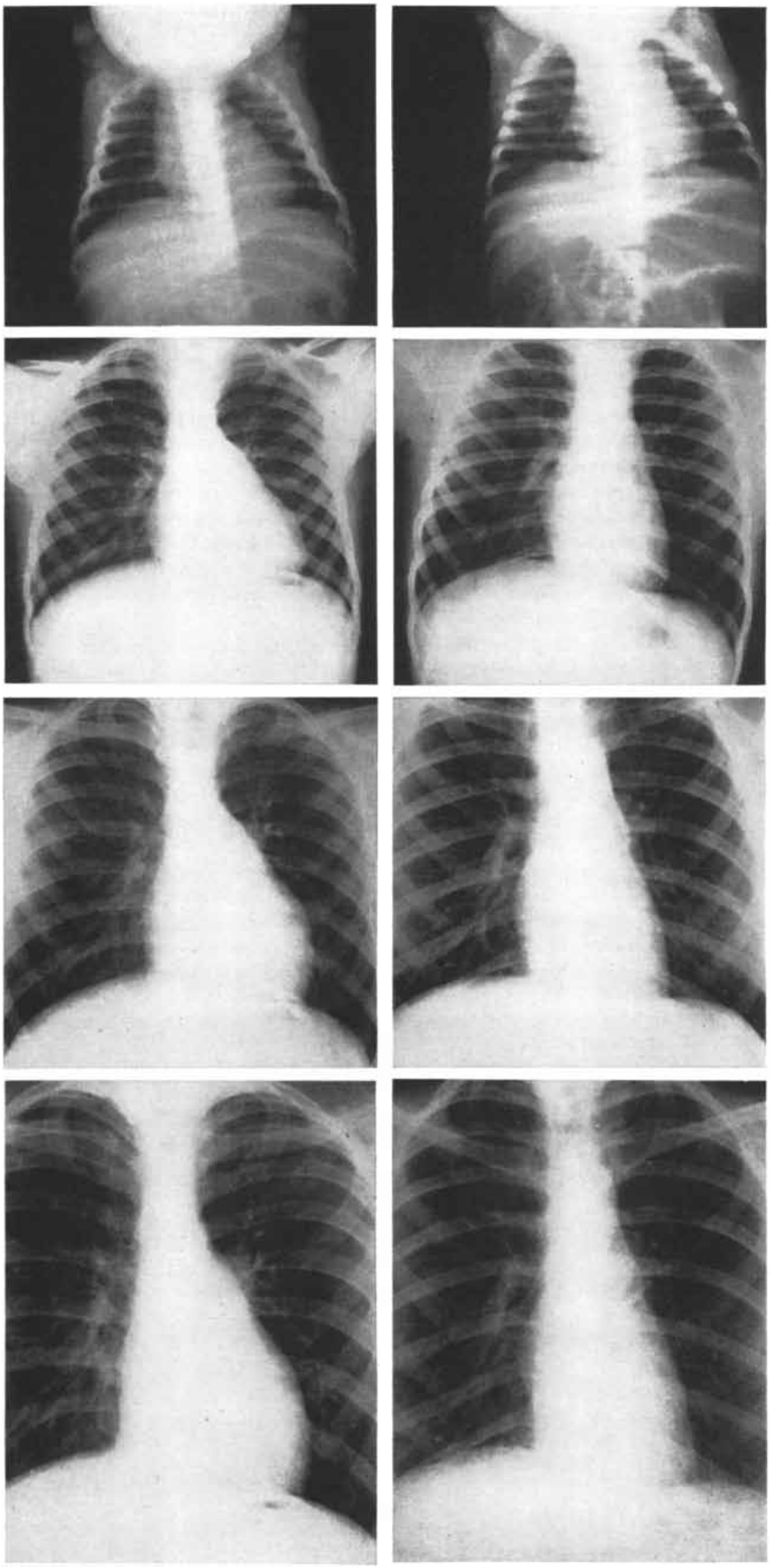
"The bone studies are my absorbing interest just now," went on Dr. Maresh. "We X-ray the left arm and leg at two-month intervals during the first six months of life, at six-month intervals from then on through adolescence and yearly thereafter. So I build up a serial picture of the growth of the upper arm, lower arm, upper leg, lower leg, and the relation of each to the growth of the body as a whole. The major difference between boys and girls is in the relative length of the forearm, which is longer in boys. That partly explains why women can't wear men's coats. My shoulders are as broad as my husband's, but his coat sleeves come down to the middle of my hand. This is a sex difference I did not expect to find. There is no difference between the male and female in the relative length of the upper arm bone or in the length of the legs in relation to body height.

Five of the children in the Denver study group are cousins; their five fathers are all brothers. These children present a wide range in size; one, a boy, is among the smallest for his age in the entire group, and another, a girl, is one of the largest girls of her age. Despite the size variation, all five children have the same structural pattern. Their pattern of relative bone length is somewhat unusual—yet it is the same for all. "We believe," remarked Dr. Maresh, "that eventually we're going to learn how people are put together, and where they inherit the bits that make up the differences. It seems clear that what a child inherits is not his body as a whole, but segments of it, or functions of it, or perhaps patterns of development."

Physiological Growth

As the body grows toward its adult form, new functions are developed and old ones are extended. The production of blood, the input of food, the output of energy, the reaction of nerve and muscle to stimuli—each plays a part in this business of growing up. And so the Child Research Council has a team of biochemists, nutritionists, hematologists and others who concentrate their talents on the physiological aspects of growth, under the general supervision of Robert

the little bony center at the end of the long bone in the upper arm with that bone. These two pairs of pictures show a boy's elbow (left) and a girl's before and after fusion. The boy's metabolism (*see chart on opposite page*) showed steep increase when this fusion was occurring.



CHANGES IN HEART SIZE in response to the demands of growth found in this study have upset accepted notions of what "normal" heart size is in children. Here the heart of a boy (left) and a girl are shown at comparable stages of growth from infancy to adolescence.

McCammon, the assistant director of the council.

Fundamental to life is metabolism—the two-way process by which nutrients are built into new tissue and, inversely, broken down to release energy. Basal metabolism, the minimum expenditure of energy required by the body at rest, is a base-line for the study of all physiological phenomena. One of the first routines established by the Council was the periodic measurement of the basal metabolism of its children. As data from these studies accumulated, staff members were appalled to discover how little was available in the way of standards for comparison. Actually the Council's own measurements of metabolic rates, published in 1940, were the first reliable tables for the ages from infancy to adolescence. Today those rates recorded in Denver are the norms for medical practice in many parts of the world.

In the same way the Council instituted studies to determine the level of red cells, white cells and other cellular components of the blood at various stages of growth. A similar inquiry measured the proportions of albumin, globulins and other proteins in the blood. Many of these blood determinations have been widely accepted by pediatricians as the most comprehensive data on blood-cell and blood-protein levels in early life.

An infant's blood differs from that of older children in its proportions of both cells and proteins, and differs still more from that of adults. There are also striking sex differences. For example, girls tend to have fewer white cells than boys, but a larger proportion of their white cells are of the specialized infection-fighting kind known as lymphocytes. At certain age levels the girls have fewer red cells per unit of blood than the boys have. Carotene, a substance the body uses to make vitamin A, is found in greater abundance in infant girls than in infant boys. But when the children reach 12 or thereabouts, the situation reverses: then the boy's blood has the greater proportion of carotene. "This finding has fascinating implications," said Dr. Washburn, "for it indicates an inverse relationship between growth and a food factor. In infancy males tend to grow more rapidly than females, but at age 12 most girls are moving into their adolescent growth spurt, while the boys' growth is still on the slow side. And note that in each sex it is only at the period of accelerated growth that the carotene level falls to a low point. I don't know what it means yet, but here we have what seems to be a relationship between the intake of a food substance, the sex of the individual and the pattern of growth."

The record of each child's food intake begins even before the baby is born. In the third month of the mother's pregnancy, Virginia Beal, the nutritionist, visits the home, examines the menus and checks on the variety and quantities of food consumed. After the infant's arrival, these periodic check-ups record exactly what the child is eating. In several cases Miss Beal has been able to spot deficiencies and predict nutritional disorders.

"On one occasion," related Washburn, "Miss Beal came in and said: 'This baby is not getting enough protein, minerals or vitamin D—she's headed for rickets.' The other staff members were highly skeptical. We had never seen a case of rickets in our entire series of children and we couldn't believe that any nutritional measurement could be so accurate. But three months later Dr. Maresh brought me an X-ray film of that child, and there it unmistakably was in the photograph. The case was mild, to be sure, but the bone structure showed evidence of rickets."

The primary purpose of these nutritional studies is to see how the child's growth correlates with its food intake. "Quantitative, as well as qualitative, changes in the blood, bones and teeth have long been recognized as related to the composition of the diet," said Washburn. "But no one yet has done a good job of determining exactly how they are related. We have found evidence that the dietary standards recommended by the National Research Council may need correcting. Our data show that the NRC stated requirements for certain nutrients during the first five years of life are too high. Not even our healthiest children are living up to them. For certain other nutrients the NRC standards are probably too low. We have found that some of our children are getting more vitamins than they need or can use. In the case of vitamins A and D, an overdose can be damaging, and this whole field of accessory food factors needs appraising to determine how much of each vitamin is the optimum ration for a growing child."

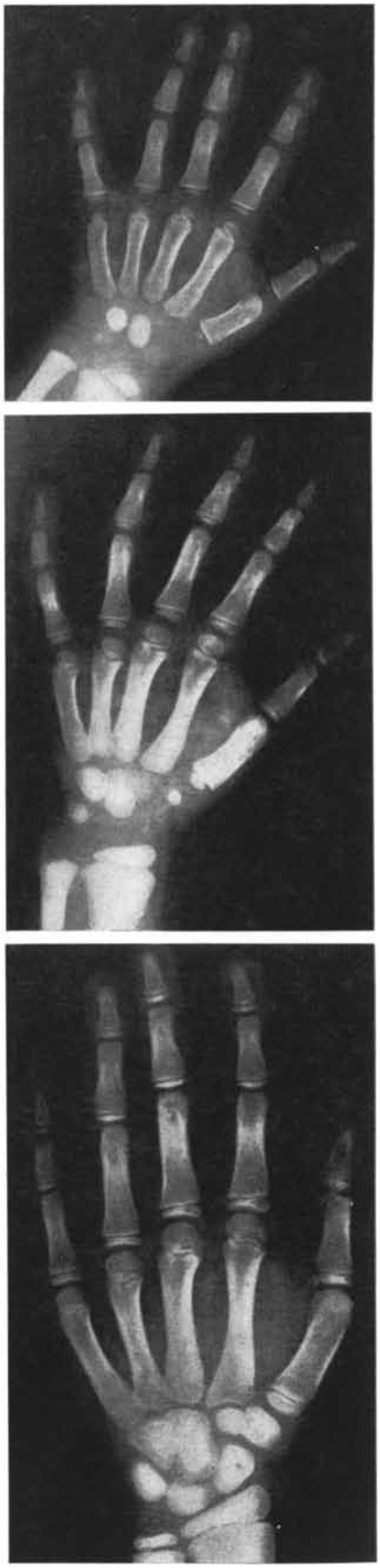
It is fascinating to watch the correlations between physical and physiological growth. One of the milestones in physical growth is the joining of the first little bony center in the elbow with the long bone of the upper arm. While this fusion is taking place, the basal metabolic rate rapidly rises to a higher level. It is as though the two processes had to be synchronized as the body's whole system poises for the tremendous adolescent growth spurt.

Dr. McCammon and the group of biochemists and physiologists recently discovered a correlation between the levels of the blood proteins beta and gamma globulin and the development of lymph tissue in the body. When a child's blood contains high levels of these globulins, he is apt to have larger tonsils, larger adenoids and more lymph nodes of every kind. The observations suggest that such children are more resistant to colds and other respiratory diseases than children with a smaller endowment of globulins.

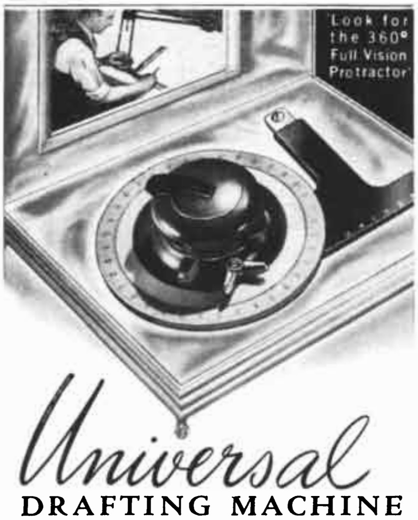
The protein content of the blood is related to the functioning of the heart. Over the years the Child Research Council has accumulated thousands of electrocardiograms of its children, and these are now in process of being analyzed. The results so far indicate that the difference in timing between the peaks and valleys of a child's electrically-recorded heart waves are correlated in some way with the levels of globulins and other plasma proteins in its blood.

"We might theorize," said Washburn, "that the same circumstance which leads the child to build up resistance to infections—namely, his stock of plasma proteins—is also concerned with keeping his heart functioning efficiently. This opens an interesting possibility. It suggests that here we may have a means of evaluating a child's ability to adapt to environmental handicaps."

Globulin relationships seem to pop up everywhere. Recently Washburn, in collaboration with the staff biochemist, Virginia Trevorrow, and the staff hematologist, Adula Meyers, completed a study of red cell sedimentation. Physicians have long used this test to diagnose certain diseases: they take a sample of blood from the patient and record the time it takes for the red cells to settle in a test tube. Fast sedimentation is taken to be a sign of an active infection, such as acute rheumatic fever or active tuberculosis. But Washburn and his associates have found that the blood of perfectly healthy children sometimes has a fast sedimentation rate, while that of rheumatic fever patients sometimes is slow. From many years of study they have concluded that there is no necessary relationship between an infection and the speed of sedimentation. They believe the sedimentation rate is influenced in part by the relative amount of certain proteins in the blood. And one of these proteins is gamma globulin! Some of the proteins are found in connection with infections,



BONES OF WRIST are index of growth. Calcification of seven bones in child's wrist is shown at two, four and eight years.



INFANT SUBJECT of study is here in midst of one of her first complete physical examinations at Denver Child Research Council which may record growth throughout her entire life.

others not; some increases in a protein represent good resistance, others not—and so the speed of sedimentation alone can no longer be accepted as a signal or measure of disease.

Psychological Growth

The Denver children vary widely in Intelligence Quotient. Moreover, the I.Q. is not constant; not only do individuals fluctuate but the group as a whole goes down at certain age levels. Studies conducted by Arnold Hilden indicate that a majority of the children are unable to function at their best in intelligence tests in the period from about age five to eight, and there is another dip at adolescence, when many youngsters fall back from 5 to 15 points.

There is a close correlation between a child's anxiety level and his performance in an intelligence test. It was found, for example, that a boy who suddenly dropped from a consistently high I.Q. to a low one was seething with resentment against his new step-mother—although she doted on him and never dreamed that the "honey-sweet" boy was other than an obedient, loving son. In instance after instance, when the I.Q. took a sudden tumble examination revealed that there was some home conflict or other development, real or imaginary, which was a source of emotional strain. It is significant that the drop in I.Q. between the fifth and eighth years coincides with the period when the child is preparing for or just entering school—a time of trial, uneasiness and uncertainty for most children. Similarly the slowing down at adolescence synchronizes with a characteristically unsettled period in the teen-ager's emotional life.

Recognizing the critical role of the emotions, the Council gives particular attention to the dynamic aspects of psychology. John Benjamin, an M.D. who has had broad experience in psychiatry, is in charge of these studies. They begin before the child is born, when Dr. Benjamin or one of his associates calls at the home to get acquainted with the parents. This prenatal visit affords an opportunity to appraise the home, the attitude of the parents toward the expected baby and the emotional and cultural climate in which it will receive its first impressions of the world—the initial environmental stimuli to growth and adaptation.

The child's early impressions are important and at about six months they become enormously so. The second half of its first year is a period of acute sensitivity. Any attitude on the part of the mother that suggests withdrawal or denial of her love, any prolonged separation of the baby from the mother, any quarreling or other chronic conflicts in the home, can have serious repercussions. The anxieties which result from such situations can adversely affect the baby's intake of food, retard its growth and build up an emotional pattern which is reflected years later in its attitudes and behavior. Just how long the effect persists is not yet known, for the Council's studies of anxiety in infants extend back less than a decade. The Council has cases in which emotional traumas inflicted in the first year or two of life have shown specific outcroppings in the per-

sonalities of children four or five years later. Some of the resulting symptoms are enough to send the shivers down your back.

There are mothers to whom breast feeding is repugnant but who dutifully nurse their babies because they have been told, or have the impression, that it is best for the baby. No matter how conscientious such a mother may be, it is very difficult for her to give the breast feedings with the full sense of pleasure and satisfaction that the child craves. Actually a mother who feeds her infant from a bottle and at the same time lovingly cuddles it against her will do a better job of child raising. She will be rearing hers with much less of the uncertainty, doubt and anxiety that inevitably beset an infant whose mother dislikes the nursing process heartily and goes about it with a coldness and matter-of-factness that cannot be disguised.

The baby's reaction may express itself in the rejection of food or in bowel disturbances such as minor diarrhea and minor constipation. The Council psychologists have observed many cases in which an emotional upset was followed by disturbances in intake of food, in handling of food and in growth.

An experiment with animals made by a graduate student of the University of Colorado last year under Dr. Benjamin's supervision brings at least a suggestion of corroborative evidence. Twenty laboratory rats were divided into two groups. Each group was supplied with exactly the same kinds and amounts of food and was provided with the same living conditions. But the rats of one group were caressed and cuddled by the investigator, while the other group was treated coldly. "It sounds silly," said Washburn, "but the petted rats learned faster and grew faster." The experiment is now being repeated, with biochemical extensions, to find out if possible how the cuddled group could grow faster on the same food intake.

Besides the usual psychological and personality tests, the Council psychologists make use of many informal techniques to study their children from the second year on. These include doll play, free play, painting, drawing and clay modeling.

In free play all the toys are displayed, and the child is free to pick up anything and play with whatever strikes its fancy. Sometimes the child will take out the toys indiscriminately, scatter them around the room, and do nothing constructive. "This is harder to interpret than direct play," said Washburn, "but the child who merely throws things about is usually disturbed, though he doesn't know how to express his anxiety."

I was given an opportunity to listen in on a free play experience of a 4½-year-old boy observed by Katherine Tennes, one of the psychologists. The child ran quickly to the open cupboard of toys and took out two pistols. "I want a gun," he said. Handing a gun to Mrs. Tennes, he added: "Here's one for you." Then he said: "I'm Roy Rogers, and you're an Indian." He told her to sit in a chair, climbed to the top of the cupboard and shouted: "I'm going to shoot you!" After shooting, he remarked: "My father's name is Roy Rogers." Then, noticing a dish of candy on the cupboard, he asked: "Can I have a piece of candy?" When Mrs. Tennes nodded, he took a piece and ate it.

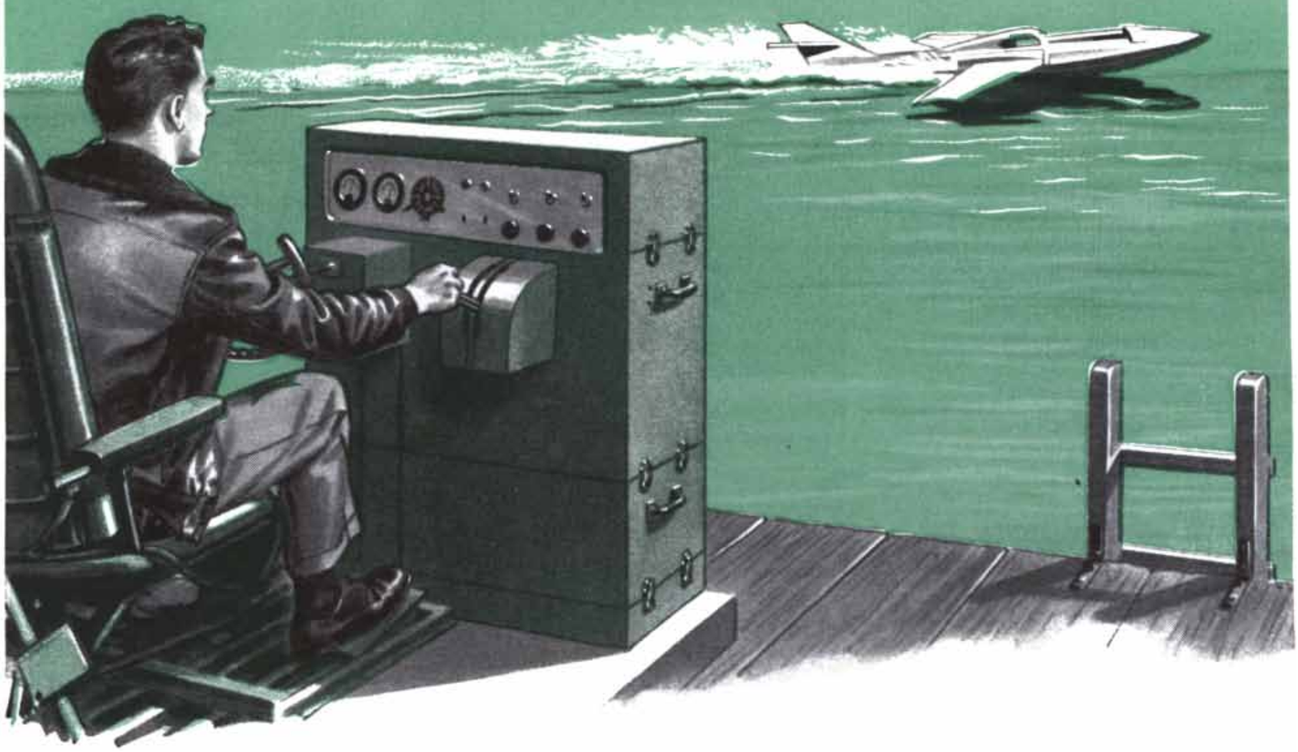
"Now that is a very simple episode," explained Mrs. Tennes, "but it conveyed a lot of meaning. This boy has aggressive feelings toward people, but he is usually quiet and polite. He expresses in play the feelings which in the ordinary circumstances of his life he is not permitted to show directly. He identified himself with Roy Rogers because Roy Rogers is someone who can't be hurt. The fact that he then called his father Roy Rogers showed that he has made a very positive identification with his father. That is one of the things we are interested in finding out about a child—whether he identifies more with his father or with his mother. It will make a difference in the smoothness of his adjustments as he grows up. The candy incident illustrated the usual polite, subdued behavior to which he returns when he is confronted with a reality situation."

Sometimes the free play becomes highly dramatic, and even violent, with the starkest sort of symbolism reminiscent of Freudian theory. What comes out in the play is checked by other procedures. In the finger painting, for example, an aggressive child will almost invariably select violent colors, such as red or purple, and lay them on in vertical strokes with broad lines, whereas one who is mild-mannered and placid usually paints with horizontal lines and soft colors.

These techniques are useful not only for unmasking the anxieties which are troubling the growing child, but also as instruments for testing, validating, and expanding personality theory. After all, the subject of the process of growing up is a person, and the final objective of all these studies—physical, physiological and psychological—is to understand how an infant person, starting at scratch, becomes the kind of adult that he does.

How to Fly a Jet-Powered Seaplane

...Before it's Built



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EVOLUTION OBSERVED

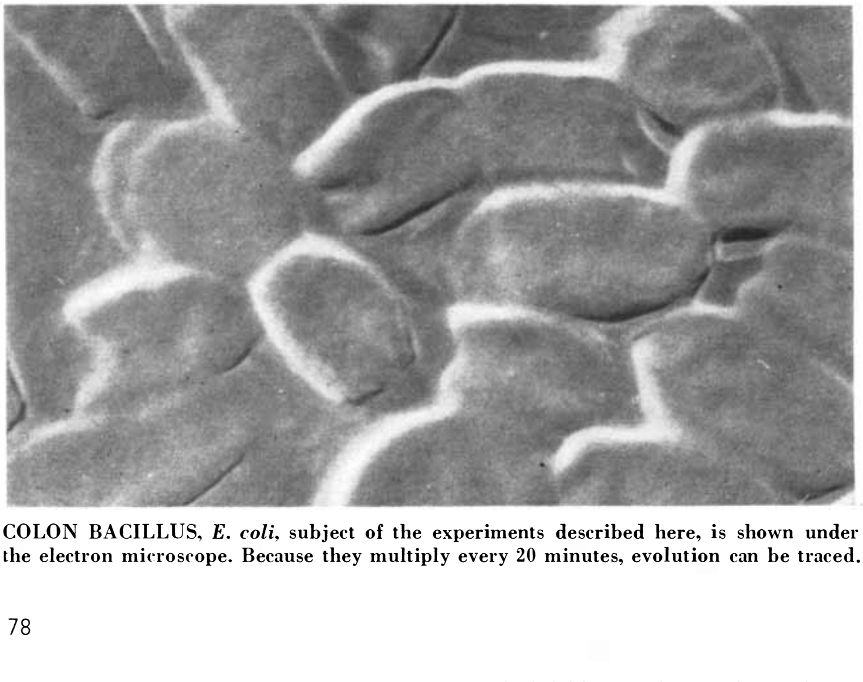
The study of bacteria through as many as 7,000 generations shows that the strain goes on improving indefinitely even in a constant environment, as mutation and selection produce ever fitter types

by Francis J. Ryan

Our ideas about evolution today, nearly 100 years after Charles Darwin launched his immensely fruitful concept, are still based largely on observation and deduction rather than on experiment. There is plenty of evidence for evolution, but it has been extremely difficult to study the process in the laboratory or to settle with finality some of the main issues, such as, for instance, the Lamarckian idea of the inheritance of acquired characteristics. The reason is that evolution is exasperatingly slow. Man today differs little biologically from the man of Ur 5,000 years ago. Almost nowhere in nature can we see evolution in action.

We are now beginning, however, to realize this objective in the laboratory. With bacteria as subjects we have actually been able to observe evolution in progress. A human generation spans some 20 years; for bacteria a generation takes only 20 minutes. In two years bacteria can grow through more generations than man has in the million years or so of his evolutionary history on the earth.

For this and many other reasons bacteria are eminently fitted for the experimental study of evolution. They can be isolated and kept in pure culture. Many, for instance the ordinary colon bacillus, will multiply in a medium consisting only of sugar, inorganic salts and water. From these elementary components the bacteria synthesize all the vitamins, amino acids and other compounds that make up their substance. Thus the conditions of their growth can be strictly controlled. Furthermore, as many as a billion organisms can be produced in a single test-tube culture. We can take a census of the population at any time simply by removing a sample from the test tube, spreading an appropriate dilution of it on agar-gel and counting the colonies that grow there. Each colony represents one bacterium in the original sample. From the number of colonies, the size of the sample and the dilution used, the number of bacteria in the whole culture can be determined.



COLON BACILLUS, *E. coli*, subject of the experiments described here, is shown under the electron microscope. Because they multiply every 20 minutes, evolution can be traced.

We study evolution among the bacteria by submitting them to some drastic treatment that selects for survival only the resistant forms. Suppose we add penicillin to the nutrients in the agar-gel. The antibiotic will kill most of the bacteria and leave only a few survivors. If we then place the colonies produced by these survivors on a fresh penicillin medium, all the bacteria will thrive and multiply. The resistance to penicillin is inherited, and the descendants will go on reproducing indefinitely, either in the presence or the absence of penicillin.

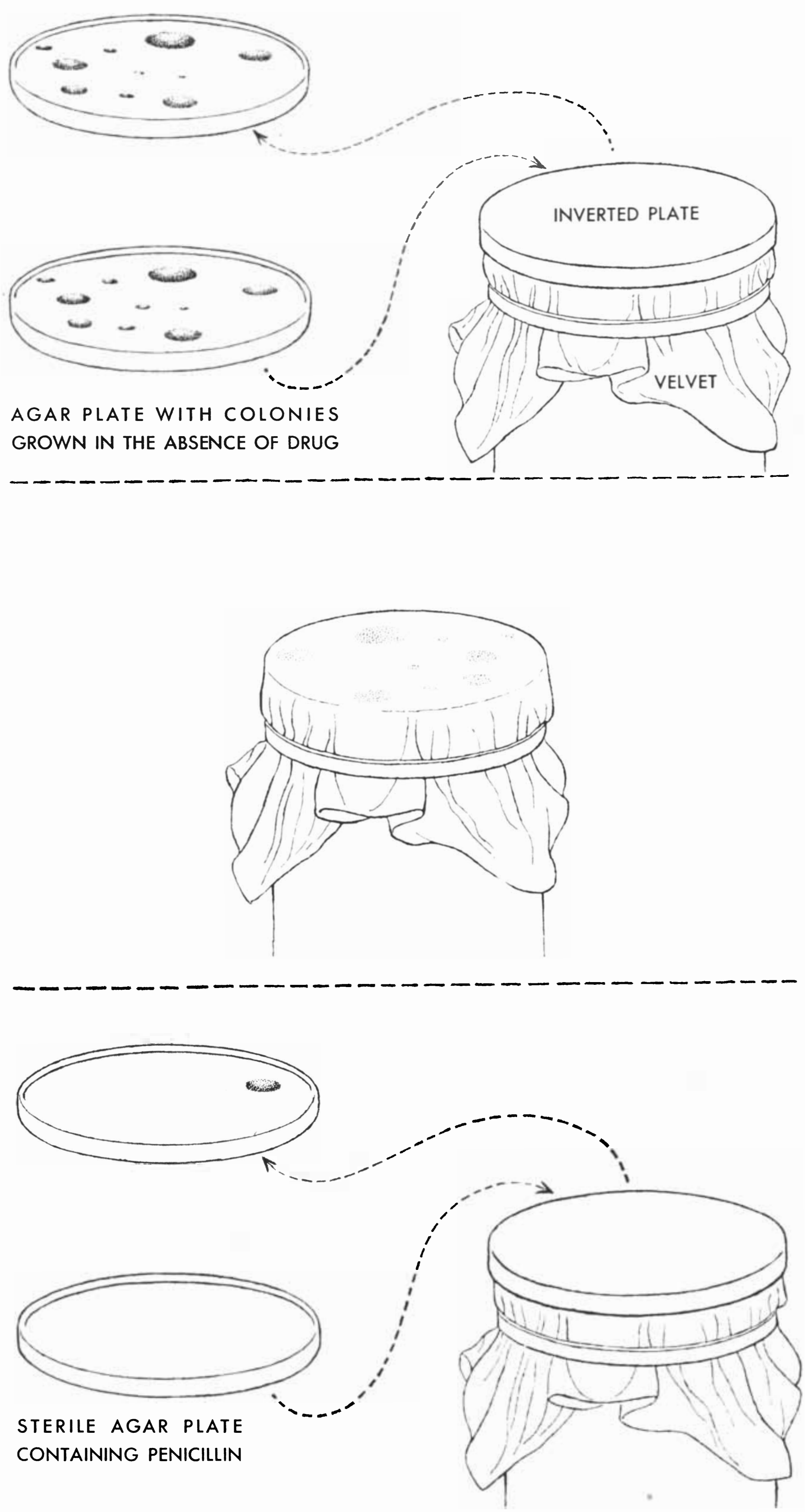
How do the resistant individuals acquire their resistance to penicillin in the first place? In any culture started from a bacterium that is sensitive to penicillin, a few resistant offspring will turn up—on the average about one in 100 million. Is exposure to the drug what makes them resistant? This possibility has been investigated in various ways, and the answer is definitely No.

An ingenious experiment developed by the University of Wisconsin geneticist Joshua Lederberg provides the most direct evidence. He first grew colonies of bacteria on a drug-free agar plate. Then he gently pressed the surface of the plate on a piece of sterile velvet. Some of the bacteria of each colony clung to the nap of the velvet; thus the colonies were imprinted on it. Now the agar plate was removed and a second plate containing a drug but no bacteria was pressed on the same area of velvet. The colonies were transferred from the velvet to this second plate in exactly the same positions they had occupied on the first plate. On the second plate only the colonies resistant to the drug grew. This showed the position of the resistant colonies on the original plate. Those colonies were then isolated, and they proved to be uniformly resistant to the drug, although they had not previously been in contact with it. The experiment demonstrated conclusively that the resistance to the drug was not produced by the drug but was already present in some of the bacteria before they were exposed to it. In other words, the ability to grow on the drug had arisen as a natural mutation among a few of the bacteria.

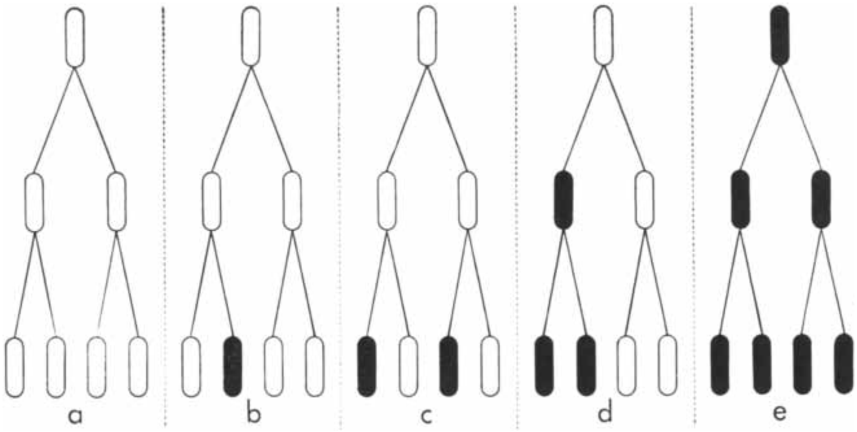
Bacterial mutations are usually random, not only in the adaptive but also in the statistical sense. However, the mutation rate cannot be calculated simply by counting the number of mutants that appear in a given population. Consider the situation in a growing bacterial culture. One organism divides into two, the two into four, and so on. In some cultures a mutation may occur in the first bacterium, and all subsequent bacteria in the culture will then inherit the mutant character. In others the mutation may not occur until later, in which event there will be fewer mutants.

To estimate the mutation rate we may employ a method based on the probability function known as the Poisson formulation. Suppose a piece of paper is ruled into one-inch squares and exposed to rain long enough to allow as many raindrops to hit the paper as there are squares. The raindrops fall not uniformly over the paper but at random: some of the squares will have no drops, some one drop, some two, a few three, four or more. With the Poisson formula one can calculate the proportion of squares that has received each number of drops from the mean number of hits per square. Conversely, one can estimate the mean number of hits if he knows only the frequency of one class of events, say the proportion of squares with no hits. In the case of bacterial mutations, we can calculate the average number of mutations in a large series of cultures from the proportion of cultures in which we find no mutations at all. We can then compute the mutation rate by dividing the average number of mutations by the average number of bacterial generations. This is the method by which we arrived at the estimate that the chance of mutation is about one in 100 million per generation. Although bacteria mutate, they are really remarkably stable!

The estimate assumes, of course, that mutations are randomly distributed among the cultures. Actually this is the only hypothesis so far suggested that predicts the unusual distribution observed. The English geneticists D. E. Lea and C. A. Coulson have made some sophisticated calculations based on the



PENICILLIN-RESISTANT BACTERIA are shown to be products not of environmental contact with the drug but of chance mutation in this experiment by Joshua Lederberg of the University of Wisconsin. *Top:* colonies grown on drug-free agar are lightly pressed on sterile velvet. *Center:* some bacteria from each colony cling to the nap. *Bottom:* the velvet is then pressed to drug-containing agar, revealing the location of a single drug-resistant colony already growing on the original plate which had never come in contact with the drug.



MUTATION RATE is based on a probability spectrum ranging from (a) no mutations to (e) the occurrence of a mutation in first cell, all offspring inheriting the mutant character.

assumption of randomness, and their theoretical predictions of the mutation distributions to be expected agree remarkably well with those actually found in cultures.

Evolution is a matter of change and selection. The environment, of course, does the selecting. The mutants arising among bacteria may be of all sorts: penicillin-resistant, bacteriophage-resistant, able or unable to synthesize certain vitamins or amino acids, and so on. Different mutations occur independently of one another, and so rarely that the likelihood of any two occurring in the same bacterium is extremely small. If the environment contains penicillin, the penicillin-resistant bacteria will be the ones that survive and grow. The original population will then be changed; it will have evolved. If a penicillin-resistant population is exposed to streptomycin, it will become streptomycin-resistant as well. In this fashion a host of new characters can be imposed on a population. By drastic environmental changes and by selection an investigator can make bacteria evolve in the direction he wishes, despite the randomness of the primary mutation.

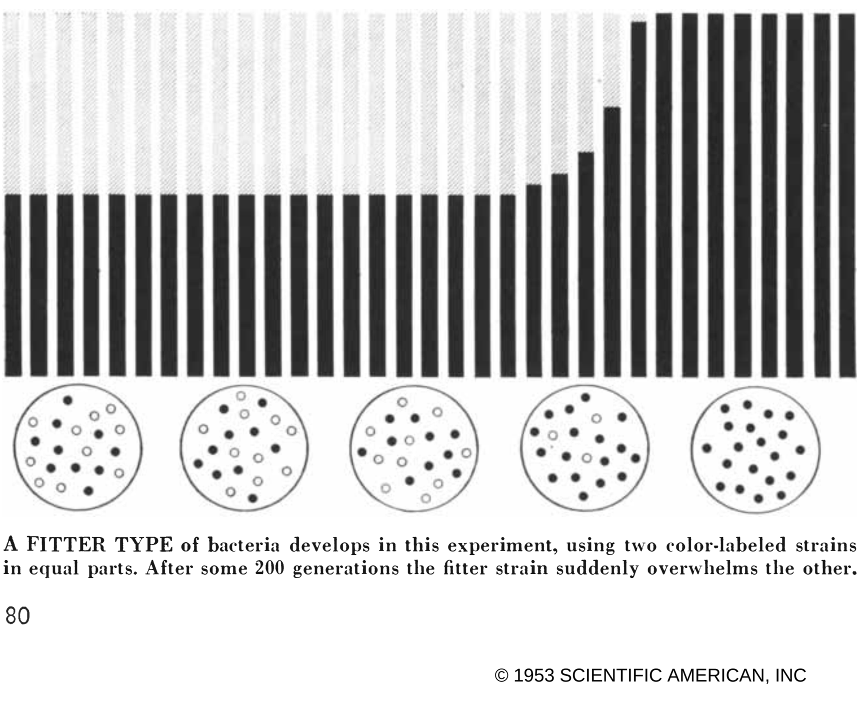
What happens when the environment remains constant? Here we are presented with a puzzle. Because bacterial mutations are reversible (*e.g.*, a drug-resistant bacterium can mutate back to sensitivity), we should expect that, in an environment in which both types can live, the proportion of mutants will reach an equilibrium equal to the ratio of the forward and backward mutation rates. But this would make a stable culture impossible. Worse than that, the culture would become so heterogeneous as to be unrecognizable. Since there are thousands of possible mutant types, the parent type from which a culture originally started would in time be all but lost in the population. Yet this is contrary to the usual experience in the laboratory; with rare exceptions bacterial cultures do remain the same.

The solution to this paradox came when it was discovered that even in a constant environment growing bacteria are continually evolving in the direction of becoming better adjusted to that environment. The experiments involved a culture in which were mixed two "labeled" strains, one a mutant of the other. The first strain could ferment the sugar lactose and formed purple colonies on a special indicator agar; the second was not able to ferment lactose and formed white colonies on this agar. The use of these genetic markers made it possible to take a census of the relative proportions of the two types in a culture at any time.

The mixed culture was grown for a long time in a medium containing the sugar glucose. At the start the proportions of the two types were half and half. This ratio remained constant for more than 100 generations. But after about 200 generations one type abruptly overgrew and eliminated the other. When the dominant new type was mixed with the original types in a fresh culture, it again took over, this time without delay. We called the dominant bacteria, which evidently had a superior adjustment to the medium, a fitter type. In further experiments we mixed together two such fitter types and after the same delay of about 200 generations one suddenly overgrew the other. It had become an even fitter type. And so the process continued: we obtained successively fitter and fitter types through 7,000 generations. All this time the medium, *i.e.*, the environment, was kept constant.

In the 50-50 mixture there seemed to be no preference as to which of the two types would overgrow the other. When the proportion of one was smaller than that of the other, however, it was invariably overgrown by the preponderant member. This is to be expected if the fitter types arise by mutation. The greater the number of bacteria of one type, the greater the probability that the mutation will occur among them rather than among the rarer bacteria.

We can now see a likely explanation of the stability of bacterial cultures. Although mutants keep coming along, one fitter type, which always arises among the preponderant parental bacteria, overgrows and eliminates all the other mutants. New mutants then occur among the fitter type, only to be eliminated when an even fitter one arises. The continued appearance of fitter and fitter types constantly depresses the number of mutants and stabilizes the parental stock. The only change allowed in a con-



A FITTER TYPE of bacteria develops in this experiment, using two color-labeled strains in equal parts. After some 200 generations the fitter strain suddenly overwhelms the other.

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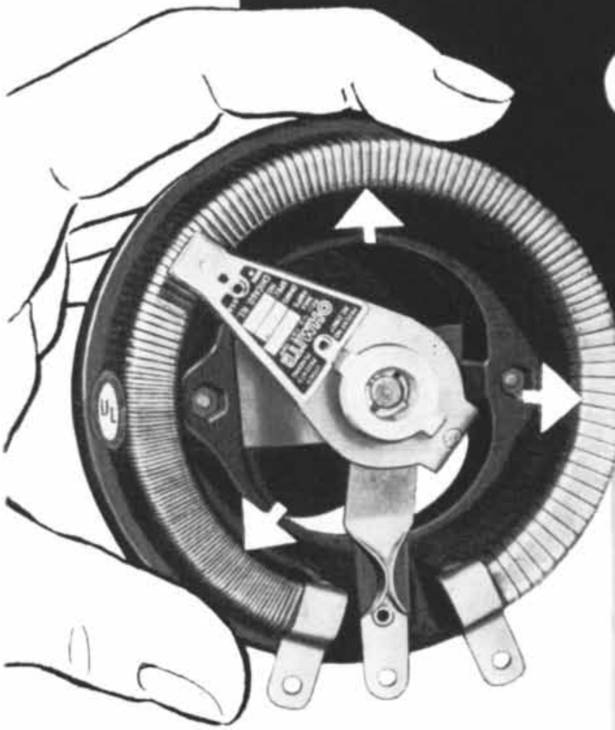

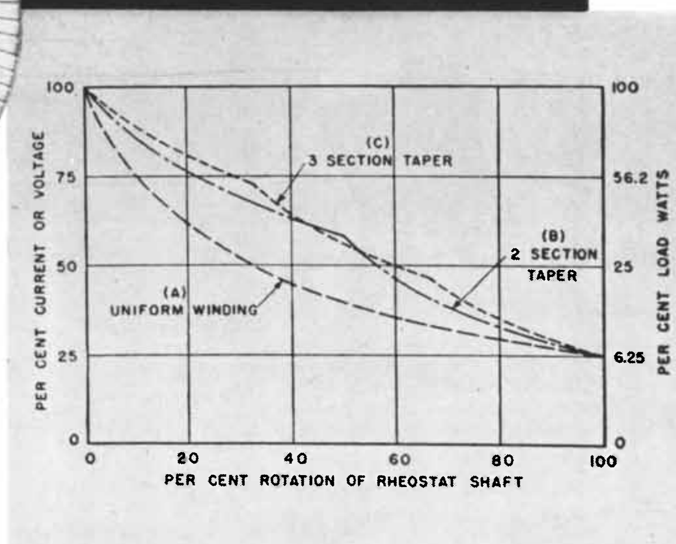

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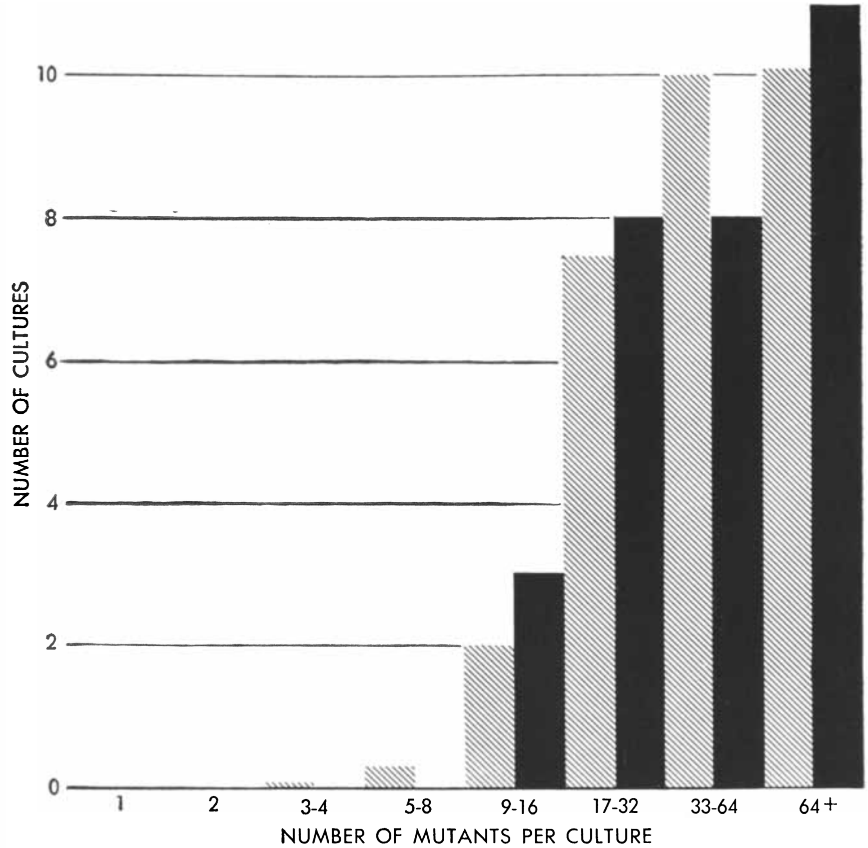

RANDOM DISTRIBUTION of mutation is elegantly calculated by a new method and it agrees closely with the numbers actually observed.

stant environment is progressive and in the direction of adaptation of the parental type to that environment.

The real enigma is that the development of fitter types seems to go on indefinitely, so far as we have observed. It seems incredible that there is no end to improvement. Be that as it may, the demonstration of this phenomenon may tell us much about the evolution not only of bacteria but also of other organisms. We can see this kind of straight-line evolution in a constant direction in such a phenomenon as the mammoths' tusks, which steadily became larger and larger.

Note that the mutations so far described all conferred an advantageous character upon the bacteria. It is sometimes contended that mutations cannot provide the raw material for evolution because they are usually deleterious. But these experiments prove that selection is a powerful force for fixing and perpetuating those rare mutations that do give an advantage.

The most important aspect of such selection is its role as a stabilizing agent. It prevents the destruction of an adaptive hereditary constitution while at the same time gradually improving it. Yet a safe residuum of all types of other mutants is maintained in the population so that when the environment changes there is a good chance that some of the population will be ready for it. In nature the environment of bacteria is in a constant state of flux. There must be a continual change in selection pressures in an infection, in the soil and in the digestive tracts of animals. It is only a few years since penicillin came into general use, yet already resistance to this antibiotic has become of real concern to physicians. Resistant bacteria are taking the place of the sensitive ones. This illustrates the unceasing combat man must accept in attempting to control the world about him.

It must not be forgotten that the evolution of microorganisms can be used in many ways to our advantage, even in the production of new antibiotics to control resistant organisms. During the last war genetic techniques bred new strains of *Penicillium notatum* which made thousands of times more penicillin available than did Sir Alexander Fleming's original strain. Beyond such practical considerations the study of bacterial evolution sheds light on questions basic to an understanding of all organic change.

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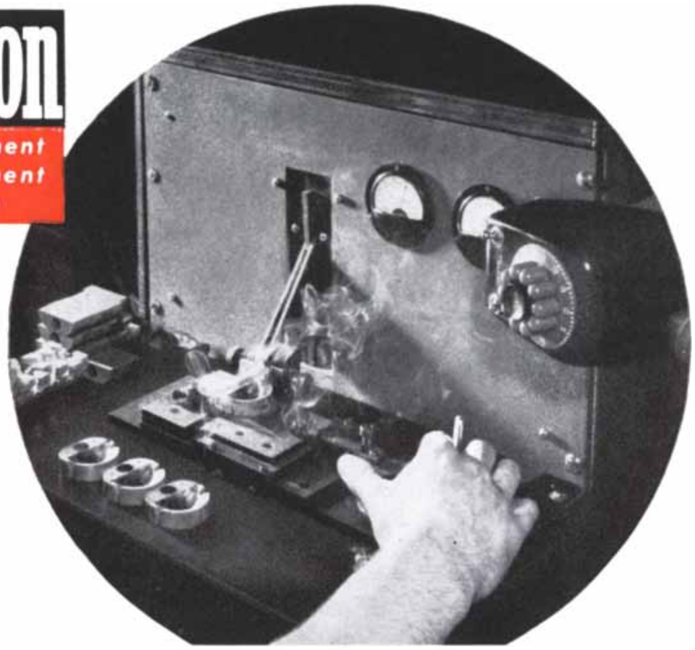

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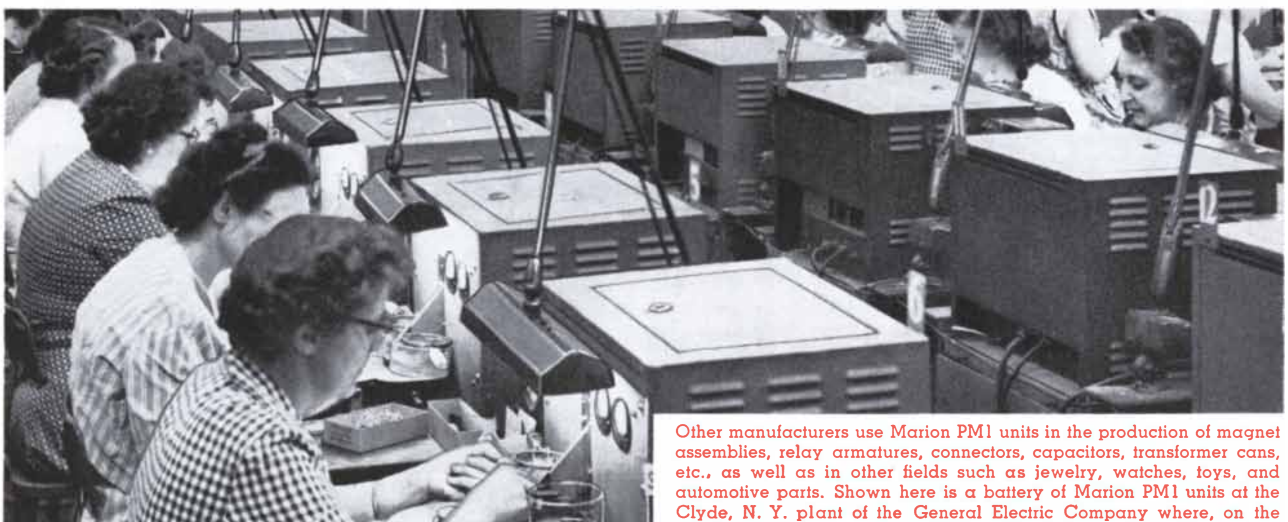

Other manufacturers use Marion PM1 units in the production of magnet assemblies, relay armatures, connectors, capacitors, transformer cans, etc., as well as in other fields such as jewelry, watches, toys, and automotive parts. Shown here is a battery of Marion PM1 units at the Clyde, N. Y. plant of the General Electric Company where, on the whisker diode line, a small pellet of germanium metal is soldered to the end of a nickel pin.

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History in a Peat Bog

The floor of an ancient Danish lake yields relics of Dark Age tribal conflicts that are remembered today in the legends of Beowulf and King Arthur

by Thomas G. Bibby

The period of British history—and indeed of the history of Europe—from the withdrawal of the Roman legions from Britain in 407 A.D. to the Norman Conquest in 1066 is not without reason known as the Dark Ages. During those six and a half centuries warrior tribes roamed and fought over the length and breadth of Europe, but their movements are only dimly lit here and there by monks' writings, and we know little about the people and the course of events until Charlemagne and William the Conqueror emerged into the full spotlight of history.

Legend and scattered writings tell us something. The collection of fragmentary manuscripts known as the *Anglo-Saxon Chronicle* says baldly that Angles, Saxons and Jutes invaded and conquered England soon after the Roman withdrawal. The Saxons without much doubt came from the Rhineland, the Angles from the district of Angel at the root of the Danish peninsula of Jutland, and the Jutes probably from the Jutland peninsula itself. About the invasions themselves history is almost completely silent; we have only the romantic legend of King Arthur, apparently a native chieftain who organized the resistance of Britain's inhabitants to the foreign invaders. Of the events that led up to the invasions we know somewhat more. According to scattered references by Roman writers it appears that in the two

EXCAVATED WEAPONS were left carefully undisturbed for this documentary photograph. In this cluster were found 80 objects, including spearheads, as in right foreground, arrowheads, buckles and knives. The white object atop the peat pedestal in center of the cluster is a quartzite firestone, the Dark Age equivalent of the modern matchbox, placed on floor of excavation to suggest scale.

centuries preceding the invasions the Danes gradually pushed westward from southern Sweden and the island of Zealand, occupying first the island of Fünen and then the Jutland peninsula. Probably it was this conquest that drove the tribes of Angel and Jutland to leave their homeland in large numbers and invade England. Danish legends recount these tribal wars, and presumably the same wars are the ones immortalized in the early English epic *Beowulf*.

Where history is silent, and legend ambiguous, archaeology steps in to confirm the dimly remembered stories with the spade. The peat bogs of Denmark have yielded in our time dramatic evidence of the pre-invasion struggle. Great deposits of weapons, of the same time as the wars described in *Beowulf*, have been discovered in the territories where major battles of those wars may have taken place. The latest of these finds, and the first to be investigated with scientific care, has been unearthed during the past three years. It promises to tell us a great deal about a dim period in the twilight of European history.

The Danish archaeological treasure first came to light during the latter half of the 19th century. In peat bogs at four sites in Denmark—Torsbjerg in Angel, Nydam in South Jutland and Vimose and Kragehul on the island of Fünen—there were found literally thousands of weapons and items of military equipment, beautifully preserved by the tannic acid of the peat. In each site, at a depth of from three to 10 feet in the peat, lay the arms and equipment of a considerable army. The weapons were swords, lances, throwing-spears, axes, bows and arrows, shields, chain-mail, helmets, scabbards and belts. With the weapons were many other items: buckles, knives, combs, flints and steels, parts of wagons, wooden buckets, harness, iron-working tools and pottery. Almost all the weapons were of the types used by the 4th- and 5th-century Germanic tribes that broke the might of Rome, though a few of the swords were Roman—evidence of booty, or perhaps of trading with the enemy!

The finds were the archaeological sensation of their day. Unfortunately they were excavated with the treasure-hunting techniques of the time, without regard for records or position; often the diggers were paid on the basis of the number of objects produced! Consequently, although the museums of Denmark and North Germany are full of exquisitely fashioned and perfectly preserved objects from these discoveries, not a single plan exists to show where and in what order the weapons lay when they were unearthed by their enthusiastic and hasty hunters.

WEAPON DEPOSITS were discovered at Illerup, Kragehul, Vimose and two other sites not indicated on this map. The deposits are believed associated with the conflict between invaders from Zealand and Sweden and the native Jutes and Angles, who fled to Britain.

Three years ago, however, an opportunity came to rectify this state of affairs. At Illerup in Central East Jutland, not far from the "invasion coast" facing Sweden and the Fünen and Zealand islands, was found a fifth weapon hoard. The Prehistoric Museum in Aarhus and its energetic young director, Peter Glob, took charge of the excavation, and for the last three years a team from the Museum has been working on the site. It has been my good fortune to have taken part in all three seasons' work.

That these hoards are the relics of battles fought by the Jutes against Danish invaders from the east is by now fairly well established by a chain of evidence. One of the links in the chain was supplied by the young Danish archaeologist Jorgen Meldgaard, known in America for his work on the earliest Eskimo cultures in Alaska. He pointed out that the pottery found in one of the Jutland sites

TWISTED SWORDS and battered bosses from shields are mounted atop peat pedestals in this view of the excavation. The slope of floor on which pedestals stand, brought out by surface of water in the bottom of the excavation at left, is the slope of ancient lake bottom.

is of a type found elsewhere only in the Danish islands to the east.

All the weapons in the five sites have one thing in common: every one was rendered useless before it was dropped in the bog. The degree of destruction is far greater than could be explained by the vicissitudes of battle. Swords are bent double or in S-shapes, spear and arrow-shafts are broken into pieces, shields and shield bosses are hacked into unrecognizable forms. At Illerup the weapons and equipment were burned before deposition, and of the weapons scarcely anything but the metal remains. Destruction was not confined to inanimate objects: there are skeletons of horses which show signs of barbarous slaughtering, with spears thrust through the ribs and with many sword-cuts in the skulls.

It appears that in most of the sites the weapons found were not all deposited on one occasion but over a period stretching from the latter half of the 3rd century to the first half of the 5th century. It has been impossible to confirm this theory of multiple deposits in the first four sites, owing to the helter-skelter methods of their excavation, but we hope that at Illerup the finds can be dated accurately.

During the last 30 years the technique of dating objects found embedded in peat has been developed to a fine art, particularly in Denmark, where the methods now used originated. At the Danish National Museum in Copenhagen a laboratory of peat geology has carried out detailed examinations of a large number of Danish peat bogs and succeeded in amassing an accurate picture of the vicissitudes of climate throughout Danish prehistory and of their influence on the formation of peat.

Peat is usually formed by the accumulation of vegetable matter at the bottom of a lake. It includes a considerable

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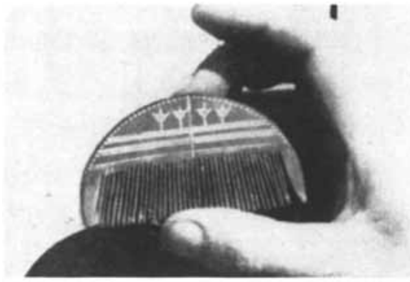

BONE COMB, decorated with geometric design, was found with weapons, excellently preserved by the tannic acids in the peat.

quantity of pollen, and this, like the remainder of the vegetation, is perfectly preserved by the acids of the peat water. Every kind of plant is uniquely marked by its pollen grains, and a microscopic examination of any sample of peat therefore gives a picture of the type of vegetation that grew near the lake. By statistical methods it is possible to construct a detailed picture of the relative proportions of the various plants growing in the region around the lake at the time when the sample was laid down.

Such analyses, made on samples taken at various levels down through a series of peat bogs all over Denmark, have produced a chronological scale of variations in tree populations in ancient times—a scale which has proved applicable not only to the whole of Denmark but also with local variations to all of Northern Europe from Ireland to Esthonia.

The shifts in tree populations were due first and foremost to changes in climate. As the climate after the last Ice Age fluctuated from warm and dry to cold and damp, one tree gave way to another as the dominant species: arctic birch was replaced by pine, pine by oak and oak in turn by beech. Almost any sample of peat can be placed in the sequence by a microscopic count of the relative proportions of pollen from these four trees.

The sequence is of inestimable value in dating objects found in peat bogs. As the age of many of the artifacts found in peat is already known, the tree variations have been transformed into a chronological scale, against which in turn, objects of unknown age can be dated. Experiments are also now in progress to date peat samples independently by means of the radioactive-carbon method developed in the U. S.

By these means, as well as by an accurate mapping of the position and level of all objects found, it is hoped that the Illerup hoard will give a more precise dating to the Danish weapon deposits and a definite confirmation of whether the deposits were made at one time or over a period.

But the question of *why* these weapons lie, destroyed and abandoned, in the peat bogs of Denmark cannot be answered by the methods of modern science. That the bogs were not the sites of the actual battlefields is certain. There are no human remains in them, and besides most of them were lakes at the time.

Historical accounts suggest the answer. Julius Caesar, describing his campaigns in Gaul in the 1st century B.C., related that the Gauls always offered the booty of their defeated enemies to the gods, and piled heaps of weapons in certain consecrated areas. Paulus Orosius, a Spanish historian of the 5th century, gave a vivid description of an orgy of destruction—of weapons, animals and captives—which followed a victory over the Romans by the Cimbri, a Germanic tribe which probably came from Jutland.

These accounts, in conjunction with the well-established fact that the early inhabitants of Denmark were in the habit of making offerings to their gods in streams, lakes and peat bogs, leave little room for doubt that the immense quantities of war material found in the Danish bogs were captured weapons, deliberately destroyed and thrown into lakes and marshes as offerings to the gods of battle.

It is a remarkable fact, though, that the legends of Denmark relating to this period make no mention of the practice. Possibly this is due to the circumstance, passingly suggested in the *Anglo-Saxon Chronicle*, that the Angles and Jutes entirely abandoned their original home country and emigrated to England in a body; there may have been no one left in the mother country to hand down to future generations the story of the weapon offerings.

Perhaps there is significance in the fact that the only legend which may refer to such a practice comes from a British source. It is told that King Arthur, after a long life spent fighting the Anglo-Saxon invaders, was finally defeated by a coalition of renegade Britons and invaders. As he lay dying, he ordered his sword, Excalibur, which in his youth he had received from a lake goddess—the Lady of the Lake—to be thrown out again into the nearest mere. One is tempted to ask whether the invading warrior-priests, who had often made similar offerings in the mist-wreathed lakes of their native Denmark, also saw there a supernatural hand—"clothed in white samite, mystic, wonderful"—reaching upwards to receive the weapons that we dig up today.

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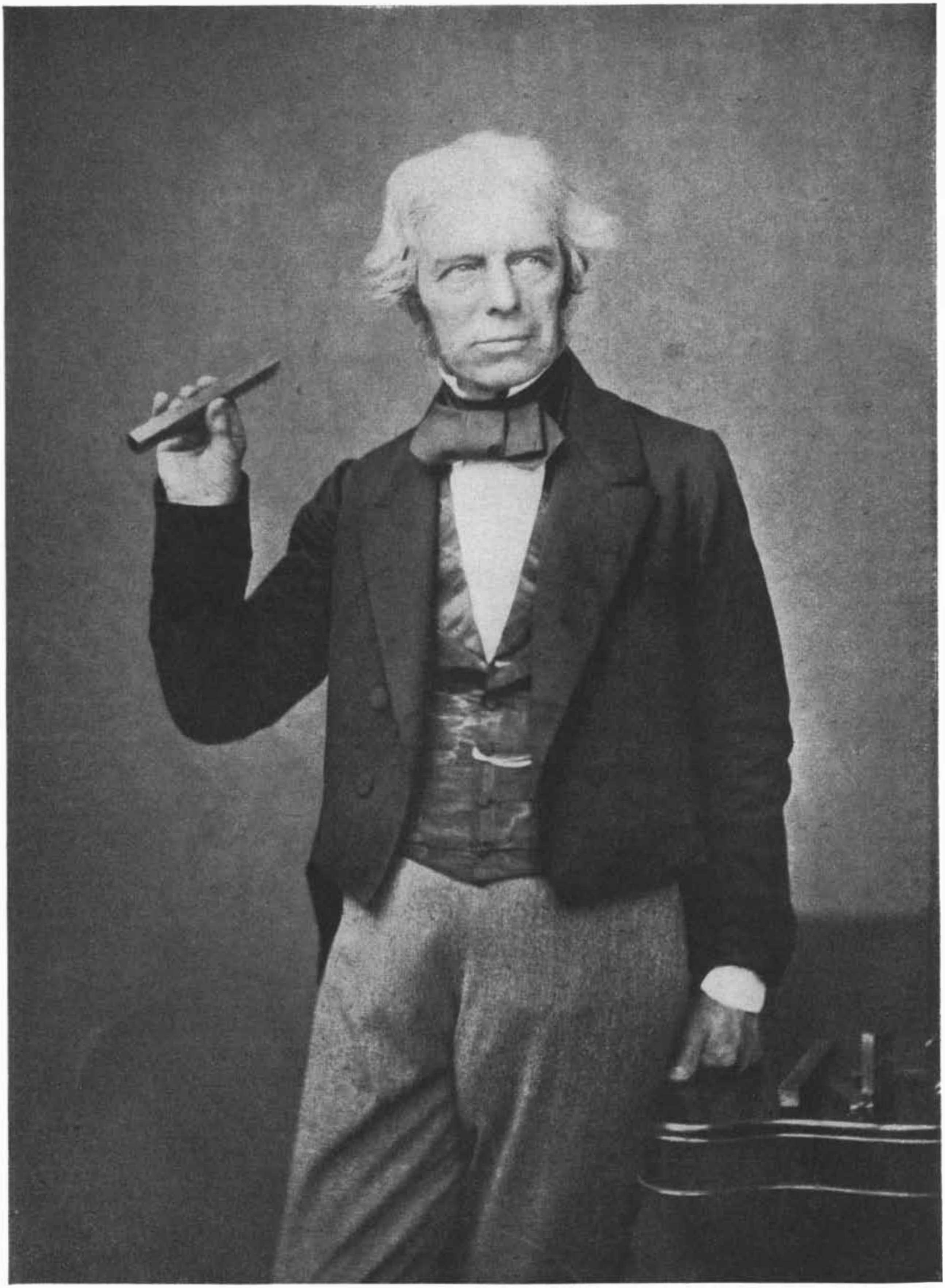


Michael Faraday (1791-1867) made advances in both chemistry and physics. In this late portrait he holds a bar of heavy glass.

Michael Faraday

His great series of discoveries in electromagnetism founded the electrical industry, but his greatest achievement was the field concept. In this he was a bold precursor of Einstein

by Herbert Kondo

Michael Faraday is celebrated as an experimenter who discovered the induction of electricity. History has more or less overlooked the fact that he was also one of the great founders of modern physics. Indeed, he can be said to be the man who started the revolution which upset the long reign of Newton and rebuilt physics on new theoretical foundations. For Faraday was the first scientist to suggest the modern idea of the field—that concept which was to become a keystone of James Clerk Maxwell's electromagnetic theory, Albert Einstein's General Theory of Relativity and the 20th century's progress toward understanding physical reality.

Not the least remarkable thing about all this is that Faraday had little mathematics and no formal schooling beyond the primary grades. To present-day physicists his achievement may well seem incredible. Actually Faraday's ignorance of mathematics contributed to his inspiration. It compelled him, when he looked for an explanation of his electrical and magnetic phenomena, to develop a simple, non-mathematical concept. His deduction of the field theory illustrates two qualities that more than made up for his lack of education: his fantastic intuition and his independence and originality of mind.

Faraday's biographers have emphasized his great intellectual energy and his obsession with his experimental researches. Fortunately for his biographers, he wrote everything down; his notes and jottings were eventually published as a seven-volume diary. Physics and chemistry were the great passion of his life; he cared little for women (although he eventually married) and less for money. He could have made a fortune from his discoveries, but he deliberately dropped every scientific project when it reached the stage of commercial value. Faraday was born in poverty and died in poverty—to him his consuming work was sufficient reward.

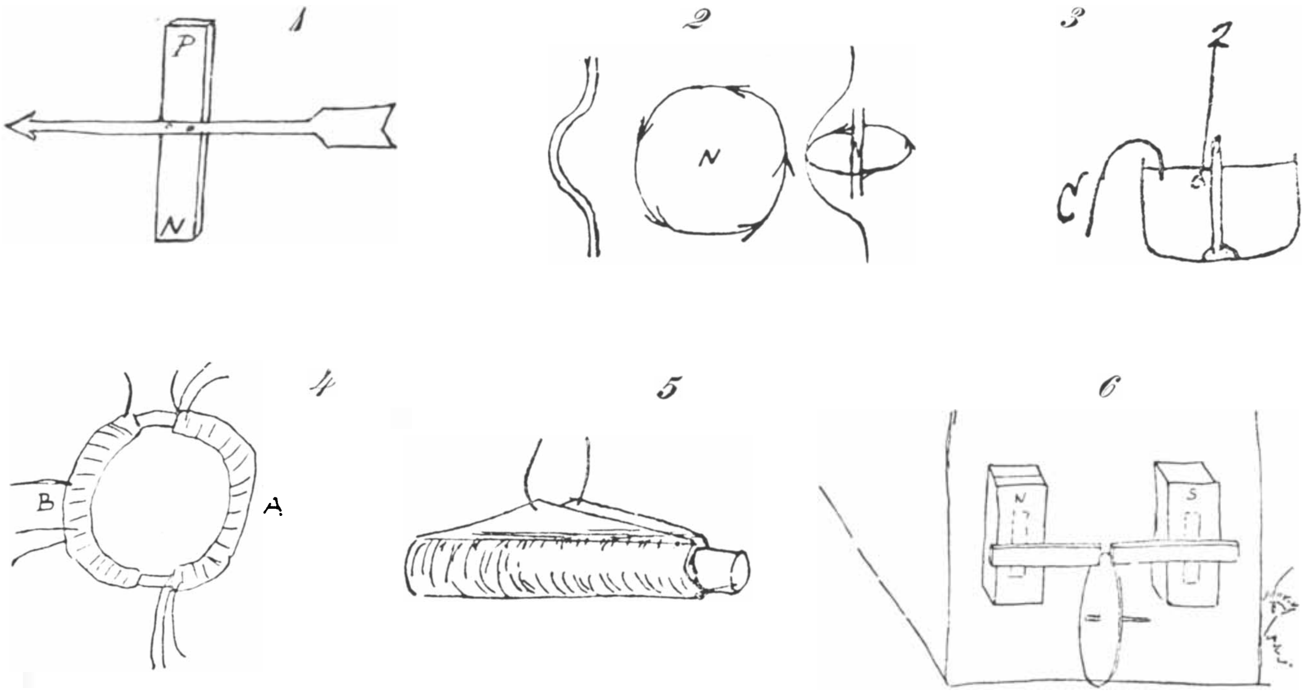
A blacksmith's son, Faraday was born near London on September 22, 1791. His family was too poor to keep him in school. "My education," he scribbled in his diary, "was of the most ordinary description, consisting of little more than the rudiments of reading, writing and arithmetic at a common day school. My hours out of school were passed at home and in the streets." At the age of 13 he took a job as errand boy in a bookshop run by a man named Riebau. A year later Riebau apprenticed him as a bookbinder for a term of seven years. Faraday developed a passionate interest in Riebau's books. "Whilst an apprentice," he wrote in his diary, "I loved to read the scientific books which were under my hands, and amongst them Marcet's *Conversations in Chemistry*, and the electrical treatises in the *Encyclopaedia Britannica*." Faraday went to hear some lectures on chemistry by the world-renowned scientist Sir Humphry Davy, and took neat and copious notes on them. He promptly applied for a job with the Royal Society and was as promptly rejected.

When Faraday's apprenticeship expired in 1812, he took a position as journeyman bookbinder with a M. de la Roche. But he was unhappy in the job and soon applied to Davy for employment, submitting his lecture notes as proof of his earnestness. Davy, a vain man, was impressed and hired Faraday as a secretary, but after a few months he dismissed the young man and advised him to go back to bookbinding. Not long afterward Davy, reconsidering, hired Faraday as his laboratory assistant.

Henceforth Faraday was to devote nearly all his working hours to research in pure science. After a two-year tour of Europe with Sir Humphry, he settled down to work in Davy's laboratory. He did experiments in chemistry, electrochemistry and metallurgy which alone would have been sufficient to establish his reputation as a scientist: he discovered benzene, produced the first "stainless steel," was the first to liquefy many gases, discovered the laws of electrolysis and the magnetic rotation of the plane of polarized light. But we are interested here in his main work—electromagnetism.

In 1820 the Danish physicist Hans Christian Oersted had announced his discovery of a relation between magnetism and electricity. He had found that a continuous current in a wire caused a deflection of a magnetic needle placed close to it. Oersted suggested that a magnetic field surrounded the wire conductor, acting in circles around the wire and perpendicular to it. In the following year the Frenchman André Marie Ampère substituted another current-carrying wire for the magnetic needle and found a magnetic force of attraction or repulsion in the two wires, depending on the direction of current flow.

Davy and Faraday, though absorbed in chemical researches, promptly became interested in the new electromagnetic discoveries. They repeated the experiments for their own satisfaction. At the same time the noted English scientist William Hyde Wollaston suggested to Davy the possibility that the magnetic field might produce rotation. Faraday interpreted this to mean the rotation of a wire about its own axis. He failed to find such a result, but he soon established for himself—whether independently or after hearing of Oersted's theory—the circular



SKETCHES FROM FARADAY'S DIARY show the progression of his electromagnetic experiments. (1) He repeats Oersted's discovery of 1820 that a magnetic needle placed near a conductor is displaced with a motion circular and perpendicular to it. (2) He bends a wire conductor into a curve, floating one end on a cork in mercury, then puts a bar magnet in the curve, causing the wire to swivel around it in the first demonstration of electromagnetic rotation. (3) In a modification of 2, he fixes the magnet upright in a bowl of mercury to allow the floating conductor to revolve completely around it—the principle of the electric motor. (4) In 1831, winding two coils of wire A and B on an iron ring and connecting A with a battery, he causes an intermittent current to flow in B, thus discovering electrical induction. (5) Plunging a magnet in and out of a hollow cylinder and coil connected to a galvanometer, he shows that induction is caused by the relative motion—the principle of the electric generator. (6) Rotating a copper disc between the opposite poles of the Royal Society's compound magnet, he induces a continuous current—the birth of the dynamo.

and perpendicular action of a magnetic field about a conductor. He therefore reasoned that if a magnetic pole were free to move, it should rotate about the conductor, and that the opposite also should be true; the conductor itself should be able to revolve about a magnetic pole.

Faraday at once undertook the famous experiments which were to lead to discovery of the basic principle of the electric motor. In his first experiment he bent a copper wire into the curved shape of a carpenter's brace; one end of the wire was stuck through a cork and floated in a basin of mercury, and the other end was connected to a battery by way of an inverted silver cup. Then he placed a bar magnet within the curved part of the wire. When current passed through the wire-mercury circuit, the curved wire swept around until it hit the fixed magnet. Faraday next modified the experiment so that the wire could revolve without obstruction around the magnet. He used a straight piece of wire with one end sticking into a cork floating in the mercury container. The passing of a current through the wire made it revolve continuously around the magnet. When the direction of the current was reversed, the wire revolved in the opposite direction. Faraday's own rough, simplified sketches of these two experiments are shown above (*drawings 2 and 3*). The straight, upright wire and the looped wire dipping into the mercury in drawing No. 3 were connected to a battery.

He now went on to perform the opposite experiment to see whether a magnet would turn around a fixed conductor. This time the bar magnet (loaded at the bottom end with platinum) floated free in the mercury and the wire was fixed. As he had expected, the magnet did revolve around the current-carrying wire.

When Faraday published the results of these experiments, he was at once charged with having used Wollaston's idea without credit. Actually Faraday had misinterpreted Wollaston's suggestion to mean rotation of a wire about its own axis; his experiments and findings were his own. In time the misunderstanding cleared up, and Faraday was nominated for membership in the Royal Society. Wollaston supported his candidacy, but Davy voted against him, possibly from jealousy. Nonetheless, he was elected in 1824.

Faraday now dropped his electromagnetic experiments and returned to chemistry. But an irrepressible idea remained on his mind. If an electric current could yield magnetism, could not a magnet produce electricity? In 1824 and again in 1825 he tried to induce current in a wire by placing a magnet near it, but these attempts failed. He did not yet appreciate the central importance of motion in the phenomena that Oersted had demonstrated. It was the motion of the electric current in the wire that produced magnetism. To obtain the reverse effect the magnet had to be moved in relation to the conductor.

In 1831 Faraday suddenly ended his chemical researches and gave himself fully to the problem that was preying on his mind. Within a single day—August 29, 1831—he found an answer that put him on the right track. His reasoning this time started from the analogy of electrostatic induction. It was known that a charged body could induce an electric charge on another body placed near it. Perhaps a current-carrying wire could induce a current in another wire placed close to it. To test this Faraday set up an astonishingly crude apparatus, illustrated here by his own sketch (*drawing No. 4 above*). Here, from his diary, is his own account of the famous experiment:

"I have had an iron ring made (soft iron), iron round and 7/8ths of an inch thick, and ring six inches in external diameter. Wound many coils of copper round, one half of the coils being separated by twine and calico; there were three lengths of wire, each about 24 feet long, and they could be connected as one length, or used as separate lengths. By trials with a trough each was insulated from the other. Will call this side of the ring A. On the other side, but separated by an interval, was wound wire in two pieces, together amounting to about 60 feet in length, the direction being as with former coils. This side call B.

"Charged a battery of ten pairs of plates four inches square. Made the coil on B side one coil, and connected its extremities by a copper wire passing to a distance, and just over a magnetic needle (three feet from a wire ring), then connected the ends of one of the pieces on A side with battery: immediately a sensible effect on needle. It oscillated and settled at last in original position. On breaking connection of A side with battery, again a disturbance of the needle."

Faraday noted that when the circuit was closed, the needle deflected in one direction; when it was broken, the needle moved in the opposite direction. But there was no deflection while electricity was flowing in the first coil.

At last he had obtained electricity from magnetism. But he was disappointed. He had expected the current in the primary coil to induce a continuous current in the secondary coil; instead, it produced only momentary impulses at the instant when the primary circuit was closed or broken. Nonetheless, he felt intuitively that he was near success. He wrote to a friend: "I am busy just now again on electromagnetism, and I think I have got hold of a good thing, but can't say. It may be a weed instead of a fish that, after all my labor, I may at last have pulled up."

Faraday continued his experiments, and on October 17, 1831, he performed one which showed that he had caught a very big fish indeed. In this, his simplest and most famous experiment, he wound a coil, the ends of which were connected to a galvanometer, around a hollow paper cylinder (*drawing No. 5 on opposite page*). When he thrust a bar magnet quickly into the cylinder, the galvanometer needle was deflected. It moved again, but in the opposite direction, when he withdrew the magnet. Actually it made no difference whether he moved the magnet or the coil, in either case he got an induced current in the wire. It was now clear beyond doubt that what produced the current was the relative motion of the conductor and the magnetic field.

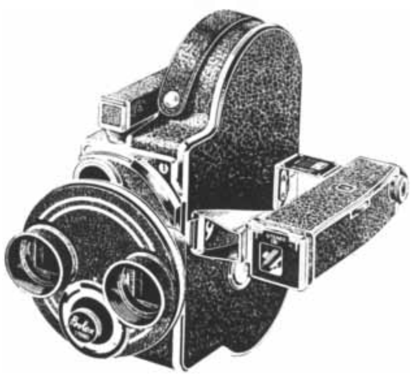
Thus Faraday discovered the basic principle of the electric generator. From this experiment it was but a step to the induction of a continuous electric current. Eleven days later Faraday achieved it with the arrangement shown in drawing No. 6 on the opposite page. Using the compound magnet of the Royal Society, he concentrated the polar strength by placing two small six-inch magnets at the ends of the large poles. Between these poles he rotated a copper disc on a brass axle. On the edge of the disc he spaced two copper contacts at different distances from the poles, connected by wires to a galvanometer. Rotating the disc, he obtained a more or less steady deflection of the needle—"more or less" because he had a hard time holding the contacts.

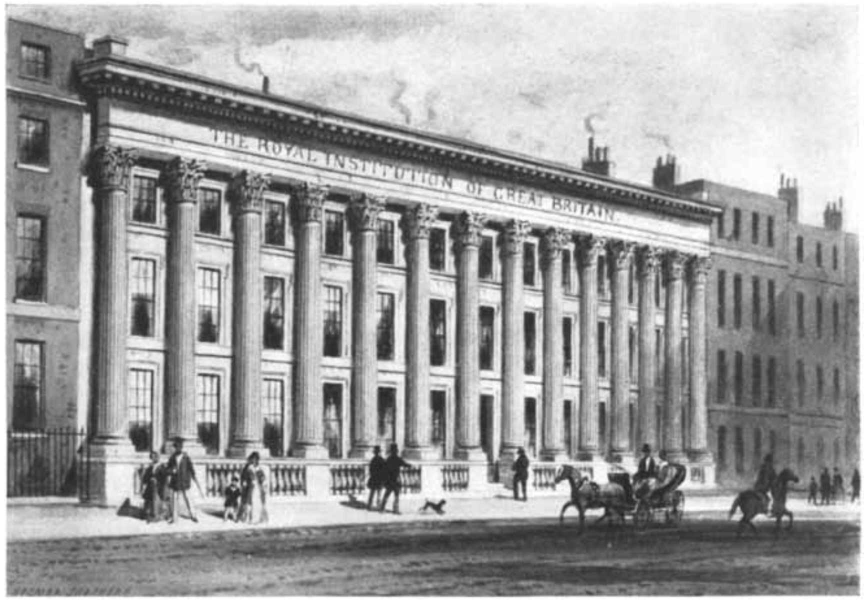
Faraday performed many other experiments in electromagnetic induction, but for the most part they were variations of these basic ones. His first experiment, with the iron ring, had given the world the first electric transformer; the one just described produced the first dynamo.

Faraday reported his results to the Royal Society within a month and later published these papers as the first part of his *Experimental Researches in Electricity*, rearranging the order of many of his experiments in a way that has confused historians.

As soon as the results were published, the question of priority was again raised. The U. S. physicist Joseph Henry had already discovered self-induction, and Leopoldo Nobili and Cavalière Antinori of Italy had claimed credit for the discovery of electromagnetic induction even before Faraday published his results. But they had performed their experiments after hearing of Faraday's, and Faraday was able to prove his priority.

Faraday was not satisfied with having discovered electromagnetic induction; he wanted to know why it occurred. Unable to approach the subject mathematically, he resorted to a physical model: the familiar phenomenon of the way that iron filings on a sheet of paper arrange themselves in a pattern of lines about a magnet. Why in lines? Faraday proposed the idea that the space surrounding the magnet was filled with lines of force. The magnetic force was manifest as invisible lines in a state of tension



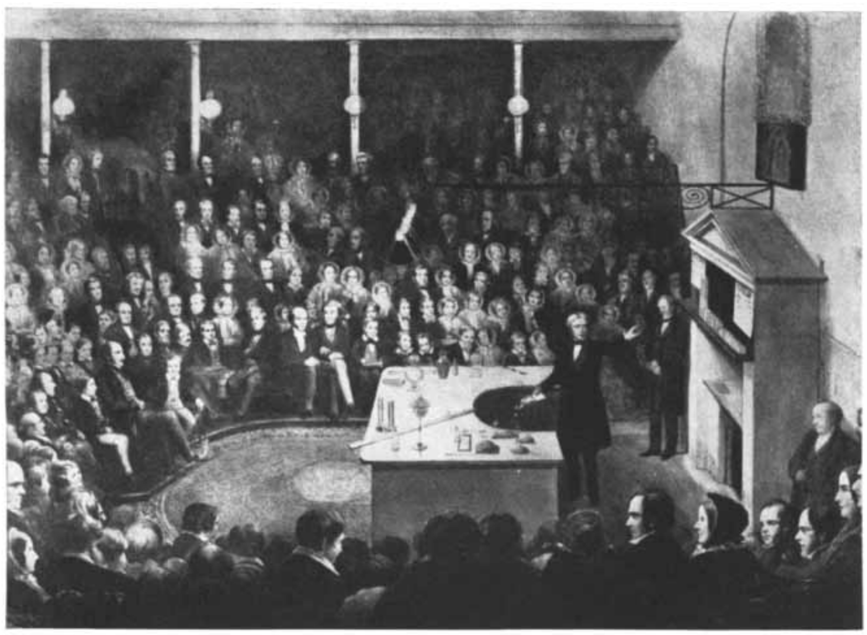


THE ROYAL INSTITUTION for diffusing knowledge was Faraday's home for half a century. It is not connected with the Royal Society, to which he was elected at age 33 in 1824.

—like stretched rubber bands—and the iron filings arranged themselves by magnetic attraction along these lines.

Faraday did not stop there. He filled *all* space with lines of force, and outlined the revolutionary concept that space was pervaded by various kinds of force: magnetic, electric, radiant, thermal and gravitational. The lines indicate everywhere both the direction and the strength of the force under consideration. For example, on a bar magnet the direction of the lines of force is from positive to negative or from north to south pole, and the number of lines of force proceeding from a magnetic pole indicates its strength at any given place. They are more dense near the magnet than they are farther away in space. Similarly the amount of electricity a body possesses is determined, according to Faraday, by the number of lines of force proceeding from it. The lines of force all terminate some place, either on another body close by, or on the walls of a room, or on the planets in space. At each terminal point there is a quantity of electricity equal in amount but opposite in charge to that on the original body.

Faraday reasoned that the lines-of-



FARADAY'S LECTURES at the Institution were attended by scientists and royalty. At the left, the Prince Consort and princes; right, Faraday's faithful assistant, Sergeant Anderson.

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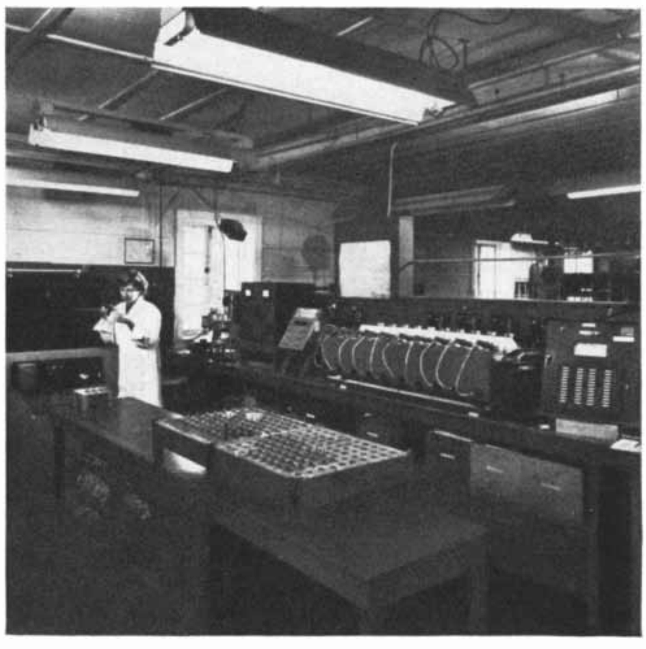

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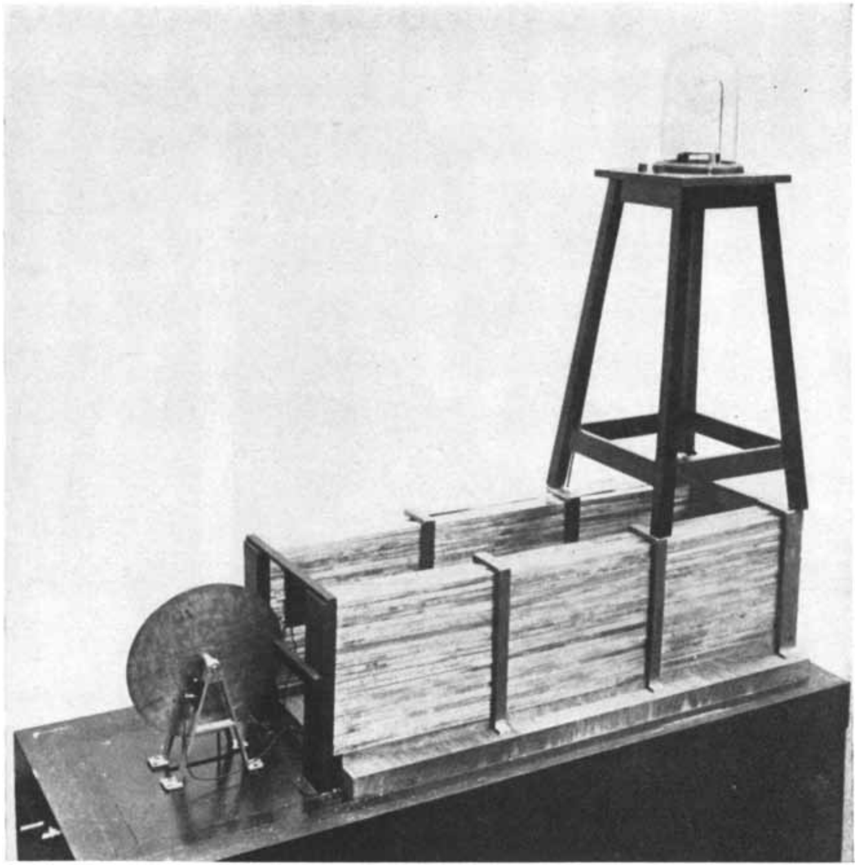

THE FIRST DYNAMO, sketched by Faraday in diagram 6 on page 92, is preserved in this model by the Royal Society in London. This apparatus founded the electric power industry.

force theory explained how a current is induced in a conductor: it is induced whenever the conductor cuts across magnetic lines of force. He discovered that the velocity of the movement was important. "If a wire move slowly," he wrote, "a feeble current is produced in it, continuing for the time of motion; if it move across the same lines quickly, a stronger current is produced for a shorter time." Strictly speaking, it is not a current which is induced but a voltage. The current merely results from this voltage.

From the idea that there are lines of force of various kinds in space, Faraday went on to suggest that these forces fill all of space. He wrote in his diary in 1846: "All I can say is, that I do not perceive in any part of space, whether (to use the common phrase) vacant or filled with matter, anything but forces and the lines in which they are exerted."

Here we have the historic origin of the field theory (see "Field Theory," by Freeman J. Dyson; SCIENTIFIC AMERICAN, April, 1953). Faraday himself never referred to his system as a "field theory" or a "field concept." In fact he held these ideas tentatively and was ready to discard them if experimental evidence could disprove them.

What is so revolutionary about the field concept? Just this. Up to Faraday physicists had concentrated on the material particle. From the particle concept they attempted to derive all phenomena. Physical processes were explained by laws of Newtonian motion and forces of mutual interaction working upon the particle. Faraday relegated the particle to the background and enthroned in its stead lines of force throughout space. To Faraday what was of critical importance was not the electric or magnetic particles but the space in which they operated. And this is the whole basis of the field concept. In field theory it is the geometric and physical condition of space itself that is fundamental.

Faraday was very clear on this point. In the *Experimental Researches* he wrote: "In this view of the magnet, the medium or space around it is as essential as the magnet itself, being a part of the true and complete magnetic system."

Here we see that Faraday actually held what is today called a dual field theory, one in which both particle and field are fundamental, but in which the field plays the basic and leading role. Thus Faraday was the forerunner of the modern relativistic revolution in physics,

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FARADAY was about 35 and doing his most important work at the time of this portrait.

and the construction of the field concept must rank as one of the greatest creations of the scientific mind.

Faraday himself did not regard the field idea as a theory distinct from the Newtonian system, but rather as one supplementing it. He did not intend to dethrone the particle concept; that came as a later consequence of his suggestion. He also started the downfall of another important concept—the idea of "action-at-a-distance." Newton assumed, and philosophers long before him had believed, that forces could act over large distances—instantaneously and without the need for any intervening medium. Only in this way, they felt, could the gravitational force between planets and stars be explained.

In the 19th century action-at-a-distance had a strong foothold in physics. But Faraday felt that this concept was unsatisfactory and that the assumptions of Newtonian mechanics were inconsistent with electrodynamic phenomena. He did not hesitate to rule out action-at-a-distance or to formulate his own concept. Force requires time for transmission, he said, and the means of conveyance are the lines of force. Wherever possible Faraday performed experiments to prove that the force in question required time. In the case of gravitational force he failed, but he did not waver from his belief that he was correct. Faraday himself did not destroy the action-at-a-distance concept; that was accomplished by Maxwell, who eliminated it from electrodynamics, and by Hendrik Lorentz, whose transformation equations banished it altogether from physics.

In May, 1846, Faraday published an interesting paper on some further speculations, entitled "Thoughts on Ray-Vibrations." In it he foreshadowed the electromagnetic theory of light. "The view which I am so bold as to put forth," he wrote, "considers . . . radiation as a high species of vibrations in the lines of force which are known to connect particles and also masses of matter together. It endeavors to dismiss the ether, but not the vibrations." Shortly thereafter Maxwell developed this "bold" view mathematically and announced his electromagnetic theory. Faraday himself had empirically established a relation between light and magnetism. In a series of brilliant experiments he had demonstrated that a magnetic field could rotate the plane of polarized light.

Faraday had a profound and prophetic belief in the underlying unity of nature and of the laws of physics. He believed that gravitational and electromagnetic forces were somehow related, and that some law or principle must govern this relationship. In 1849 he scribbled in his laboratory book: "Gravity. Surely this force must be capable of an experimental relation to electricity, magnetism, and the other forces, so as to bind it up with them in reciprocal action and equivalent effect. Consider for a moment how to set about touching this matter by facts and trial." But the numerous experiments he undertook to show such a relationship all ended in failure. In a sad yet optimistic note, he concluded: "Here end my trials for the present. The results are negative. They do not shake my strong feeling of the existence of a relation between gravity and electricity, though they give no proof that such a relation exists."

He was still at work on this problem 10 years later when he wrote his last paper. He was then in broken health, but had not given up experimenting and musing. He suffered prolonged lapses of memory, and would forgetfully repeat an experiment which he had successfully completed only a short time before. The born-to-poverty, unschooled scientist was now a life professor of the Royal Institution, living at Hampton Court. In 1867 his niece, Miss Reid, wrote to Faraday's close friend Bence Jones: "Dear uncle kept up rather better than sometimes, but oh! there was always a pain in seeing afresh how far the mind had faded away . . . This year we came with a melancholy thought of dear uncle's declining, half-paralyzed state." On August 25, 1867, Michael Faraday died peacefully in his study chair, little realizing the turmoil that was to come over whether the field or the particle is supreme.

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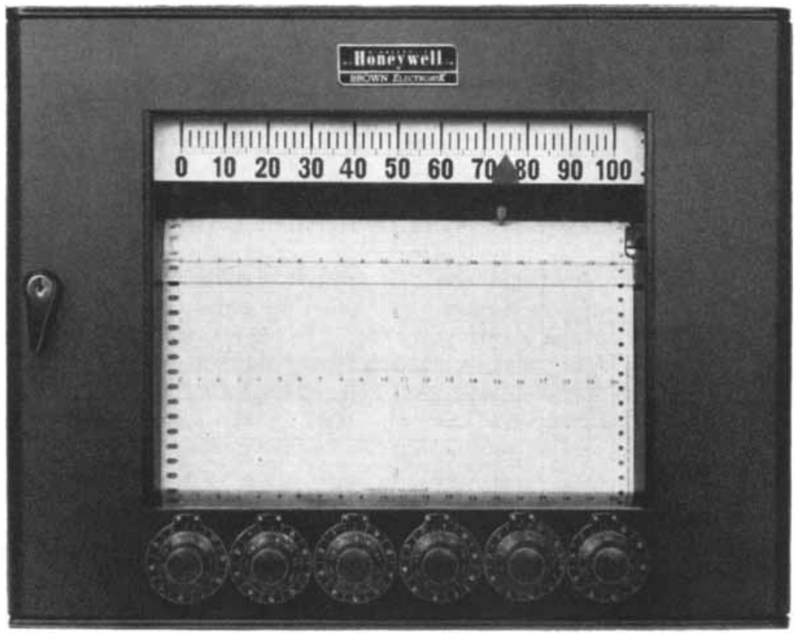

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HOW A RATTLESNAKE STRIKES

An investigation with high-speed photography probes a question of some interest to herpetologists as well as potential victims: Does it stab you with its fangs or close its jaws in a true bite?

by Walker Van Riper

When a rattlesnake strikes, do its fangs bite the victim or stab it? This rather minor but not uninteresting problem has intrigued many herpetologists, partly because opinions differ sharply and partly because the question is not easy to investigate.

Harmless snakes, most experts agree, do bite: observers have often seen bite marks from their upper and lower teeth. But about the chief poisonous snakes in the U. S., the pit vipers (rattlesnakes, copperheads and water moccasins), the evidence is ambiguous. According to some medical writers, the only marks these snakes leave on a victim are two punctures made by the two fangs in the upper jaw, indicating that they do not bite but stab into the flesh with the force of the strike alone. On the other hand, a number of experimenters and keepers of snakes insist that they have observed pit vipers biting just as harmless snakes do.

The question is hard to settle because the strike of a pit viper is extremely fast—much too fast for the human eye to analyze. Several years ago it occurred to me that the issue might be resolved by catching the action with high-speed photography by means of the electronic flash (strobe light) invented by H. E. Edgerton of the Massachusetts Institute of Technology. The investigation turned out to be less simple than it seemed. After a number of experiments and changes in tactics to deal with new problems that kept coming to light as the investigation developed, I was able to get some clear-cut results, which are illustrated by photographs accompanying this article.

The pit vipers are so called because they have two facial pits above the nostrils; the pits look like a second pair of nostrils. They are heat-detecting organs, and they apparently stimulate the snake to strike at a warm target. A pit viper's fangs are two long, hollow teeth, like hypodermic needles, connected with venom glands which lie behind the eyes. At rest the fangs are folded back against the roof of the mouth. When the viper strikes, it opens its jaws wide and the fangs point almost directly forward.

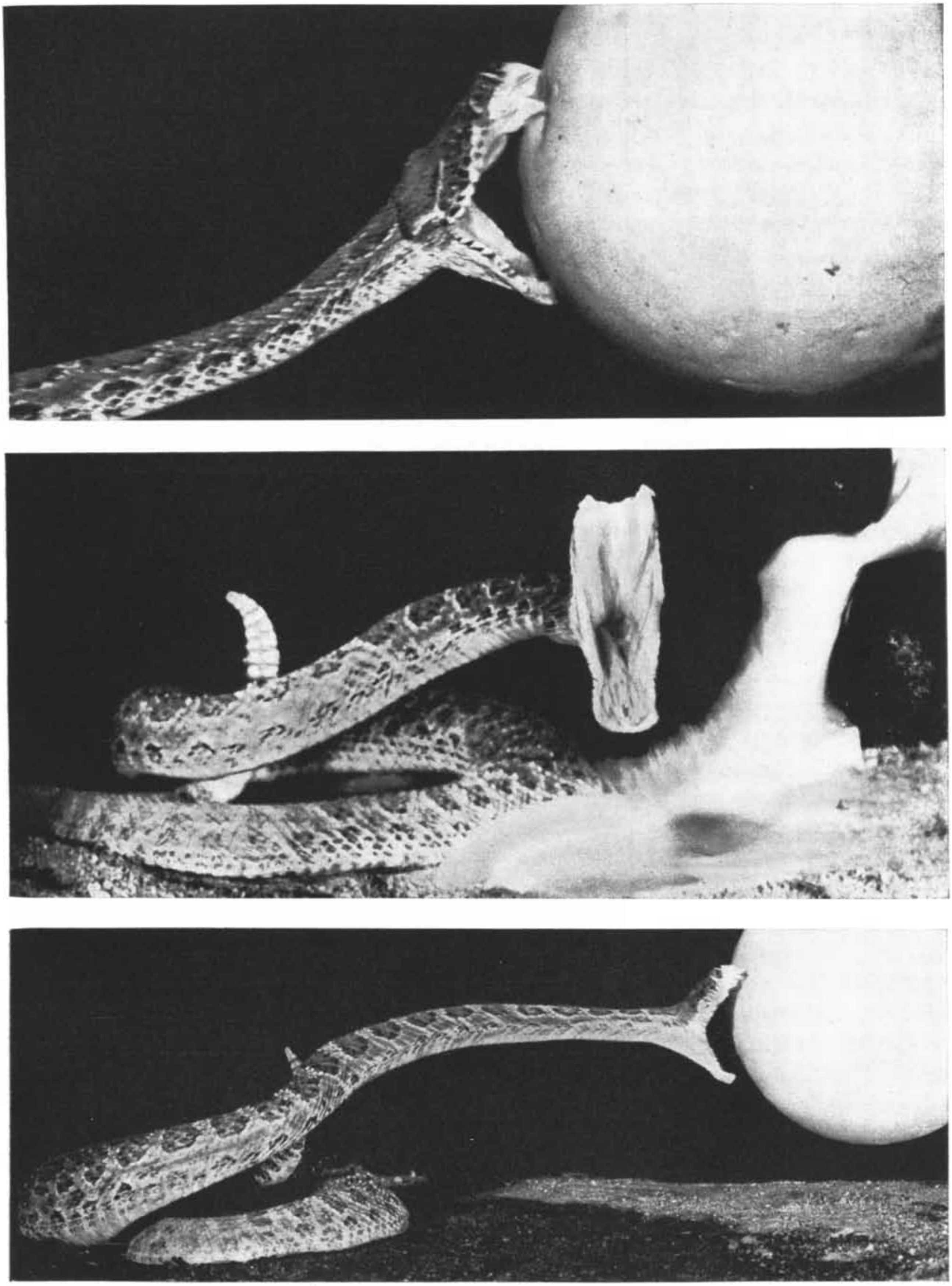
The subjects of my experiments were Prairie Rattlesnakes, the only species found around Denver. In photographing them I found that some of the folklore about rattlesnakes is wrong. For instance, there is a notion that a rattlesnake cannot strike upward; actually some of mine hit a target held directly overhead. The rattlesnake is conventionally pictured fully coiled for nearly its whole length. From this position it would have a hard time striking, for its head would roll round and round as it untwisted. As a matter of fact the snake coils only the hind part of its body, in one or two coils, and its fore end strikes from a weaving posture. This set-up limits the snake's striking range to about half its own total length.

Now to the main issue. The first problem was to get the rattlers to strike for the camera. I found that I had to work with freshly caught wild snakes, because the Prairie Rattlesnake grows tame rather quickly in captivity and then can scarcely be made to strike at anything. This limited the experiments to short periods in the early summer and late fall, when the snakes emerge from and return to their winter dens. In midsummer one rarely sees a rattlesnake in the open, for the hot sun would quickly kill it and it tends to go abroad only at night.

I started by trying to photograph the strike by the snapshot method, but this was futile; human reaction time is much too slow to hit a movement as fast as the rattlesnake's on the nose. So to improve the timing of the flash I rigged up two electric circuits which would shock the snake into striking and set off the camera and flash immediately afterward. The two switches for the circuits could be closed in rapid succession by a quick sweep of the hand. One switch administered the shock, by way of two electrodes near the snake's tail; the other triggered the camera. The target was an electric light bulb (for warmth) covered with cotton padding. I moved the target about in front of the snake until it appeared ready to strike, then threw the switches and jerked the target away.

This system worked very well. I got some excellent pictures of the rattler in the midst of its strike, with its jaws wide open. But the exposure of about 1/20,000 of a second caught only an extremely thin slice of the total action; it was impossible to tell from the individual pictures exactly what stage of the strike was shown or whether the snake ever closed its jaws in a bite.

A naturalist friend, R. J. Niedrach, then suggested that I use as a target a rubber balloon, with which the snake could make contact and which would get out of the way of the camera as soon as the rattler struck it. This time I set up a circuit which made the snake trigger its own picture. One lead of the flash circuit was attached to a conducting bed on which the snake lay, the other to the surface of the balloon, made conductive by dipping it in a warm salt solution containing detergent as a wetting agent. When the snake hit the balloon, it closed the circuit and set off the flash. Incidentally, this illustrates a great virtue of Edgerton's trigger circuit for experimental work. The circuit carries a high voltage with practically no current, so that a great deal of resistance can be penetrated with no appreciable shock or burning at the contacts. The applications of the device are limited only by



STABBING STRIKE of the rattlesnake is shown in these three photographs. In all three, its jaws are fully extended, with no sign of biting action. Top two pictures freeze the action just before and just after the bursting of a balloon; target at bottom is solid.

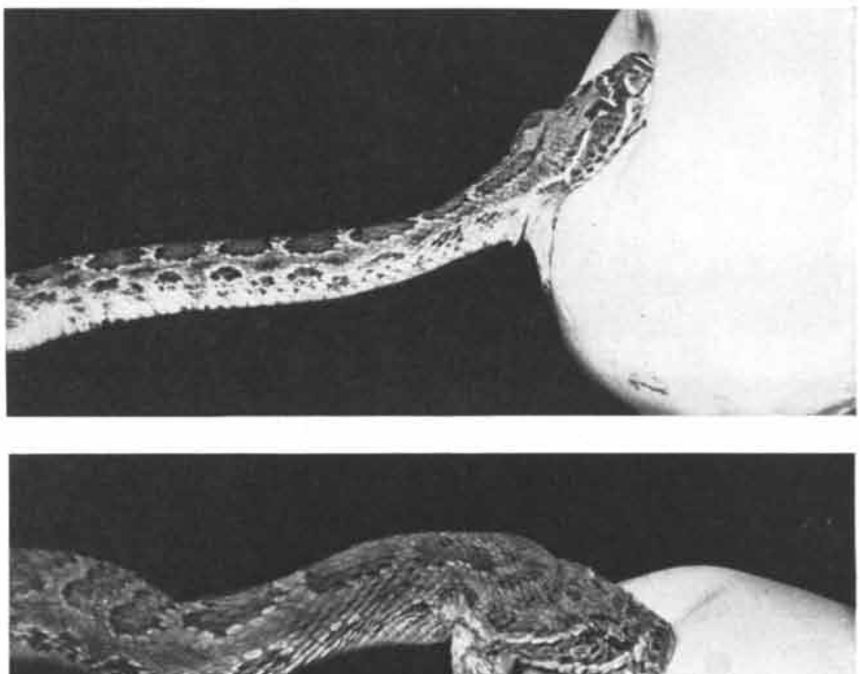
human ingenuity. Anything that moves can be made to take its own picture at a precisely predetermined instant.

All the pictures taken by this means showed the same thing: the snake hitting the balloon with its jaws spread wide and its fangs pointed forward. Even when a delayed-timing arrangement snapped the picture an instant after the hit, there was no evidence of any biting action. This was not, however, conclusive proof. I had been working on the assumption that the strike was a reflex action which would be completed whether or not the snake had something to bite on. But one of my friends objected that the disappearance of the punctured balloon might stop the snake's bite. The next step, therefore, was to provide the rattler with a bitable target.

The target that finally evolved was a 3-inch bulb with a latex cover and a stuffing of aluminum wool. The circuit could be closed only if the snake's fangs penetrated the cover and made contact with the aluminum wool inside. The target was mounted on an insulated brass rod to give the rattler something rigid to bite against.

Now, using a number of snakes as subjects, I made a long series of pictures, with instantaneous, delayed and double and triple exposures. In not one of these pictures did the snakes show any biting action. All of them simply stabbed the target.

When I circulated these results among my herpetological friends, some of them were still skeptical. They had often seen rattlers grab and hold small prey. Perhaps, they suggested, my target was too big. Accordingly, the following summer I tried smaller targets of various sizes. I found that by holding a snake down with a loop a few inches behind its head I could make it bite into a target. Thus I got a picture of what a true bite looks like. I then made a free test of my subjects, of which, unfortunately, at this time I had only two available. One of them turned out to be a biter! It bit not only small targets but the large one as well. I can only conclude that rattlesnakes exhibit individual differences, and that the experiment gives a very good demonstration of the validity of the Harvard Law of Animal Behavior: "Under carefully controlled conditions, animals behave as they damn please."



RATTLESNAKE BITES the target in bottom picture here. In contrast to stabbing strike, shown at top, the lower jaw is firmly clamped in the target. Whether a rattlesnake stabs or bites appears to be a question of individual idiosyncrasy. But in this study few snakes bit.

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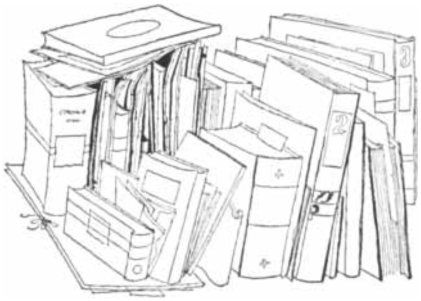

BOOKS

A new edition of Galileo's dialogue brings his greatness vividly to life

by Ernest Nagel

GALILEO'S DIALOGUE ON THE GREAT WORLD SYSTEMS, edited by Giorgio de Santillana. The University of Chicago Press ($12.50).

Galileo Galilei's *Dialogo dei Massimi Sistemi* was first published in 1632. The only English translation is one made by Thomas Salusbury in 1661. Most of that edition was destroyed in the Great Fire of London, and for three centuries the historically fateful masterpiece has been practically unavailable to English readers. The need for an adequate English rendering of this work, which marked a turning point in modern scientific and philosophic thought, is amply satisfied by the present handsomely printed volume. It contains a painstaking revision by Dr. de Santillana of the Salusbury version, augmented by an illuminating historical introduction and several hundred valuable annotations of the text. Moreover, an appendix by William D. Stahlman gives a clear exposition of the Ptolemaic-Copernican techniques for analyzing planetary motions, thereby throwing additional light on some issues raised in the *Dialogue*. This splendid edition thus provides the modern reader with the opportunity to understand, through the medium of Salusbury's vibrant Jacobean prose, the substance and significance of Galileo's scientific achievements, the power and reach of his mind and the passion and tragedy of his personal history.

Galileo wrote the *Dialogue* not for specialists but, in Salusbury's words, "chiefly for gentlemen." He wished to give his generation a coherent picture of the rapidly developing new concept of the universe that was undermining the ancient cosmology. He also wanted to exhibit the lineaments of the true method for the rational investigation of the nature of things, contrasting this rationalism with the legalistic verbalism corrupted from Aristotle and the number mysticism derived from Plato. He hoped thereby to generate a climate of educated opinion which would promote and sustain the growth of science in Italy.

In this last respect Galileo failed completely. The repressive machinery of the Counter-Reformation was unequal to the task of wedding the new scientific conceptions to the essentials of Catholic faith and obedience, and Galileo's forthright advocacy of the new philosophy and his unconcealed contempt for those who opposed it did not ease the way for the authorities to deal judiciously with him and his ideas. Despite the fact that the *Dialogue* had received the official *imprimatur*, the book was condemned and banned, Galileo was imprisoned by the Inquisition and compelled to abjure his alleged errors, and free scientific thought in Italy was effectively throttled. The *Dialogue* nevertheless became a seminal influence in the rest of Europe, and it continues to say things pertinent to the intellectual concerns of our age.

Nominally the *Dialogue* is an evaluation of the comparative merits of the Ptolemaic and Copernican theories of celestial motion. But Galileo's discussion is not focused primarily on purely astronomical questions; it is directed chiefly to the new physical and dynamical ideas that made credible the Copernican theory of a Sun-centered universe. Copernicus himself had offered no fresh observational data to support his theory, and for some 70 years after he proposed the theory in *De Revolutionibus* it had been regarded as a convenient mathematical device for calculating celestial orbits rather than as a rival to the Aristotelian scheme of a cosmos with an immovable Earth at its center. Copernicus' book had encountered little philosophic or ecclesiastical opposition, for it was not felt to be a challenge to the established system of belief.

But the situation was radically altered when in 1610 Galileo invented the telescope and discovered a number of facts which seemed clearly to give physical support to the Copernican hypothesis. The phases of Venus, the lunar mountains, the moons of Jupiter, sunspots, the stars so distant that their diameters could not be measured—these and other facts explored by Galileo required for their explanation a system of ideas totally incompatible with a physics based on the assumption of a fundamental difference between celestial and terrestrial matter. In the *Dialogue* Galileo presented a new dynamics attempting to treat in a unified manner all motions, whether they occur on the Earth or in the heavens. The Copernican theory, which construed the Earth as one celestial body among others, was of interest to Galileo in large measure because it served to illustrate in an impressive way the scope of his own physical system.

In the nature of the case Galileo could not be completely successful in the ambitious undertaking he had set for himself. The *Dialogue* reveals him grappling masterfully with principles that entered into the foundations of Newtonian physics, suggesting breathlessly ingenious experiments for confirming his conjectures and disposing effectively and with biting irony of objections to the new ideas. But it also shows him falling into hopeless errors, ignoring important discoveries and concepts and filling gaps in his argument with improvised explanations which are sometimes little short of being spurious. Galileo subscribed to the classic, and also modern, conception of the task of science as that of "saving the phenomena"—that is, of finding a system of principles which make the observed facts understandable and, granted the principles, inevitable. But he apparently never quite freed himself from a central assumption of ancient Greek thought: namely, that the fundamental motions of the cosmos must be perfectly circular. Thus, despite the fact that he broke fresh ground in his analysis of inertial motion, he argued that such motion must be circular, because if it were rectilinear it would carry all bodies into limitless space and make impossible the established cycles of cosmic change. He never mentioned the Keplerian laws, though Kepler had sent him presentation copies of his publications; it seems likely that Galileo never read these works. Galileo also argued at length that the tides are the effect of the combined diurnal and annual circular motions of our planet; he failed to recognize the merit of the notion, advanced by some of his contemporaries, that tidal phenomena were associated with the moon.

Galileo's extended discussion of his theory of the tides doubtless was a source of special irritation to the Pope. Prior to his elevation to the papacy, Urban VIII had encouraged Galileo to undertake the writing of the *Dialogue*, with the explicit proviso that no attempt would be made to decide between the Copernican and Ptolemaic systems on the basis of physical questions. Galileo disregarded this instruction, though he did conclude his work with a dutiful echoing of the papal dicta on the subject. He has Simplicius, the representative of the Peripatetic philosophy, declare that God can bring about things in many ways, some of them being above the reach of our intellect. To which Salviatus, Galileo's spokesman, responds: "An admirable and truly angelic doctrine, which is answered with perfect agreement by that other one, in like manner divine, which gives us leave to dispute touching the constitution of the Universe, but adds, withal (perhaps to the end that the exercise of the minds of men might not cease or become remiss), that we are not to find out the works made by His hands. . . . Let, therefore, the disquisition permitted and ordained us by God assist us in the knowing, and so much more admiring, His greatness by how much less we find ourselves capable of penetrating the profound abysses of His infinite wisdom." However, not even a casual reader could misunderstand Galileo's own convictions, nor mistake the import of his physical theory for a rational decision between the Copernican and Ptolemaic systems.

The flaws in Galileo's execution of his undertaking diminish neither the grandeur of his task nor the glory of what he actually did achieve. Despite his surrender to authority in order to avoid physical martyrdom, despite even his occasional use of the tricks of the theater to carry a point, the *Dialogue* is a monument to a passionate intellectual integrity and to an almost childlike faith in the power of cogent argument to dispel error. Galileo had the robust conviction that human reason is capable of discovering the definitive truth in some matters, even if it cannot comprehend the infinite complexity of all existence. His apparent flouting of established authority was a consequence of a deep-rooted belief that the new view of nature could win over even its most obdurate opponents if only the evidence for it was clearly presented. He maintained that in pure arithmetic and geometry the certitude and perfection of man's knowledge were indistinguishable in kind from the knowledge possessed by God. He also believed that the bodies and processes found in nature possess precise mathematical properties. When suitable allowance is made for the grossness of our senses and the approximateness of our measurements, he held, what is true in abstract mathematical theory holds also in the concrete. The discrepancies between theoretical calculation and observation, Salviatus instructs Simplicius, "lie neither in abstract nor in concrete, nor in geometry, nor in physics, but the calculator, who does not know how to adjust his accounts."

Galileo was certainly not the first to attempt a mathematical formulation of natural occurrences. But after his work was done, it was no longer possible to dismiss mathematical analysis as inherently irrelevant to the study of the dynamics of nature, inanimate or living. Galileo's mathematical method forced fundamental revisions not only of cosmology but also of other tenaciously held beliefs. Galileo did not trust to logic alone; he also saw clearly the necessity for testing by experience. This fusion of mathematical analysis with controlled experimentation dominates the discussion throughout the *Dialogue*, and it was his vigorous espousal of this method which distinguished Galileo from other intellectual rebels of his day. The *Dialogue* contributed not only to a new vision of nature but also to reconstruction of the logic of inquiry.

It is a gross mistake to assume, as so much popular history does, that Galileo's conception of scientific method was the same as that of his contemporary Francis Bacon. Galileo was much too good a pupil of Archimedes to suppose that theoretical knowledge can be achieved simply by multiplying miscellaneous "facts" and comparing random observations on the basis of a few rules of classification. He was skeptical of casual sensory experience, and urged that one should learn "to be more circumspect and less confident about that which at first blush is represented by the senses, which may easily deceive us." Indeed, part of his standing quarrel with the Peripatetics was over their readiness to accept crude experience at face value and to give unhesitating credence to what customarily passes as observation. He saw clearly that the data of experience must be analyzed and interpreted if they are to count as significant evidence, and he recognized that theoretical ideas may be suggested by but cannot be deduced from what is observed. Experiments are important as tests of theoretical conjectures, but their results are significant only insofar as the circumstances under which the experiment is conducted approximate a "pure case," in which the relevant factors are reasonably well insulated against uncontrolled disturbances. Moreover, Galileo shrewdly realized that experimental results must be qualified by the limitations in the sensitivity and precision of available experimental techniques.

Galileo frequently fell back upon rationalistic principles and "mental experiment," to establish a point; like Archimedes, he sometimes permitted *a priori* considerations of symmetry to decide an empirical issue. For example, his argument for the principle of inertia is essentially as follows: A ball rolling down a frictionless inclined plane will move indefinitely with increasing velocity; when it is shunted to an upward inclined plane, its speed will decrease. Hence, if an initial impulse is given a ball on a level surface, it must continue to move indefinitely with constant speed, for "if there be no cause of retardation, even less should there be any cause of rest." Galileo here employed a principle which was subsequently baptized by Leibnitz as the Principle of Sufficient Reason, and later still was given the more appropriate label of the Principle of the Equal Distribution of Ignorance. However great may be the heuristic value of such mental experiments and the principle of symmetry, Ernst Mach thoroughly exploded their merits as ways of demonstrating factual truth. Nevertheless, Galileo was indubitably a master of the hypothetico-deductive method. For example, in an arresting passage in the *Dialogue* he considers the objection that though the heliocentric theory suffices to explain the observed facts, the argument is inconclusive because there is no proof that those facts necessitate the theory. Galileo argues in effect that this demand is spurious because it is logically impossible to fulfill it. He makes evident that everything has been done in physics that can be done when it is shown that the given facts are explained by no known alternative theory.

Galileo was fully aware of the thoroughgoing intellectual revolution the new science was creating, and he understood the dismay which filled many men at the prospect that answers to all questions could not be resolved by consulting the writings of Aristotle. "To whom then should we repair for the decision of our controversies," the worldly Sagredus asks, "if Aristotle were removed from the choir? What other author should we follow in the schools, academies and studies? What philosopher has written all the divisions of Natural Philosophy, and so methodically, without omitting so much as one single conclusion? Shall we then overthrow that building under which so many voyagers find shelter?" To such queries Galileo had no reply which could satisfy the vested interests in the intellectual *status quo*. His ultimate rejoinder to those who sought to stem the rising tide of the new science was to reject entirely the facile gnosticism which assumes the universe to be a finished, tidy affair, and which hopes to find or eventually to construct a complete repository of all genuine knowledge. And so he declares:

"I always accounted as extraordinarily foolish those who would make human comprehension the measure of what Nature has a power or knowledge to effect, whereas on the contrary there is not any least effect in Nature which can be fully understood by the most speculative minds in the world. Their vain presumption of knowing all can take beginning solely from their never having known anything; for if one has but once experienced the perfect knowledge of one thing, and truly tasted what it is to know, he shall perceive that of infinite other conclusions he understands not so much as one."

This is clearly not an expression of skepticism concerning the possibility of knowledge, but a vigorous protest against intellectual provincialism. And it is the provincialism as well as the futility of explanations in terms of final causes that roused Galileo's ire, and provoked from him some of his most memorable utterances. A reader steeped in the outlook of post-Darwinian science may find it difficult to take seriously such arguments as that the stars could not be at immense astronomical distances from the earth, because if they were the "vast vacancy" between the outermost planet of the solar system and the stellar bodies would be "superfluous and to no purpose." But such arguments carried conviction to Galileo's generation, and in variant forms they continue to impress even eminent men of our own times. Galileo felt it necessary to blunt the force of teleological explanations without hurting religious sensibilities or violating his own Catholic convictions. This was not an easy task. His way of handling the issue is as effective in argument as it is majestic in manner. He makes Salviatus declare:

"If this grape receives all that it is possible for it to receive from the Sun, not suffering the least injury by the Sun's production of a thousand other effects at the same time, well might we accuse that grape of envy or folly if it should think or wish that the Sun would appropriate all of its rays to its advantage. I am confident that nothing is omitted by the Divine Providence of what concerns the government of human affairs; but that there may not be other things in the Universe that depend upon the same infinite wisdom, I cannot, of myself, by what my reason holds forth to me, bring myself to believe. Surely, I should not forbear to believe any reason to the contrary laid before me by some higher intellect. But, as I stand, if one should tell me that an immense space interposed between the orbs of the planets and the starry sphere, deprived of stars and idle, would be vain and useless, as likewise that so great an immensity for receipt of the fixed stars as exceeds our utmost comprehension would be superfluous, I would reply that it is rashness to go about to make our shallow reason judge of the works of God, and to call vain and superfluous whatever thing in the Universe is not of use to us."

Contrary to a fashionable interpretation of the 17th century, Galileo's insurgence against the verbal physics of scholastic philosophy was not an insurgence against reason itself. It is undoubtedly true, however, that the disciplined reason to which Galileo appealed was not the reason of the scholastics. Perhaps the chief excitement that the *Dialogue* provides a modern reader comes from its vivid portrayal of the forging of a conception of reason and rationality which has already radically altered man's ancient view of the universe and transformed the human scene, and which promises even more than it has yet achieved.

Short Reviews

THE CHEMICAL REVOLUTION, by Archibald Clow and Nan L. Clow. The Batchworth Press ($10.00). In this exceptional achievement of scholarship the Clows give an account of one of the most important phases of the Industrial Revolution: the emergence of the chemical industry in Scotland and England from 1750 through the first few decades of the 19th century. Drawing on a wide variety of primary reference sources, the authors are able to present detailed histories of the principal chemical manufactures during the successive periods of this development. They also deal with the more general economic consequences of industrialization, the melancholy influence of chemistry on social conditions and the appearance of embryonic trade union groups to resist the more extreme attempts to exploit industrial workers (*e.g.*, a 16 or 18 hour day in the mills was not uncommon). Among the more than two dozen chemical industries covered are the manufacture of soap, hydrochloric and sulfuric acid, bleaches, dyes, calico printing, rubber and waterproofing, paper, glass, pottery, iron, lead products, tar, matches, coke and gas, beer, artificial preservatives. It is impossible in a short review to describe the vividness and sustained interest achieved by the Clows in their skillful blending of a vast array of technical, economic and social data. They enliven the story with absorbing sidelights: on Sir George Colebrook who tried to create a world corner in alum; on Charles MacIntosh, who incurred the wrath of the "members of the medical faculty" because his excellent waterproofs were a "decided enemy" to the doctors' "best friends, colds and catarrhs"; on the new paper-making machines which already by the end of the 18th century had reduced the time of making a given amount of paper from three weeks to three minutes; on food adulterants which maintained their popularity despite the fact that the least obnoxious of their effects was instantaneous death. The Clows bring out the point that the science of chemistry learned as much from industrial practices as industry learned from the theoreticians and chemical philosophers.

INFINITY, by Lillian R. Lieber, with drawings by Hugh Gray Lieber. Rinehart & Company, Inc. ($5.00). Lillian Lieber, head of the Department of Mathematics at Long Island University, and her husband, who heads the Fine Arts Department, have become known as original and gifted popularizers of mathematics. They have written books on non-Euclidean geometry, group theory, symbolic logic, relativity and kindred topics; in this volume they escort the reader through the edifice of Georg Cantor's *Alephs*. The German mathematician David Hilbert described Cantor's work as "the most wonderful flowering of the spirit of mathematics and indeed one of the greatest achievements of human reason." Mrs. Lieber leads up to her difficult subject gradually. She explains, among other things, the role of infinity in ordinary geometry and in the non-Euclidean offshoots, the structure of the number system, the arithmetic of the alephs, the theory of transfinite ordinal numbers and Cantor's hierarchy of infinities, the paradoxes of Zeno, the

Whitehead and Russell Theory of Types. Some of this is very difficult stuff, and not all of it is well explained for the ordinary person. Mrs. Lieber writes fairly simply and, in a further attempt to make mathematics at least look easy, she has her books chopped up typographically so that there are rarely more than five or six words to a line. It is not obvious that this device makes things clearer; nevertheless it must be said that Mrs. Lieber handles it with virtuosity. Mr. Lieber's drawings are sentimental and have a studied weirdness. They are not of much help in explaining mathematics, but the text is on the whole up to the job, and for a popular account of infinity you will certainly find no better book.

ADVENTURES IN ARTIFICIAL RESPIRATION, by Peter V. Karpovich. Association Press ($7.50). There are 117 known methods of artificial respiration and resuscitation. This curious volume, based on research undertaken for the Office of the Surgeon General, gives the descriptions and histories of all of them. Early methods included placing live coals or animal excreta on the victim's abdomen, blowing air or tobacco smoke into his mouth, hanging him upside down from a tree, laying him on the back of an ox or rolling him over a barrel. These were only moderately effective. The many and various procedures tried in modern times, though often of indifferent value, have at least had the laudable aim of getting the victim's lungs working without splintering his bones. Dr. Leroy-d'Etiolles suggested pressure on the abdomen and chest; Dr. Howard thought the limp wretch should be turned over after every push; Dr. Brosch contended he should be laid across a chair; Dr. Baker argued for dropping him on his face and Dr. Schaefer advocated "prone pressure," to which Dr. Sylvester objected that, at least as regards female patients, it was manifestly improper for the operator to place himself "athwart the patient." The Schaefer method prevailed for many years, but recently the experts have come to the support of a process first suggested by Dr. Sylvester, namely, lifting the patient's arms to make his own muscles do the work. The technique now officially advocated by most lifesaving authorities, developed by Holger Nielsen of Denmark, places the patient on his back and combines rhythmic pressure on the lower ribs with raising of the arms above the head to restore natural breathing. But an ounce of prevention is obviously preferable to 150 pounds of cure seated on one's chest.

The Papers of Thomas Jefferson (Volume 6), edited by Julian P. Boyd. Princeton University Press ($10.00). The period covered by this volume (May, 1781–March, 1784) was one of personal humiliation and tragedy for Jefferson. The Virginia Legislature conducted an inquiry into his conduct as Governor; he was fully vindicated, but the events left a scar and provided his enemies with material for renewed attacks in later years. The death of his wife was a much heavier blow. But Jefferson's immense energy and prolific interests soon restored him to his usual tempo of activity. He prepares legal opinions, drafts and reports on the constitution of Virginia and the disposition of the Northwest territories. He writes letters of introduction for James Monroe, code letters and long communications of political and personal content to James Madison. He asks George Rogers Clark for the "teeth of the great animal whose remains are found on the Ohio" and for other fossil specimens. He sets down a detailed description, for his friend Isaac Zane, of an ingenious new way to construct a water wheel. Colonel Archibald Cary, a wonderful observer and a no less wonderful speller, provides Jefferson with zoological information about the "anamals" of Virginia: "Dears," "Possams," "Rabbets," "Hedg Hogs," "Ratts" and "Bers." Jefferson is impressed by the possibilities of balloons. "This discovery seems to threaten the prostration of fortified works unless they can be closed above, the destruction of fleets and what not." As the successive installments of this great edition appear, one becomes convinced that Jefferson is the only man of history who deserves to be celebrated in 50 volumes, and that all of them, if you can afford it, are worth owning.

Cerebral Mechanisms in Behavior, edited by Lloyd A. Jeffress. John Wiley & Sons, Inc. ($6.50). This is the record of the Hixon symposium on the brain, held in September, 1948, at the California Institute of Technology. John von Neumann presents a challenging analysis of the theory of automata, in the course of which he extends a principle outlined about 15 years ago by the noted English logician A. S. Turing. He concludes that it is theoretically possible to construct automata—these need not be purely computing machines—capable of self-reproduction, and indeed of making other automata of greater complexity than themselves. Warren S. McCulloch's paper, "Why the Mind Is in the Head," is as provocative as its title. He is inclined to doubt the possibility of electronic tubes and circuits making man obsolete in the foreseeable future: "The joy of creating ideals, new and eternal, in and of a world, old and temporal—robots have it not. For this my mother bore me." Other participants in this exceptional symposium include the psychologist K. S. Lashley, the chemist Linus Pauling, the philosopher and psychologist Wolfgang Köhler, the experimental psychologist Ward C. Halstead. It is a book with meat and savor.

THE LIVING BRAIN, by W. Grey Walter. W. W. Norton & Company, Inc. ($3.95). One of the pioneers of electroencephalography here gives a fascinating report on advances in our knowledge of the mechanisms of the brain, the "enchanted loom." The electroencephalograph records the rhythmic tides of electricity as they surge through the brain cells: the alpha rhythm, resembling a scanning device; the delta waves, essentially the "billowy rhythm of sleep"; the theta rhythm, "scarcely visible in good-tempered adults" but evoked even in them by a disagreeable stimulus or by disappointment. (A French student whose head was being stroked by a "young lady from Wales" erupted into a vehement theta display whenever the young lady stopped stroking.) The discovery in 1946 that brain-wave activity can be substantially increased by "rhythmic stimulation," particularly by turning a bright light on and off in front of a person's eyes, has turned out to be a powerful instrument. Dr. Walter describes the correlations between rhythms and disease, between flicker patterns and personality. He discusses the simple automata which can be used not only to accomplish our more bloodthirsty purposes but which may even help us to understand what makes us bloodthirsty. The author does not think the human brain will evolve to a larger, more complex organ, but it seems reasonable to suppose that fuller and better use can be made of the existing equipment. Altogether this is a handsomely written book—poetic, witty, exciting both in its facts and in its conjectures.

THE APPLE AND THE SPECTROSCOPE, by T. R. Henn. Methuen & Co., Ltd. ($2.75). The title of this admirable volume is an apt summary of its conjunction of beauty and wisdom. In 1947 a group of Cambridge science students asked the University to organize a series of lectures "for their special needs" on some aspect of English literature. Henn, who prepared the course, is a noted critic of W. B. Yeats and an English lecturer at St.

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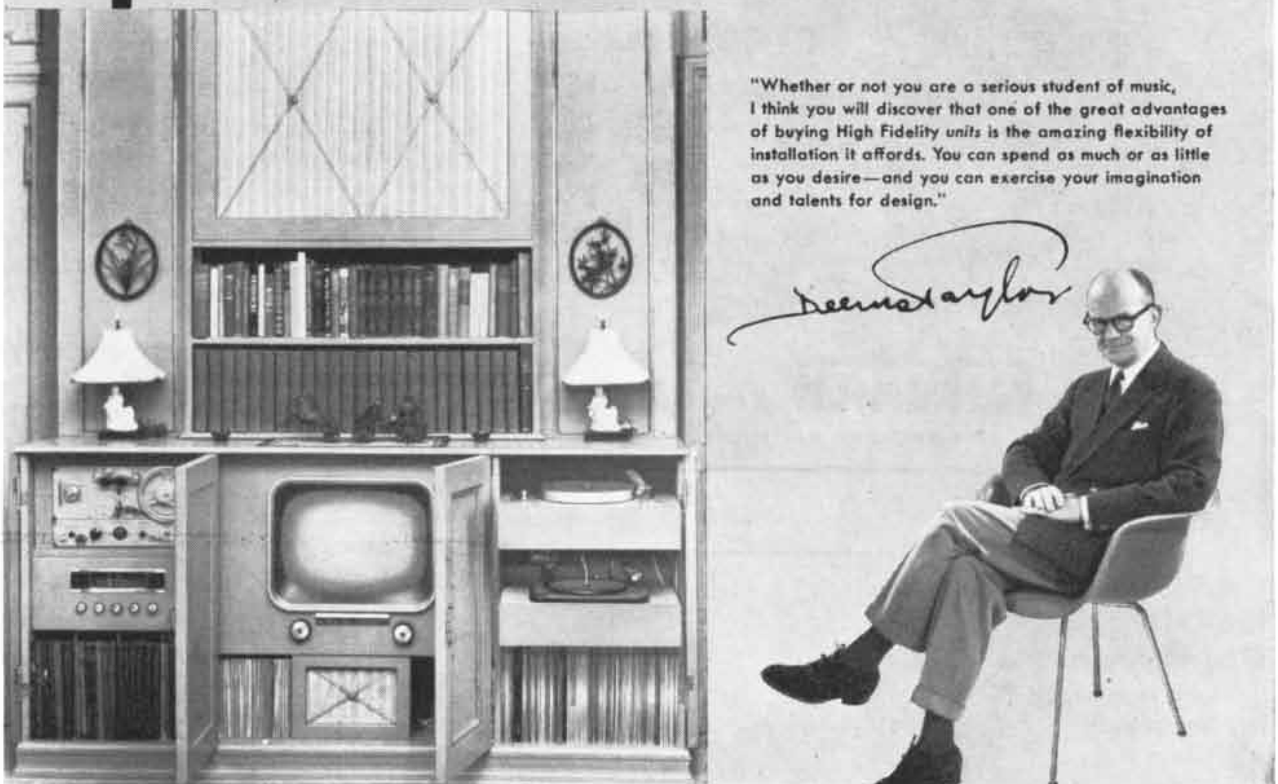

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Catherine's College. He surveyed the "mechanisms and technique of poetry" from the 15th-century Scottish ballad of "The Twa Corbies" to T. S. Eliot's "The Waste Land." In his lectures Henn hit just the right note, neither condescending nor taking too much for granted, treating the problems of poetry rationally and with no high-flown obscurities. In part he spoke to the science students in the language of science: *e.g.*, he used diagrams and simple mathematical symbols to explain poetic structure and relationships. The collected lectures make an intelligent, original and uncommonly fine book.

I DRANK THE ZAMBEZI, by Arthur Loveridge. Harper & Brothers ($4.00). Loveridge, the curator of the Harvard Museum of Comparative Zoology, spent a year in Nyasaland, a British protectorate in Southeast Africa, collecting specimens of frogs, lizards, snakes and mammals for the Museum. With the help of his wife, his sister-in-law, native guides and a Dodge truck, he gathered 4,000 examples of the disappearing wild life of this region, where the forests are going rapidly. Loveridge imparts his amusing and hazardous adventures on the Zambezi River with well-mannered zest. His opinions on the backwardness of African natives and the folly of entrusting them with even partial self-government probably would not offend Premier Malan, but otherwise this is a better-than-average naturalist's diary.

MAN AND THE CHEMICAL ELEMENTS, by J. Newton Friend. Charles Scribner's Sons ($6.00). Friend, an English chemist, tells the story of the chemical elements from the earliest time, when no one knew what they were, to the present, when a surfeit of knowledge has reduced us to learned confusion. Besides presenting a clear and accurate account of the main aspects of his subject, Friend rambles over many diverting side paths: The largest bell in the world, the 200-ton Monarch of Moscow cast in 1735, doesn't ring. The word "gibberish" is derived from Geber, a famous Arabian alchemist who was a master of the jargon of his profession. The German word for the spiteful goblins who inhabit mines is "Kobalds," whence we get the name "cobalt." The largest diamond ever found (the Cullinan, discovered on a farm near Pretoria) weighed 3,016 carats (1.3695 pounds), was valued at £20 million and won its finder a knighthood. The first authentic article of aluminum was a rattle for the infant who grew up to be Napoleon III.

What General Electric people are saying . . .

C. W. LaPIERRE

Mr. LaPierre is Vice President and General Manager—Aircraft Gas Turbine Division

". . . In my opinion, research and development organizations, including our many capable universities, should always be primarily interested in exploration which leads to establishing principles. They should not attempt, by themselves, to direct the course of aviation progress. For example, they should establish the operating limits on a particular material or the relative merits of different thermodynamic cycles. But they should not try to dictate how their findings should be used. This responsibility must be left to the designer. Research and development organizations should work with the industry in helping establish limitations and principles; they should anticipate problems and solve them. Their solutions make it possible for the aircraft industry to overcome obstacles that might otherwise delay progress for years.

But regardless of *who* conducts our research and development projects, or how they are conducted, the nation's efforts in this field must not be allowed to dwindle.

The Soviet has, and will undoubtedly continue to hold, the advantage of mass—mass of manpower and material. We cannot hope to overtake them on those two scores. But our system of government is such that it encourages freer thinking and more rapid development. Our defense lies in the ability to outdevelop them—to neutralize their ponderous weight of arms with more advanced machines and methods. Our nation is blessed with the brain power and facilities to press this advantage. Our danger lies in the curse of lethargy that would allow them to lie fallow.

at The Air Force Association
Washington, D. C.

A. W. SCHMITZ and H. L. PALMER

Mr. Schmitz is Manager of Equipment Engineering, Industry Control Department

Mr. Palmer is Manager of Electronic, Regulator and Aircraft Engineering, Industry Control Department

". . . Today's high production speeds require controls with swiftness of response that can no longer be supplied manually. Self-regulating controls are the answer. At the same time, there's a constant evolution of control principles and amplifying means to obtain even faster speeds of response, and more accuracy of performance.

In the 1930's, the amplidyne—or rotating amplifier—was applied in industry where the sensitive capabilities of electronic tubes weren't needed, and where there was reluctance to use such fragile equipment. In subsequent years, however, control equipments were designed using the electronic tube and amplidyne in combination. Today, by contrast, the trend is toward replacement of both types with the static, or magnetic, amplifier.

Of tremendous help to the engineer in solving the complex control problems that lie ahead will be mechanical and electronic calculating machines. For in addition to solving mathematical equations, they can be used to simulate the electric machinery for which the control is designed. Thus, a more thorough test of the control can be made in the factory prior to installation at the customer's plant. This new technique has already reduced installation and tune-up time to a high degree.

Controls of the future may well include computers and information-storage devices to permit measurement and integration of operating factors in a process. That is, the control itself will make necessary calculations and automatically correct the process to get the desired end product. When we reach this stage of control, our nation's industrial productivity will have no limits.

G.E. Review

C. F. GREEN

Dr. Green is Engineer—Advance Developments, Aeronautic & Ordnance Systems Division

". . . The successful conduct of the rocket flight of a complex piece of experimental equipment is an arduous undertaking. Not only is it necessary to have equipment operating properly and reliably without personal attention; but also it is necessary to co-ordinate a large field of operations involving final missile assembly, handling and firing details, a network of optical and radar tracking stations, a system of radar receiving stations, a range safety group for protection of inhabitants and for command cut-off of rocket motor power in the event of a probably dangerous trajectory and a recovery group. Because of the large number of people involved in a firing, the date and hour of firing is fixed considerably in advance. Deadlines are not easy to meet with varied pieces of laboratory type equipment. There are problems of doing adequate pre-flight check-out of equipment under difficult field conditions—such as extreme temperatures, sand storms, rain, hail and winds. In general, each flight, since it carries different equipment, separately engineered for its particular requirements, places special problems upon the missile men as well as the experimental agency or agencies, all working together with a common incentive to accomplish the planned objectives.

at Oxford University
Oxford, England

You can put your confidence in—

GENERAL ELECTRIC

THE AMATEUR SCIENTIST

On the nationwide net of weather observers and the ruling of a grating on a cylinder

Conducted by Albert G. Ingalls

The U. S. climate tends to reach its extremes in the nation's four corners. Wynoochee Oxbow, Wash., is the wettest locality: during one 13-year period annual rainfall there averaged about 150.73 inches. The most violent downpour, however, was recorded in the Southwest at Thrall, Tex., where during a 24-hour interval on September 9, 1921, a rain gauge measured 38.20 inches. The southeast corner of the nation claims the second heaviest rain: 23.22 inches during a 24-hour period in October, 1924, at Smyrna, Fla. Greenland Ranch in Death Valley, Calif., records the smallest rainfall: a yearly average of only 1.35 inches. Greenland Ranch also claims the temperature high, 134 degrees registered on July 10, 1913. The record low is 66 below zero, observed in Yellowstone National Park on February 9, 1933. From the remaining corner, the state of Maine insists that a snowfall of 96 inches in four days puts her in competition with California's 884 inches—more than 73 feet—during the winter of 1906-07. The best that the central states can do is to claim a record for the largest hailstone ever measured: a stone which fell at Potter, Neb., on July 6, 1928, and, placed on the scales immediately, weighed 1½ pounds!

All of these statistics, together with unnumbered millions of others, were gathered by members of an organization of amateur weather men who cooperate with the U. S. Weather Bureau. Officially they are known as Cooperative Weather Observers. Their geographic distribution across the nation is indicated by the map on page 115. No matter where you go in the U. S. you can find an amateur meteorologist within 50 miles, and the chances are not remote that one lives across the street from you. Most of these amateurs are cooperative observers for the Weather Bureau.

These amateurs play a direct role in all our lives. They contribute to our comfort and stretch the pennies in our pocketbooks. The price of fuel oil for space heating, for example, is largely determined by the cost of local distribution. If your fuel dealer can hold down the frequency of his deliveries by making maximum use of the storage capacity of your tank, he can reduce his bill. If you are willing to cooperate, the dealer will permit the pattern of your local climate to dictate your delivery schedule. In the U. S. that pattern is charted almost solely from data contributed by the Cooperative Weather Observers. What you will pay for coffee a year from now can be estimated from their reports. These observers also play a military role. Should the date for testing a guided missile at White Sands proving ground in New Mexico be set for October 15 or November 15? The probability of the desired weather on each date can be ascertained by Army meteorologists in a few minutes —from records compiled through the years by cooperative observers. On which side of Indianapolis, Ind., should you erect a new factory for, say, making fine electrical instruments? Where in the U. S. would breadfruit thrive? Should your daughter plan to hold her garden party early or late in June? Collectively the cooperative records can give you climatic odds to meet any of these needs, along with a factor of probable error that is exquisite in its refinement.

Like amateur groups in general, cooperative observers come from all walks of life. The first weather records on the American continent, according to W. F. McDonald, Chief Climatologist of the U. S. Weather Bureau, were kept by the Reverend John Campanius at Swedes Fort near Wilmington, Del., in 1644. It was not, however, until 1891, nearly 250 years later, that the immensely valuable work of the amateur weather observers came in for official recognition. The present dean of the observers is Dudley I. Craig, a civil engineer who lives on the Pinal Ranch in Arizona. Mr. Craig became a cooperative observer on March 1, 1893, at the age of 18. There is no adequate measure of the service he has freely contributed to his fellow citizens. His record spans more than 60 years.

At the other age extreme we find the granddaughter of Charles F. Brooks, Director of the Blue Hill Observatory of Harvard University, who became an assistant cooperative observer at her home in Missouri at the age of six. Her admission to the ranks illustrates the fact that sometimes whole families get into the act. All seven of Dr. Brooks' children are interested in weather observation and forecasting—one of them professionally. It is not at all uncommon for a son to continue records first kept by his father. Hundreds of the thermometers and rain gauges that the Weather Bureau has issued to amateurs over the years are now being tended by the third generation.

Few amateurs in science can compete with the weather men and women in regularity and devotion. Hundreds of them have been reading their "max-min" thermometers seven days a week at precisely the same time each day, 7 a.m. or 7 p.m., for more than a decade at the same address without a single miss! Some have done so for more than 50 years.

Offhand it may seem that keeping track of the weather and making studies of local climate can scarcely provide enough activity for a full-scale avocation. To learn what keeps an amateur meteorologist busy, we dropped in on William Martin recently. His weather station at Long Branch, N. J., has earned a Class B rating, which means that he is authorized to disseminate official Weather Bureau forecasts for his community. Mr. Martin works for the telephone company and lives in a large, two-story house in a quiet part of town.

We asked him how an amateur meteorologist spends his day. "It begins at 5:30 a.m.," he said, "and often fishing crews begin calling even earlier. I don't have much time for breakfast, because the recording instruments have to be serviced, and two of them, the water thermograph and wave recorder, are located on the beach more than a mile away. They show the temperature of the ocean and how rough it is. Often I have to make a special trip to the pier to fly storm warnings. When these jobs are out of the way and all the readings are in hand, I call New York. We have a direct wire to the Weather Bureau office there and I usually spend half an hour or so exchanging data. Then I get busy on the paper work. Meanwhile Mrs. Martin handles the incoming calls. We have two telephones and average about 50 inquiries a day. During hurricane weather the calls go up to 400 or more. When the records are finished, it's time for me to get down to the local broadcasting station, where I go on the air with the weather at 7:30. After the broadcast it's time for work. We amateurs have to earn a living the same as anybody. The evening routine is pretty much the same, except that other chores substitute for the charts and broadcast. We have quite a few instruments to maintain, and that means an endless round of tinkering."

Martin's instruments are installed all over the place. Several were supplied by the government. A 65-foot tower near his garage supports a recording air vane, two anemometers—one for measuring wind speeds down to one mile per hour and the other for gusts of hurricane intensity and an ultra-high-frequency radio antenna. Two rain gauges, one an automatic dump-bucket type which registers inches of rainfall on a graph in the house, are installed in his back yard at a spot protected from the wind. Behind the garage a 14-foot tower supports a small, ventilated enclosure reached by a stairway. This is the instrument shelter. It is made of slats, somewhat like a Venetian blind, which permit a free circulation of air. It houses conventional minimum and maximum thermometers, a barograph, a thermograph, a hair hydrograph, wet- and dry-bulb thermometers and a thermocouple which works with a remote dial in the house for convenience in reading outdoor temperature. The sensing element of a sun gauge is mounted on the roof of the house and registers on a graph indoors.

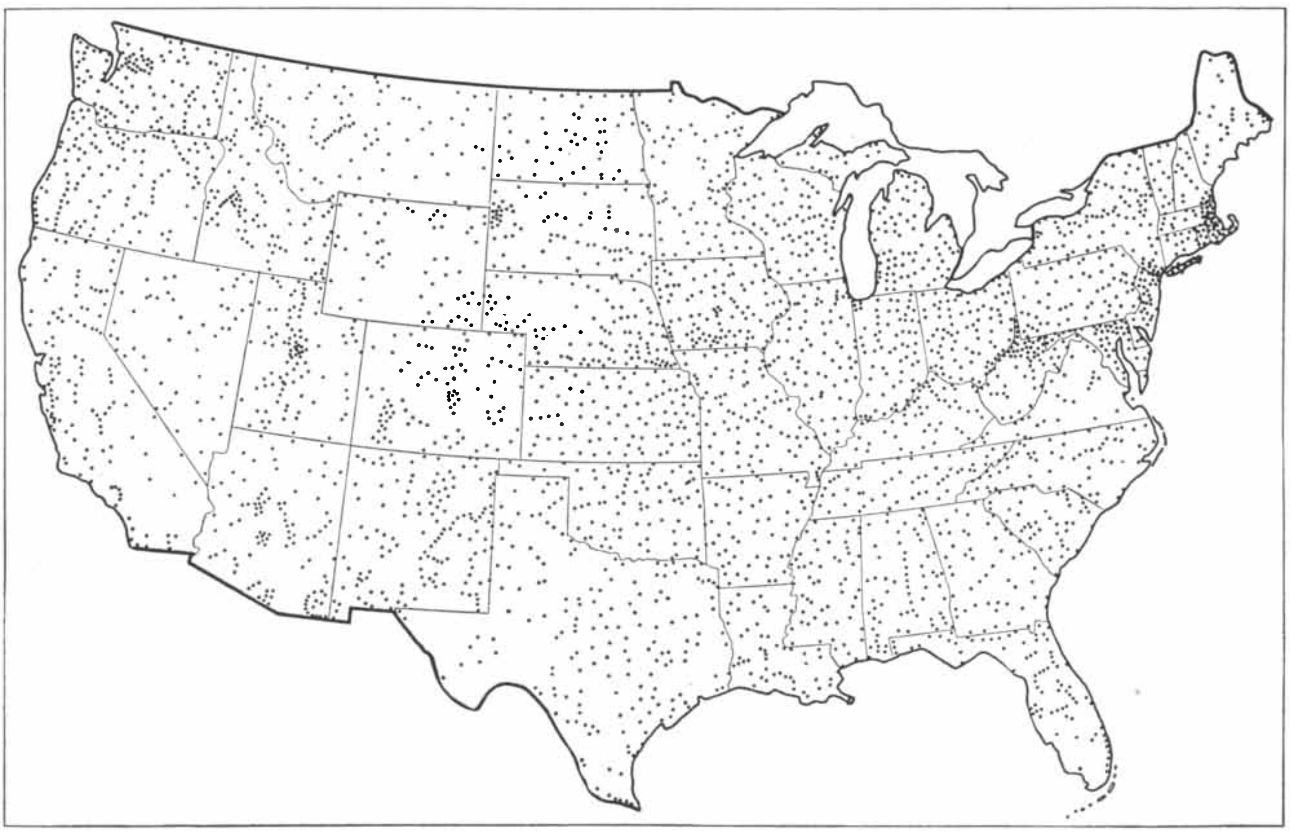
A converted bedroom on the second floor serves as the operating center of the station. Two sides of the room are taken up by instrument panels. All over the room is a clutter of cloud charts, weather maps and related tabular displays such as you would find in a Weather Bureau office.

"Not much activity tonight," observed Mr. Martin. "We will have nice weather today and tomorrow. There's a big high moving in slowly from the midwest and another off Bermuda. You've probably heard about Barbara. That's the name of the season's second hurricane. She's about 300 miles east of the Florida coast right now and moving north at eight miles per hour."

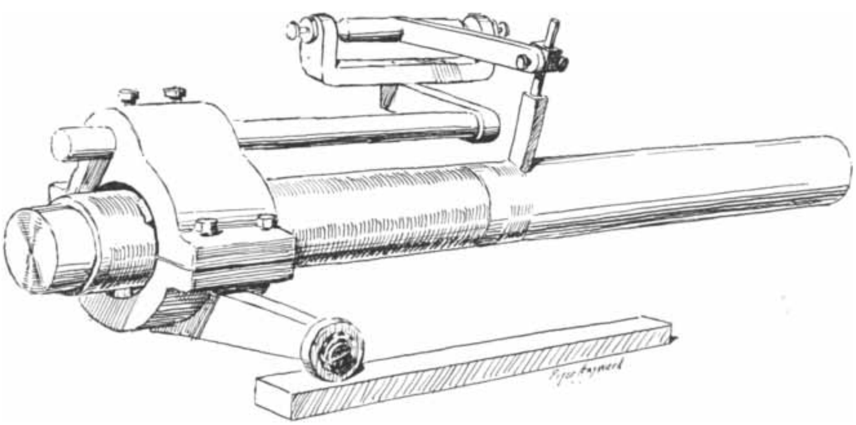
At that moment the telephone rang and Mrs. Martin told a local yachtsman that it would be all right for him to take a cruise off the Jersey coast the following day. "If the pattern of highs fails to move as it should," Martin continued, "Barbara can give us some nasty weather. But she will need at least three days to reach here. When hurricanes threaten, we get a lot of calls like the one Mrs. Martin just answered. You should come down the day after tomorrow if you want to see how things go when we get busy."

We asked Mr. Martin what he finds most interesting in his hobby. "I enjoy reading about the scientific aspects of weather a lot," he said, "but I rely on the Weather Bureau for technical information. Some of the other fellows, like Harry Larkin, who keeps a station at Elma, N. Y., or Wendell Kilmer, out on Long Island, go in for meteorological research. I specialize more in the application of weather information."

Martin's reference to Harry Larkin reminded us of our visit to Elma some



This pattern of dots shows amateur weather stations that cooperate with the U. S. Weather Bureau



The basic principle of the Merton ruling engine

months ago when Larkin described his seismological station for this department. Larkin's interest centers principally in the dynamic processes of weather. As his account in our April, 1952, issue remarked, he is concerned with the relation between the movement of low-pressure regions in the atmosphere and the intensity of microseisms in the earth.

For several years Larkin has also been investigating the theory of pre-frontal waves. According to this theory, the violent interaction of two air masses can generate waves of pressure which are propagated a considerable distance, as much as 150 miles, in advance of the front. Such waves, appearing without warning, may explain why aircraft sometimes get into trouble while passing through zones thought to be free of dangerous turbulence. If such pre-frontal waves exist, Larkin reasoned, under appropriate meteorological conditions thin clouds should form in the low-pressure regions of the waves and disclose their presence. To check the theory Larkin set up a horizon-to-horizon motion picture camera which makes time-lapse photographs of the sky every day from dawn until dusk. The results, although incomplete at present, have attracted wide attention in professional meteorological circles.

The theory of pre-frontal waves is only one of a great number of meteorological problems open to study by amateurs. The field of micrometeorology, for example, offers almost endless opportunity. Several years ago amateurs in a section of Long Island, among them Kilmer, who is a professional photographer, noticed a curious disagreement of their early-morning temperature readings. The thermometers in a narrow region near Kilmer's station read some 20 degrees lower than those in the surrounding countryside. From this accidental observation grew a study which took many months. More than a score of amateurs cooperated in establishing a fine-grained network of observing stations in this area, and in this way they discovered and mapped Long Island's famous "ice box."

The ice box occupies an elongated depression in the vicinity of the Brookhaven National Laboratory. It lies between two low ridges that shield it from heat radiated by Long Island Sound on one side and from the Atlantic Ocean on the other. A narrow valley links it with the sea. Its soil consists, for the most part, of light-colored sand.

By making many closely spaced observations of temperature and wind direction near the surface, the amateurs gradually learned what makes the ice box work. The explanation begins with the fact that heat is radiated from the sand more readily than from the soil of the surrounding terrain. When the sun goes down, this cooling creates a layer of dense air over the area. The cool air then flows down to the sea. Thermometers begin to drop. Cool air forming over the surrounding terrain also is drawn into the ice box and flows to the sea. The ice box thus becomes a meteorological drainage area. In the meantime the surrounding terrain is absorbing heat radiated from the Sound and the Ocean. Hence the temperature differential continues to increase, with the coldest air always flowing into the drainage system. From a practical point of view your appreciation of the ice box will depend on whether you are a truck farmer intent on raising late tomatoes in it or an office worker seeking a dwelling site in which to escape the heat of the city.

Amateur interest in micrometeorology has risen sharply during the past decade as cooperative observers have learned its importance in analyzing local climate. Climatologists need to know at all times how much water is being held in the soil. It is very hard to get an accurate estimate of the evaporation from the soil or the transpiration of water by plants by any conventional means. Micrometeorology suggested a simple solution. Moisture escaping from the ground first enters a thin and relatively stationary "boundary layer" of air at the surface. It then diffuses into a relatively thick turbulent layer above, which carries it away. The mixing process tends to distribute moisture uniformly through the turbulent layer, but if water continues to enter the layer from the ground, the humidity is relatively high at the bottom of the layer and decreases with height above the surface. In other words, the layer shows a moisture gradient. Accordingly, micrometeorological measurements of temperature, wind velocity and humidity at successive intervals through the turbulent layer indicate the rate at which water is being carried away.

Frederick Lichtgarn, an amateur in Chicago, recently invented an electronic hydrograph element which he hopes will lead to the design of a direct-reading evaporation meter by utilizing the micrometeorological method. Lichtgarn's element, a specially processed ceramic, produces a voltage proportional to the vapor content of the air. When this voltage is combined through an appropriate analogue circuit with others proportional to temperature and wind velocity, the resulting voltage should represent the total transportation of moisture from the soil.

According to David Ludlum, a cooperative observer who combines pleasure with business by editing *Weatherwise*, the popular journal of the American Meteorological Society, you can't name a branch of science that is not intimately bound to meteorology in some way. That is why many meteorological amateurs parallel their enthusiasm for weather watching with an equal interest in some other field.

"I can name scores of cooperative observers," said Ludlum, "who go in for the earth sciences. When the study of today's climate fails to absorb enough free time, many of the fellows get fun out of checking up on the weather in their community as it used to be—not merely a decade or so ago but thousands or millions of years ago. During the Silurian and Jurassic periods the earth drifted along for thousands of years with one balmy day merging into the next. That is how periods like the Pennsylvania could produce such giant ferns and other lush vegetation. The times enjoyed an ideal balance of moisture and temperature.

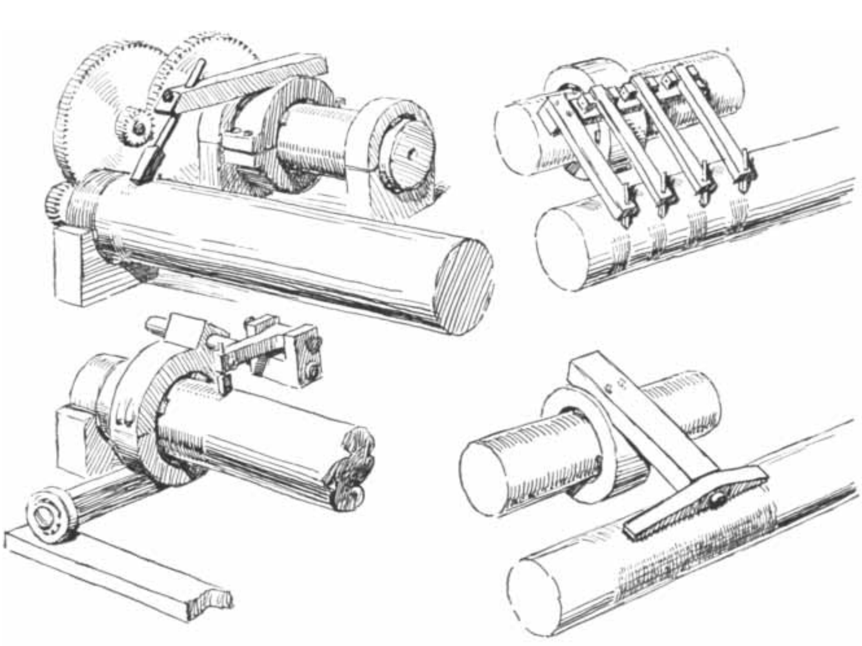
"When an amateur meteorologist goes fossil hunting, he is looking for something more than a curio for his mantelpiece. The story he learns to read in the rocks adds to his knowledge of paleoclimatology. Not all amateurs live near a region that abounds in fossils, of course, but this does not bar the study of ancient climate to them. One advantage of climate as a hobby is the fact that we have weather everywhere—and always have had. So the fellow in Wisconsin or Iowa can go in for geochronologic climatology or documental climatology.

"Did you, as a boy, ever dig your bare toes into the mud of a pond or lake bottom when the water was low and wonder what caused the soil to settle in thin, sharp layers somewhat like tree rings? These layers are called 'varves.' During the rainy season run-off transports silt into the lake, where the coarse material drops to the bottom quickly. Then in winter when the surface freezes a second coat is added—a thin layer of material so fine that it takes many weeks to settle out of suspension. The combination of these two layers marks the passing of a year. Wet years produce thick varves and dry years thin ones—just as in the case of tree rings. The idea of using varves to extend investigations of climate back year by year was suggested by Gerard De Geer in 1878. An event which took place in Sweden some 150 years ago has enabled us to tie our own climatic chronology into varve geochronology. In 1796 the Swedes totally drained Lake Ragunda. Fortunately the operation did not destroy the uppermost varve; hence it is dated definitely. More than 1,100 others below it have been carefully counted and their thicknesses charted. Because no two years are identical climatically, each span of time is marked by its own pattern of varves. Varves from one locality often can be matched up with those of another. That is how the record is extended, and persistent work has driven it back nearly 14,000 years.

"Only a few of the gang, so far as I know, go in for documental climatology to any extent. These amateurs browse through old manuscripts which, though usually written for some purpose unrelated to climate, give valuable clues about it—the movement of populations, bumper crops, periods of famine, changes in trade routes forced by floods or droughts, mention of a rainless year. Several amateurs have used this method in extending the records of the U. S. climate back to the days of the first colonists. They comb old newspaper files and the archives of local historical societies for any bit they can find.

"Most of us, however, get all the paper work we want just keeping track of today's weather. We do not find that part of our hobby tedious or dull."

For several years ruling-engine experts (see Scientific American, June, July, August, 1953) have watched the progress of a new method of ruling diffraction gratings being developed in England by the spectroscopist Sir Thomas Merton and others. Merton has designed a machine which, instead of making parallel grooves by means of a diamond shuttling back and forth over a flat blank, rules a continuous spiral groove like a fine screw thread on a metal cylinder. The cylinder is then coated



Variations on the basic Merton principle with a cellulose liquid which dries on as a thin film or skin. This cylindrical skin is slit lengthwise, peeled off like the bark of a tree, uncurled and mounted on flat glass for use.

Much research has been devoted to the improvement of this method by Merton, by R. G. N. Hall, G. D. Dew and L. A. Sayce of the British National Physical Laboratory and by the optical firm of Hilger and Watts, Ltd.

The Merton machine has met with the usual extremes of overenthusiastic praise and derision, according to the critics' predilections. Objective observers are waiting to see how it works out, remembering that in a century of ruling-engine experimentation there have been many machines whose performance failed to equal the predictions that the experimenters were apparently unable to resist publishing.

The Merton principle is an attempt to get around the inherent difficulties of the traditional method—the uncertain positioning of the ruling diamond due to variations in lubrication as the engine continually stops and starts, and the residual errors in parts of the engine. It substitutes for the back-and-forth action "a continuous lathe-like action, avoiding all intermittent and reciprocating movements and maintaining constant stress in every component of the machine throughout the whole ruling operation." Yet the Merton method has its own inherent difficulties, which have only been partly remedied. Therefore the following is a progress report and not a final one.

The method in practice is not simple. No existing lathe can rule a spiral groove on a cylinder with enough precision to qualify as the matrix for duplicating a diffraction grating, in which the tolerance of error is only one millionth of an inch. It is uncertain that a perfect lathe can ever be built. Nevertheless Merton found a way to make a lathe accomplish the miracle of reproducing an almost perfect helix directly from an imperfect helix ruled by a lathe. Let's look at the apparatus that does this, shown in its original form by Roger Hayward's simplified drawing on page 116. A polished stainless steel cylinder an inch in diameter and a foot in length is put in a precision lathe and threaded at 2,000 turns per inch for a distance of half its length plus an inch. This ruled helix will have all the serious periodic errors inherent in the lathe. Next a nut is run on the cylinder with an extension rod that places the diamond on the unruled portion. A wheel on the end of a side arm below the cylinder (*see cut*) keeps the nut from revolving while the cylinder rotates. (The means of rotation is not shown in the drawing.) The nut therefore moves along the cylinder. As it does so, the diamond rules a practically perfect secondary helix on the unruled part.

How can you rule a perfect helix from an imperfect one as a guide? Here is the answer. The threads of the nut consist of three small equally spaced strips of unthreaded cork coated with graphite, each about three eighths of an inch wide. The trick lies in the elasticity of the threads. The cork is elastic enough, or a part of it slips enough, or both, to average out the periodic errors of the primary grooves and produce almost perfect secondary grooves. The cylinders are practically free from taper and ellipticity and are honed and lapped optically smooth with pitch. This method of causing a part of a cylinder to act as its own lead screw also eliminates the thrust bearings that give trouble on conventional engines. Optical evidence in the Merton articles proves that the periodic errors due to the lathe practically disappear.

In 1950 Kenneth R. Eldridge, scientific liaison officer at the Office of the U. S. Naval Attaché in London, investigated the Merton machine and variations of it at the National Physical Laboratory and at Hilger and Watts. He found the Laboratory using a cylinder 1½ by 12 inches, on which it had engraved a thread with a pitch of one 15,000th of an inch. The ruling was made with a simple lathe like an ordinary South Bend make. The thread of course was full of periodic errors. But in ruling the rest of the cylinder these errors were averaged out by the elastic follower nut already described. Since a diamond ground to simple knife-edge shape can be used as the ruling edge on the cylinder, the difficult technique of shaping a diamond for the oscillating type of ruling engine is simplified.

Eldridge found that Hilger and Watts had a machine which avoided the problem of optically finishing a long metal cylinder. The principle of their machine is shown in the upper left-hand drawing on page 117. It uses two short cylinders, each rotating in corklined end bearings having threads with zero pitch (closed rings instead of a helix). The lathe first engraves a coarse thread on the rear cylinder for a length of two inches. The thread has one thirtieth as many turns per inch as the final spacing desired for the grating; for example, it is ruled with 500 turns per inch to produce a grating with 15,000 turns per inch. A cork elastic nut is then mounted on the rear cylinder, and the front cylinder is rotated by out-

side means not shown. Because of the 1-to-30 gear ratio, the diamond, moved along the front cylinder by the nut on the rear cylinder, engraves on the front cylinder 30 grooves in the space of each groove on the rear cylinder.

A length of one inch is engraved by this method, and this will contain the errors of the gearing. These errors are then got rid of by mounting an elastic nut on the front cylinder, attaching the diamond to that nut and engraving a groove along its length (*lower left-hand drawing on page 117*). As the nut leaves the original one-inch of thread, it is picked up by the thread being engraved and carried forward, self-driven by the thread.

The physicist observer at the U. S. Office of Naval Research in London reported that in the experiments the progressive errors had proved to be very small, but that they remained a problem. Another problem was the fact that the delicate grooves already engraved were damaged when the elastic nut passed over them.

Last year Hall and Sayce of the National Physical Laboratory described some of the inherent faults of the Merton method. The helical grating still had two kinds of errors: periodic, caused by regularly repeated errors of pitch of the fine helix, and progressive, caused by comparatively slow and usually irregular variations of pitch. The principal problems in producing helical gratings are the elimination of these errors and the production of grooves of such profile that they will reflect and diffract the light in the same direction (blazed gratings). Two methods are being investigated.

The first method uses the gearing already described in a modified form (*see upper right-hand drawing*). A four-inch length of primary helix is cut on the rear cylinder with a single diamond. This helix therefore possesses all the progressive errors of four inches of the lathe's lead screw. A gang of four diamonds, or perhaps six, simultaneously cuts a four-inch length of helix on the front cylinder. By this dodge the helix ruled contains the progressive errors of only one inch of the lead screw, since only one inch of that screw has been used. The four portions of the composite helix may be out of phase with one another, but experiment shows that this does not adversely affect its guidance of the Merton nut on the rear cylinder. The subdivision of the primary helix may be further extended and the four diamonds multiplied indefinitely by substituting for the diamonds a six-inch strip of abrasive material (*lower right-hand drawing*). A few turns of the lathe inscribe on the front cylinder a large number of scratches, each with the correct helix angle. From this a Merton nut is found to inscribe a secondary helix free from both periodic and progressive errors. The method is not without practical difficulty, and its details have not yet been fully developed.

The second method being investigated attempts to escape from two difficulties: the damage to the primary helix when it is used for generating a secondary helix, and the fact that the grooves guide best when symmetrical in profile, while a symmetrical profile is rarely required in a grating. The solution, not shown in the drawings, is the use on the same cylinder of two trailing diamonds instead of one. The first rules the guiding grooves while the second is ruling a blazed grating groove some inches farther along.

Experimenters have found the pith of the elder tree, used by jewelers, to be an even better material than cork for the elastic nuts. If well lubricated, it shows no tendency to cause progressive error. Hidurex, an aluminum bronze, is a better material for the cylinders than steel. Cylinders an inch in diameter have proved most convenient.

Some critics, reasoning that these fantastic methods ought not to work, have therefore concluded that they do not work. They are partly correct. The proof of the pudding is not in the reasoning but in the gratings, which are good but not good enough. The spectra they make are said to be completely free from ghosts, but progressive errors remain.

In sum, the experimenters say they have been able to rule plane gratings 2¾ by 7 inches free from all periodic errors, with predetermined blaze. Most of these have been relatively coarse gratings, spaced 5,000 to 12,000 grooves in an inch. To try to rule finer gratings with the required freedom from progressive errors, the experimenters are building an improved lathe. They are also building an experimental engine to rule concave gratings. All this is the mechanical part of the Merton method. The final stage, most difficult of all, is to be able to reproduce the gratings ruled. Dew and Sayce reported in 1951 that they had developed a process by means of which they were able to achieve fidelity between the grating and replica, as far as spacing goes, within a very small fraction of a wavelength of light. Unfortunately the same replica may not be faithful in the shape and depth of the grooves. This essential problem, in addition to those already described, has therefore not yet been solved.

INDEX OF ADVERTISERS

OCTOBER, 1953

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful. The lists are not intended as bibliographies of source material for the articles. The references selected will provide supplementary information.

ALGAE AS FOOD

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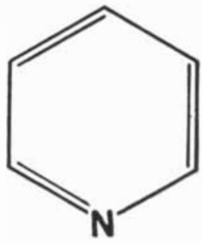

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