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May 1951

Bad News for Bugs

BUGS are in for the surprise of their lives. *They're going to zoom into allethrin, the new insecticide ingredient. It looks like especially bad news for many of the insects that pester you most.*

Take flies, mosquitoes and gnats . . . allethrin's paralyzing touch searches them out . . . delivers the blow that knocks them down fast . . . leaving its slower acting companion ingredients in the spray or powder to complete the kill.

Until now this type of insecticide came from flowers picked by the natives in Asia and Africa. But *allethrin is an all-American product,* synthesized under scientific controls and has the definite advantages over importations of uniformity in strength and quality.

It is only natural that the people of Union Carbide pioneered in the production of allethrin on a commercial scale. For they were already making most of the needed chemical ingredients.

As a result, the people of Union Carbide are already providing allethrin in ever-increasing quantities to manufacturers of household and dairy sprays. And researchers all over the country are now engaged in testing its value for the control of agricultural pests and for other purposes. Other Union Carbide chemicals are important ingredients in many other insecticides and fungicides. One or more of them may have a place in your future plans.

FREE: *Learn more about the interesting things you use every day. Write for the illustrated booklet "Products and Processes" which tells how science and industry use Union Carbide's Alloys, Chemicals, Carbons, Gases, and Plastics in creating things for you. Write for free booklet C.*

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More news from Chrysler Corporation

Engineering developments that improve the riding qualities of cars, military vehicles, trucks and railroad freight cars

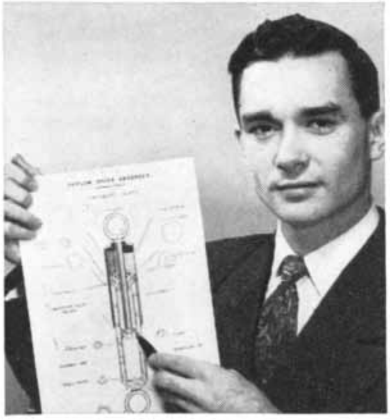
New uses of suspension are doing important things for wheel-borne transportation.

Cars that move along the highways, military vehicles that transport men and equipment, trucks that haul the products of farm and factory, and freight cars rolling on the railroads—all benefit from developments introduced by Chrysler scientific research and engineered production.

This M-37 cargo carrier, *built by Chrysler Corporation, can travel more rapidly and surely over rough country than our World War II cargo carriers. The ride is steadied for men and cargo by new suspension principles, improved springs and heavy-duty shock absorbers that provide extra cushioning power on bad roads and roadless terrain.*

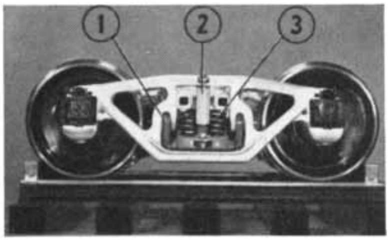
A new and softer ride is now incorporated in military design ambulances and trucks being built by Chrysler Corporation. Often a military ambulance must operate in rugged country where there are no roads. With improved suspension, special springing and new type shock absorbers, jolts and discomfort are minimized as never before.

Another important advance in riding comfort comes from Chrysler's "Oriflow" shock absorber, an exclusive feature on all our new Plymouth, Dodge, De Soto and Chrysler cars, on Dodge ½, ¾ and 1 ton trucks, and all Route Vans. It uses hydraulic principles in a new way to give cushioning power *three times* that of ordinary shock absorbers. On every kind of road, "Oriflow" works in harmony with synchronous springing, shockproof steering and scientific weight distribution to provide a smoother, safer ride.



In this drawing *of Chrysler's new "Oriflow" shock absorber, the engineer is pointing to one of the tubular passages through which cushioning fluid flows. This is a new use of hydraulic principles which helps "Oriflow" absorb bumps by controlling jounce and rebound more smoothly than any design used before.*

For railroad freight cars, which also require protection from shocks along the rails they travel, Chrysler engineers have developed a new "balanced suspension." It absorbs both vertical and lateral shocks gently, so that cargoes can ride steadier and safer.



In this accurate scale model *you see three reasons for smoother "ride." (1) swing hanger which soaks up shocks that come from jolting side motion. (2) unique friction snubber which works with (3) long travel coil springs to cushion vertical shocks and control bounce. Engineered by Chrysler, this mechanism is produced for railroads by qualified equipment manufacturers.*

On the highways, in the fields and on the rails, Chrysler Corporation's scientific developments and engineered production help meet the nation's military needs, and advance the safety, dependability and efficiency of wheel-borne transportation.

CHRYSLER CORPORATION

The Price of Success

What is it that brings one man success in life, and mediocrity or failure to his brother? It can't be mental capacity. There is not the difference in our mentalities that is indicated by the difference in performance.

The answer is, some men succeed because they cheerfully pay the price of success while others, though they claim ambition and a desire to succeed, are unwilling to pay that price.

The Price of Success is—

To use all your courage to force yourself to concentrate on the problem in hand; to think of it deeply and constantly; to study it from all angles, and to plan ahead.

To have a high and sustained determination to achieve what you plan to accomplish, not only when conditions are favorable to its accomplishment, but in spite of all adverse circumstances which may arise.

To refuse to believe that there are any circumstances sufficiently strong to defeat you in the accomplishment of your purpose.

Hard? Of course. That's why so many men never reach for success, yield instead to the siren call of the rut and remain on the beaten paths that are for beaten men. Nothing of note has ever been achieved without constant endeavor, some pain and ceaseless application of the lash of ambition.

That's the price of success. Every man should ask himself: *Am I willing to endure the pain of this struggle for the rewards and the glory that go with achievement? Or shall I accept the uneasy and inadequate contentment that comes with mediocrity?*

If you are willing to pay the price of success, the Alexander Hamilton Institute can help you chart your course and supply the knowledge of business fundamentals that is necessary for well-rounded executive competence.

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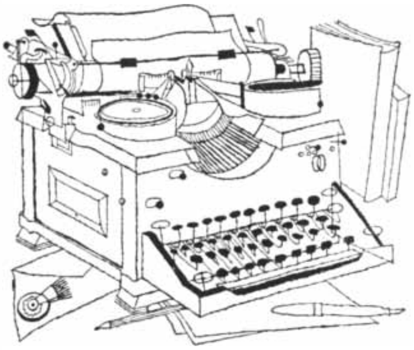

Sirs:

The intemperate attack on Professor Walter Gellhorn's scholarly book entitled *Security, Loyalty and Science* made in the letters department of your March issue by Dr. Mark Graubard of the Division of General Studies at the University of Minnesota should not go unanswered. As Chairman of the Special Committee appointed by the Council of the American Association for the Advancement of Science to bring in a report on Civil Liberties of Scientists, I had the privilege of working closely with Professor Gellhorn. My associates on the above Committee and I had the benefit of his assistance in the preparation of our report (available from the A.A.A.S. Washington Office in mimeographed form), and had ample opportunity to see the meticulousness of his approach to the problems of reconciling the needs for national security with the equally important need to protect the freedom of individuals, without which the name democracy is a sham and a delusion.

Today we face a world situation in which it will be very easy for any nation to become so frightened by the prospect of atomic, biological, chemical and conventional warfare that it might succumb to the siren songs of essentially authoritarian minorities leading its peoples to exchange freedom for apparent security.

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LETTERS

There are powerful groups in the U. S. and elsewhere who are stridently offering such a fraudulent exchange. Professor Gellhorn in his excellent book has warned us with factual material of the reality of the dangers and has shown how a rational man can solve the dilemma of security with freedom as far as science and scientists are concerned. Dr. Graubard has, on the other hand, shown us how unscientific a scientist can become when he deserts the scientific method in a vituperative attack on ideas to which he has become emotionally antagonistic, even when the ideas are those which grow directly out of the principles of the dignity and worth of the individual in a democratic society. Professor Gellhorn's book is an important document, so acclaimed by social and natural scientists alike, in large number and in vigorous language. Every reader of *Scientific American* should read the book to draw his own conclusions as to whether democracy or authoritarianism is the road for America to follow in its treatment of science and scientists.

MAURICE B. VISSCHER

The Medical School
University of Minnesota
Minneapolis, Minn.

Sirs:

Dr. Graubard's letter in your March issue concerning the review by I. I. Rabi of *Security, Loyalty and Science* by Walter Gellhorn is a perfect example of unscientific reasoning. . . .

His own certain assumption that war between the U.S.S.R. and the U. S. is an inevitable fact of the future leads him to value only one kind of conduct, that conduct which sacrifices all long-term goals such as democratic discussion to the short-term goal of preparation for war. His willingness to close discussion rather than develop it by a positive contribution is indicated by his implication that all those who disagree with him are fellow travelers, have "embraced the folklore of radicalism," or are "so sorely frustrated as to embrace philosophies of violent hate and resentment."

He appears to be confused as well. He accuses the scientists he is criticizing of "uncompromising hostility to existing conditions or their government" but is willing to include Mr. Acheson and the Administration among those he is criticizing. He accuses the scientists he is criticizing of "embracing philosophies of violent hate and resentment" yet uses emotionally loaded words and various

techniques designed to arouse the emotions of the reader against the scientists.

He is apparently unable to comprehend that the great need of our time is the more precise analysis of exactly what we mean by freedom of inquiry, freedom of speech and academic freedom. It is just because we have not sufficiently discussed these matters on a national scale that we are faced today with the possibility of their removal. It may well be that the fight of those interested in the future of science, education and democracy must be intensified, and that only out of a vigorous, forthright, cooperative battle for these values will a stable, legal conception be ultimately evolved. . . .

WILLIAM WEIFENBACH

Department of Philosophy
Kansas City University
Kansas City, Mo.

Sirs:

John Tyler Bonner's piece on the horn of the unicorn in your March, 1951, issue is very interesting but an oversimplification of the problem. The twisted horn, which can be found in pictures from the 15th century, is a comparatively late development, and while this was the preferred alicorn of the artists, just this horn—properly and unmistakably identified with the tusk of the narwhal—was not accepted by apothecaries and physicians.

There is a considerable amount of literature from that period which is devoted to a discussion of *unicornum verum* and *unicornum falsum*. Paulus Ludovicus Sachsius, for example, has written a whole book, *Monocerologia seu de genuinisunicornibus* (1676), in which the twisted horn, the narwhal tusk, is classified as *unicornum falsum*. Almost as soon as such twisted horns appeared on the market it also became known that they came from a marine creature of some kind. *Unicornum verum* was found in the soil, and descriptions, pictures and actual specimens leave no doubt that the "true alicorn" was a mammoth tusk. It is obvious that the very fact that such alicorn was suddenly found did a great deal to enhance the mystery which surrounded it from the outset.

In addition to "found" alicorn, which usually ended up in pharmacies, there existed some beakers of "alicorn" which were carved from the horn of the animal which, by virtue of being very dimly known, started the whole legend, namely the rhinoceros.

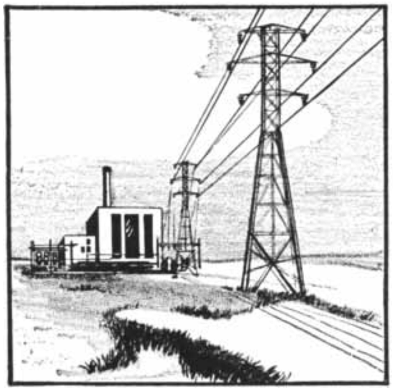
As Richard Ettinghausen ("Studies in Muslim Iconography, I. The Unicorn," Smithsonian Publication 3993; Washington, D. C., 1950) has shown recently, the alicorn of the Muslim world differed from that of the Christian world. They also warned that the wrong horn was

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Like other suppliers, Revere offers its metals in a wide variety of alloys. This is for the reason that no one metal or alloy is suitable for every purpose, for every requirement. In order to help solve the sometimes complex problems that arise concerning metal specification, fabrication, and use, Revere offers the services of its Technical Advisory Staff. Here is an example of its work.

When an electric utility was re-tubing a condenser, Revere Research had an opportunity to obtain samples of the tubes that were removed. A laboratory examination showed them to be made of an excellent alloy; let us call it "Alloy X," since the tubes were made by a competitor. This alloy is usually specified for conditions of erosion-corrosion, but our examination indicated that the tubes also were subject to severe attack by air entrainment and high-velocity, turbulent water. The Revere Technical Advisor, who inspected the condenser in person, suggested that longer tube life might be obtained if cupro-nickel in the 10% nickel alloy were used. As a test, 50 such tubes were installed alongside the new "Alloy X" tubes.



At the end of only three months, the utility was disturbed to find that some of the "Alloy X" tubes were beginning to fail. Samples were sent to Revere Research, which once again reported that these competitive tubes were good ones, mechanically and as to alloy. The Revere Technical Advisor immediately returned to the utility, where he spent two days and nights on the job, much of the time inside the condenser itself. He found the cupro-nickel tubes in fine condition. Recommendations included putting a perforated iron sheet in the water box to reduce turbulence and air entrainment, and the use of 10% cupro-nickel tubes throughout. These suggestions were followed.

Two years later the cupro-nickel tubes were inspected, and found to be in excellent condition. As a result, a new generating station of the company was equipped with them.

Please note our statement that the tubes made by a competitor were all right as tubes. If Revere Tubes in the same alloy had been installed there, the same trouble would have been experienced. It was natural enough for the utility to blame the tubes, but Revere knows that if condenser tubes do not give long and economical service the fault most probably lies in the selection of an alloy unsuitable for operating conditions. In many cases, as in this one, Revere has been able to suggest changes in alloy or in operation, or both, bringing about important economies for users of condensers.

What Revere does in this way is not unique by any means. Suppliers in every industry do as much for their prospects and customers, every day in the week. They do it gladly, because a happy, satisfied customer is a precious asset. So we suggest that no matter what your business is, no matter what you buy, nor from whom, you take your suppliers into the closest possible confidence, permitting them to learn all they can about the conditions their materials have to meet. This will cost you nothing, and may save you much.

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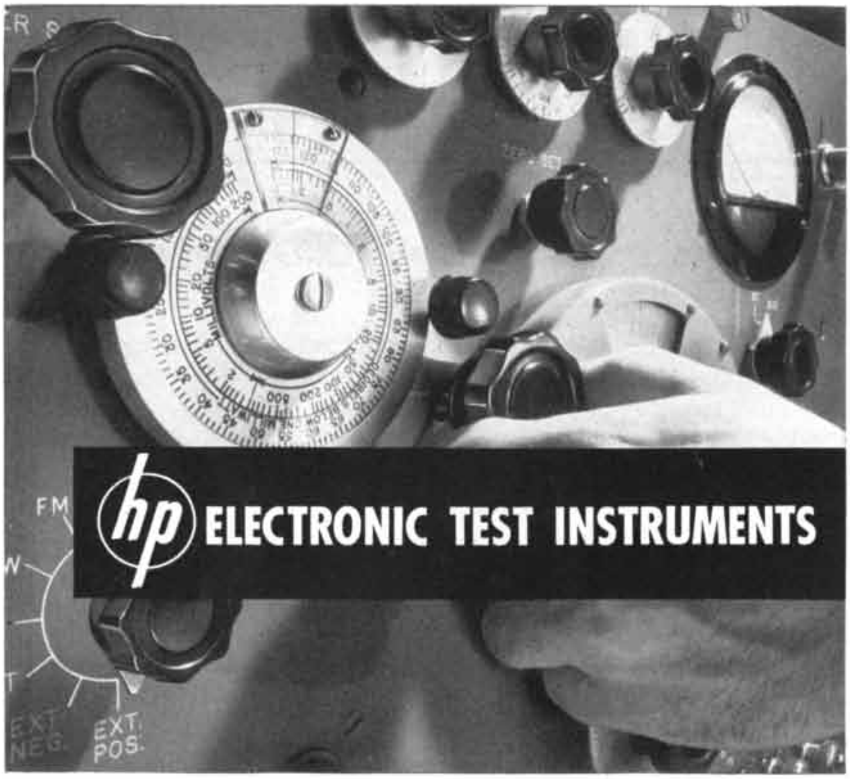

occasionally sold, but to them the "true" horn was the tusk of the walrus.

WILLY LEY

Jackson Heights, N. Y.

Sirs:

I read with interest your article on color blindness in the March *Scientific American.*

I have observed an additional fact which may have some bearing on the subject. Among a large class of elementary physics students who were experimenting on the use of the spectroscope, there was a large variation in the range of wavelengths to which individual students were sensitive, even when they were normal by the ordinary yarn tests. Several could see the lithium red line but could not see the potassium red line. At the other end of the spectrum several could see the 3,650 Angstrom group of lines in the mercury arc spectrum quite easily, but a majority could not see them at all. Those who could see the 3,650 lines all reported that they looked blue rather than purple, unlike the lines near 4,000 Angstroms.

WALTER HUGHES

Ojai, Calif.

Sirs:

Mr. Hughes is quite correct in his observation that people differ markedly in their sensitivity to the extremes of the spectrum. Gibson and Tyndall (Gibson, K. S., and Tyndall, E.P.T. "Visibility of Radiant Energy," *Scientific Papers of the Bureau of Standards,* 1923, 19, No. 475) compared 52 normal observers and found quite a lot of variability. Interestingly enough, there seemed to be more variability to wavelengths in the long wavelength end of the spectrum than to those in the short wavelength region. Crittenden and Richmyer (Crittenden, E.C., and Richmyer, F.K. "An 'Average Eye' for Heterochromatic Photometry, and a Comparison of a Flicker and an Equality-of-Brightness Photometer." *Transactions of the Illuminating Engineering Society,* 1916, Volume 11, Pages 331-356) had 114 observers compare the luminosities of yellow and blue lights. Here again there were sizable differences.

I have just recently completed a study of the variability among color-blind and normal observers to the long wavelength end of the spectrum, but have not published it yet.

ALPHONSE CHAPANIS

Department of Psychology
The Johns Hopkins University
Baltimore, Md.

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- **GREATER ACCURACY:** The single-beam principle eliminates problems of making a beam attenuator achromatic, linear and free of vignetting effects.
- **MINIMUM STRAY LIGHT:** Only these single beam instruments use a filter-type beam chopper, reducing stray light effects to a minimum (less than 2% at 15 microns with the IR-2).
- **MINIMUM SCANNING TIME:** Optimum recording efficiency is achieved because each spectral slit width is traversed in a time proportional to the response period of the recording system. Any other scanning rate loses either resolution, time or accuracy.
- **MAXIMUM RESOLUTION:** Slit width control has the advantage that the instrument is always working at maximum resolution for the chosen amplification and scanning speed.
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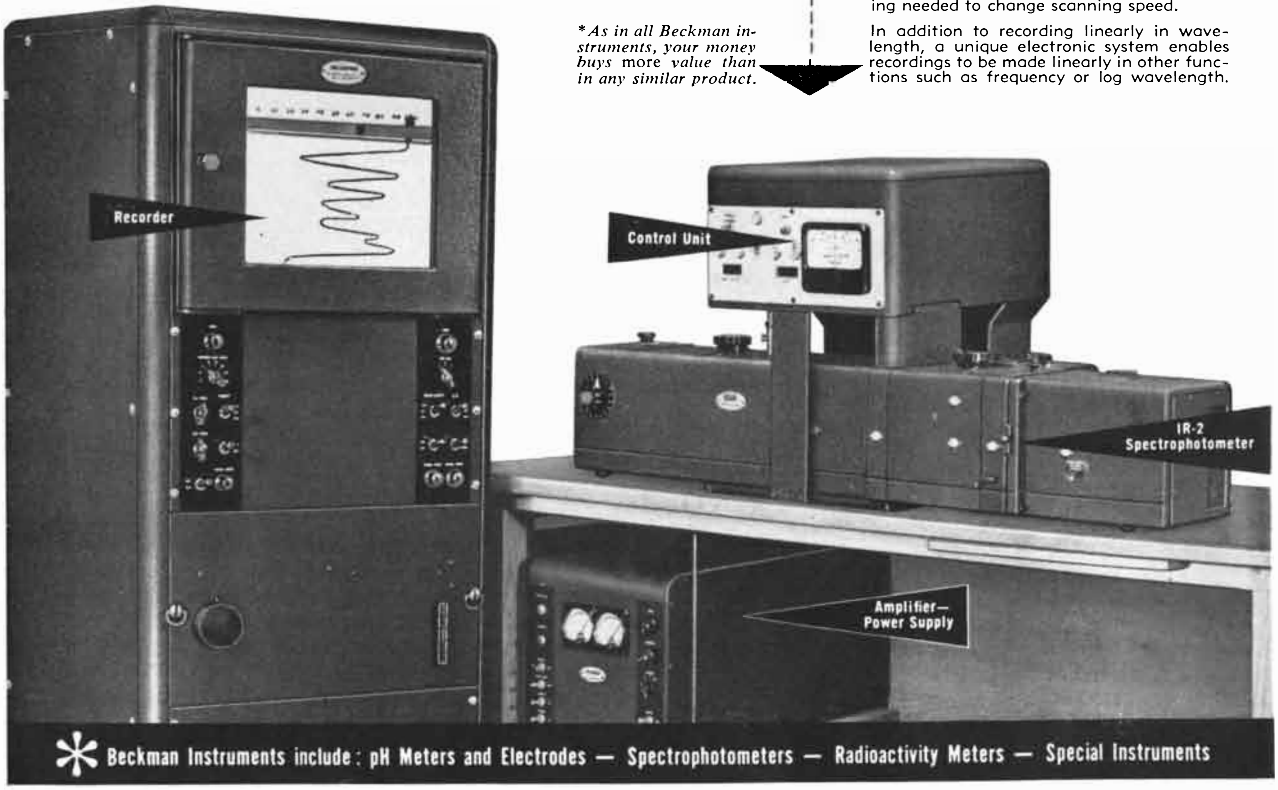
In addition to recording linearly in wavelength, a unique electronic system enables recordings to be made linearly in other functions such as frequency or log wavelength.



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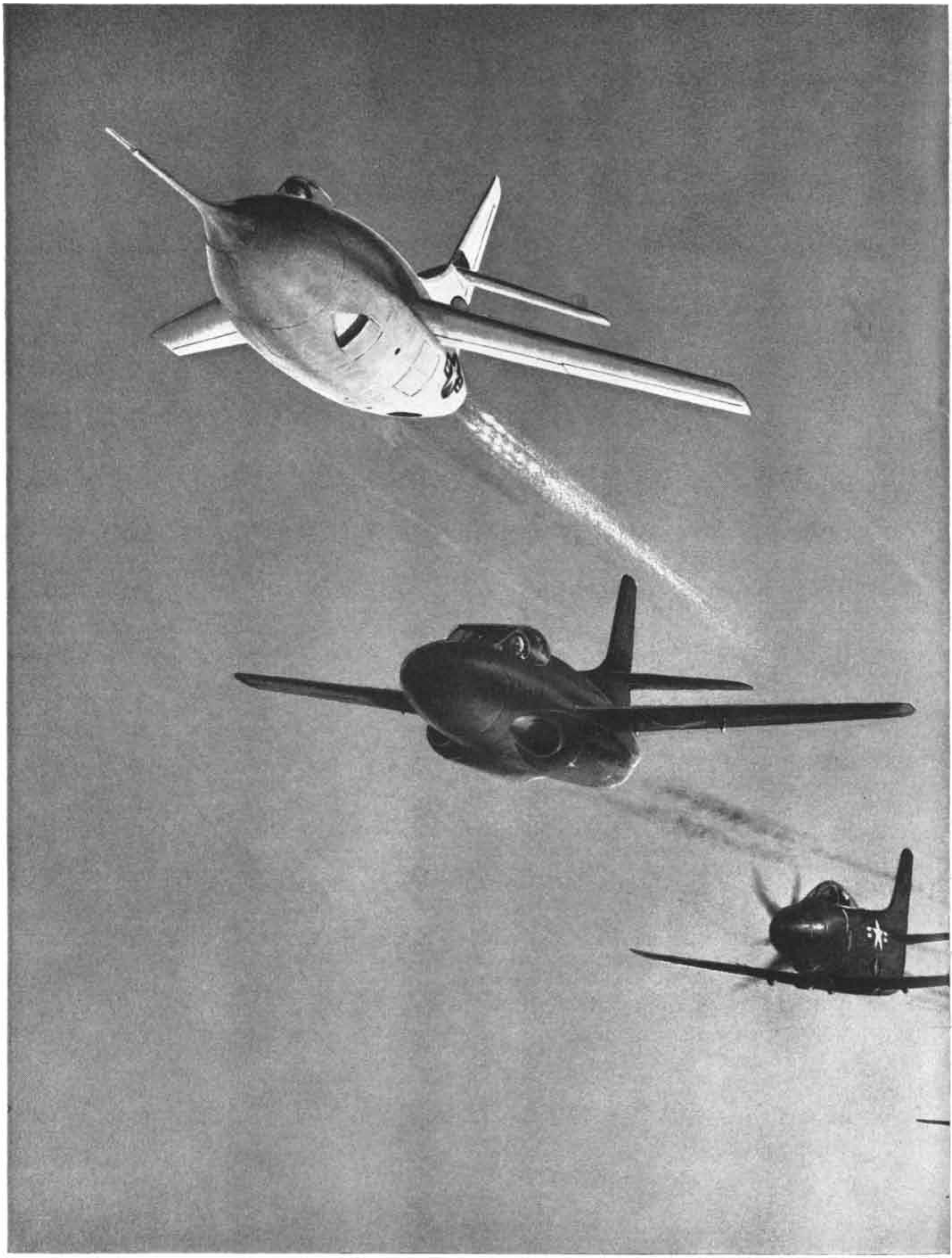

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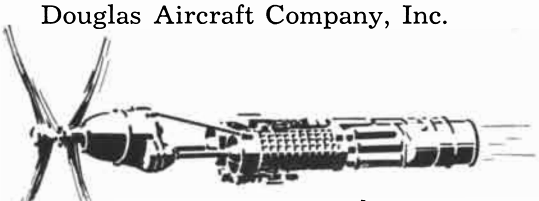
Best known of these Big Four is the AD-Skyraider. This reciprocating-engined attack bomber has been in production since 1946, and is now a battle-tested veteran after years of service with the Fleet.

In 1950 the twin-jet F3D Skyknight was started down the production line at El Segundo, following enthusiastic reports from Navy test pilots.

Now being flight tested in preparation for line production is the A2D Skyshark, turbo-prop attack plane. And above Edwards Air Base the rocket-powered D-558-2 Skyrocket is thrusting its needle-nose into the thin air, looking for scientific data that will help build newer type aircraft still in the classified status.

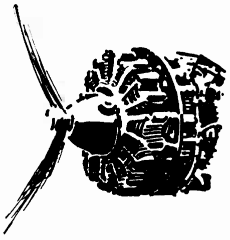
By carefully manipulating the design, development and production of these diverse power types, the Navy and Douglas have arrived at a flexible, “balanced power” position from which our air strength can be increased without delay. Douglas Aircraft Company, Inc.

ROCKET ENGINE delivers supersonic speed for Douglas “Skyrocket” (top).



TURBO-PROP ENGINE combines speed and endurance for Douglas A2D “Skyshark” (third).

TWIN-JET ENGINE gives pure jet thrust for Douglas F3D “Skyknight” (second).



RECIPROCATING ENGINE provides work-horse efficiency for Douglas AD “Skyraider” (bottom).

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50 AND 100 YEARS AGO

MAY 1901. "It is now generally agreed that Prout's law, that the atomic weights of the elements are exact multiples of the atomic weight of hydrogen, is decisively contradicted by experiment. The case of chlorine, whose atomic weight is 35.455, is in itself conclusive so far as the supposed law is concerned. But, as pointed out by R. J. Strutt, there remains the fact that many of the atomic weights approximate very closely to whole numbers, so much so as to suggest strongly that some law of nature is in question. Taking the nine best-known atomic weights—*viz.*, bromine, 79.955; carbon, 12.001; chlorine, 35.455; hydrogen, 1.0075; nitrogen, 14.045; oxygen, 16.000 (standard); potassium, 39.140; sodium, 23.050; and sulphur, 32.065—the sum of the deviations from the nearest integral number is 0.809, or about 0.1 for each element. The probability of that occurring by chance is about 1 in 1,000, so that we have 'stronger reasons for believing in the truth of some modification of Prout's law than in that of many historical events which are universally accepted as unquestionable.' "

"Dr. S. P. Langley's report of the Smithsonian Institution for the year ending December 30, 1900, has been made public. The Institution has continued research work in various fields of science, including experiments in the solution of the problem of mechanical flight, and, through its Astrophysical Observatory, investigation on the solar spectrum. The Institution has made some interesting experiments during the year on 'radioactive substances.' The income of the Hodgkins Fund is devoted to investigations of the properties of air."

"If Prof. J. J. Thomson's corpuscular hypothesis be absolutely demonstrated, our ideas in regard to chemistry will be revolutionized. In a recent lecture before the Royal Institution he selected as his subject 'The Existence of Bodies Smaller than Atoms.' He briefly referred to work which had been done by others in theory and practice, in order to determine the size of an atom. One method of doing this was by ascertaining the charge of electricity which an atom carried during the process of electrolysis, and from the charge to calculate the mass. The experiments of the lecturer were made with the view of ascertaining the mass of small particles which carry an electric discharge through attenuated gases. The next experiment was made with the object of ascertaining the mass of all the particles used to carry the charge and also their number. For this purpose some of the experiments of Mr. Wilson on the sudden expansion of a gas saturated with moisture were used. Prof. Thomson concluded that the small particles carrying the charges of electricity were only one-thousandth of the size of an atom. These experiments were all made with discharges of negative electricity. It was also found that these small particles negatively charged were given off from incandescent matter and from radium. When he first enumerated his theory to the scientific world three or four years ago, it was received with considerable incredulity, but has now been adopted by many scientists. He regards the chemical atom as made up of a large number of similar bodies which he calls 'corpuscles.' A normal atom forms a system which is electrically neutral. The electrification of a gas consists in the breaking off from the atoms of a few corpuscles."

MAY 1851. "We have just had the pleasure of seeing a present sent by the King of Prussia to our countryman, Prof. Morse, in acknowledgement of his success in perfecting his Electro-Magnetic Telegraph, which is pronounced by his Majesty's Commissioner, after comparison and experiment, to be the most efficient of any in the world for great distances."

"Iron is the most abundant metallic mineral our country affords. The most valuable mine is one in Salisbury, Conn., which yields 3,000 tons annually. In Ohio, 1,200 square miles are underlaid with iron. A region explored in 1838 would contain 1,000,000,000 tons. By taking from this region 400,000 tons annually (a larger quantity than England produced previous to 1829), it would last 2,700 years—as long a distance, certainly, as any man looks ahead!"

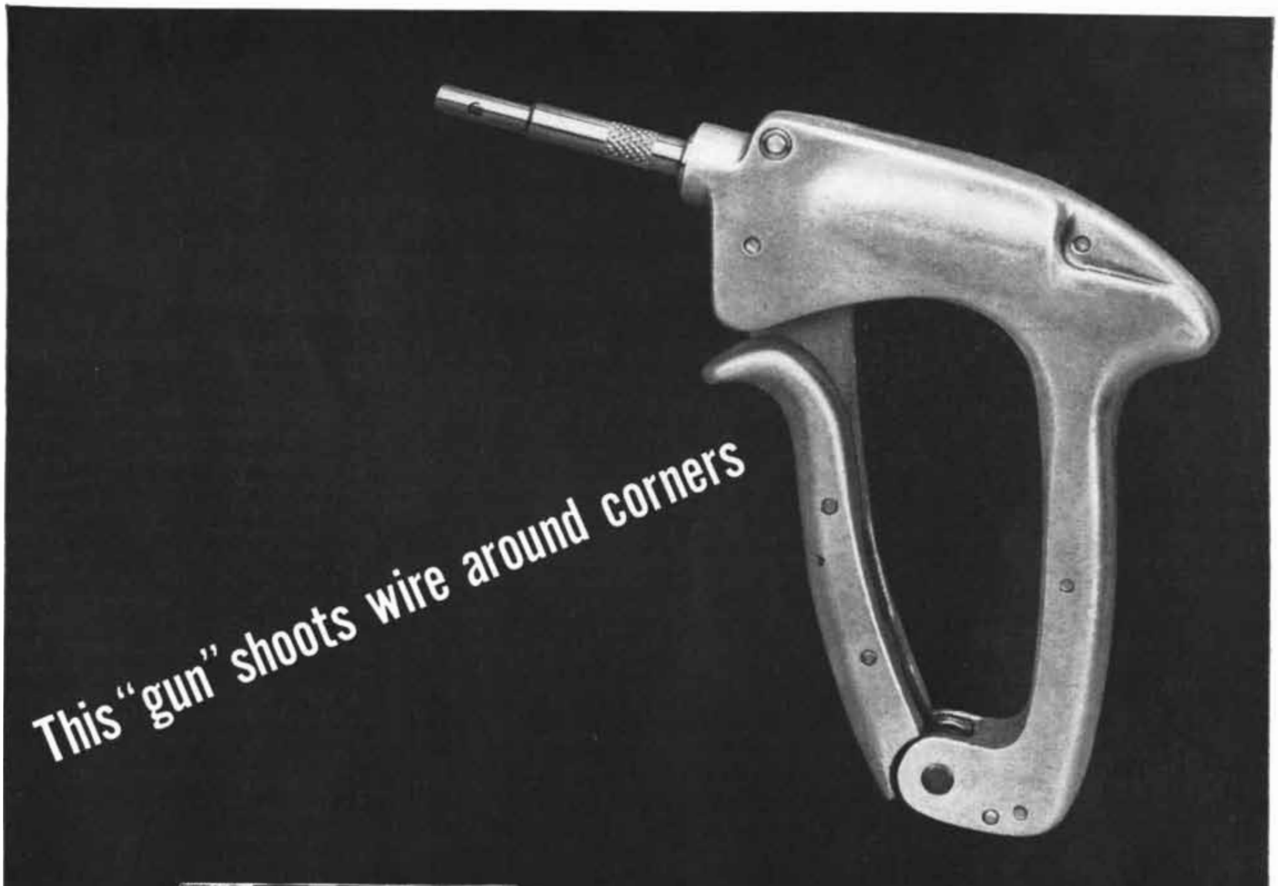
"In a paper presented to the French Academy of Sciences—'On the rapidity of the propagation of the nervous agency in the spinal nerves'—Helmholtz described at length some experiments of his, from which he concludes that the nervous irritation passed over a space of 50 to 60 millimeters (about two inches) in from .0014 to .0020 of a second."

"A patent has been granted to Linus Yale, Jr., of Newport, N. Y., for an improved lock and key."

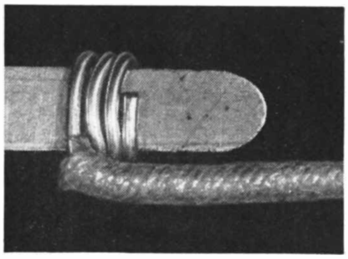
"Although much has been recently said and written about the application of electro-magnetism as a prime mover, it is not a new subject by any means. Our own Prof. Henry, now of the Smithsonian Institution, first demonstrated the method of developing great magnetic power in soft iron by a small battery, and as a natural result he applied it to propel machinery. Among the many successful investigators and experimenters in electro-magnetic science, the name of Prof. Page stands high; and his recent experiment with an electro-magnetic locomotive at Washington, is the greatest effort of the kind ever made. It makes no matter how much mechanical power may be developed by electro-magnetism, if that power is derived at too great an expense to compete with steam."

"The American Association for the Advancement of Science met at Cincinnati on April 5, and adjourned on April 10. The people of Cincinnati exhibited to the members the noblest hospitality; we hope the people of Albany, N. Y., where the next meeting of the Association is to be held, will not forget this. Prof. Bache, of Washington, presided. The meeting was opened with a prayer by the Rev. Mr. Fisher, and there was a goodly attendance of members. Among the many curious papers read was an address by Prof. Pierce, of Harvard, respecting the ring of the planet Saturn. Prof. Agassiz read a most interesting paper on the coral reefs of Florida, which he had been exploring last winter."

"We learn that Mr. James Young, of Manchester, England, has taken out a patent in England for a new discovery in the treatment of coal, which consists in a peculiar method of treating bituminous coal, and obtaining *parafine oil.* This parafine is very valuable for lubricating purposes. This is certainly a new process, and shows how our coal fields may be turned into oil &c. It is, however, too expensive to compete with our other oils at present prices."



Bell Telephone Company craftsman wraps a wire to complete a connection. Wire is inserted into the nozzle and a rotating spindle whips it around terminals.



Close-up of connection made with new tool—neat, tight windings.

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Now this job is done much more efficiently with a new wire wrapping tool invented at Bell Telephone Laboratories. This "gun" whirls wire tightly around terminals before solder is applied. The connection is better and there is no excess wire to be clipped off — perhaps to drop among a maze of connections and cause trouble later.

The new tool is being developed in different forms for specialized uses. The hand-operated wrapper in the illustration is for the telephone man's tool kit. Power-driven wrappers developed by Western Electric, manufacturing unit of the Bell System, are speeding the production of telephone equipment. The gun's small nozzle reaches where fingers couldn't — a big advantage these days when efforts are being made to produce telephone system parts smaller as well as better.

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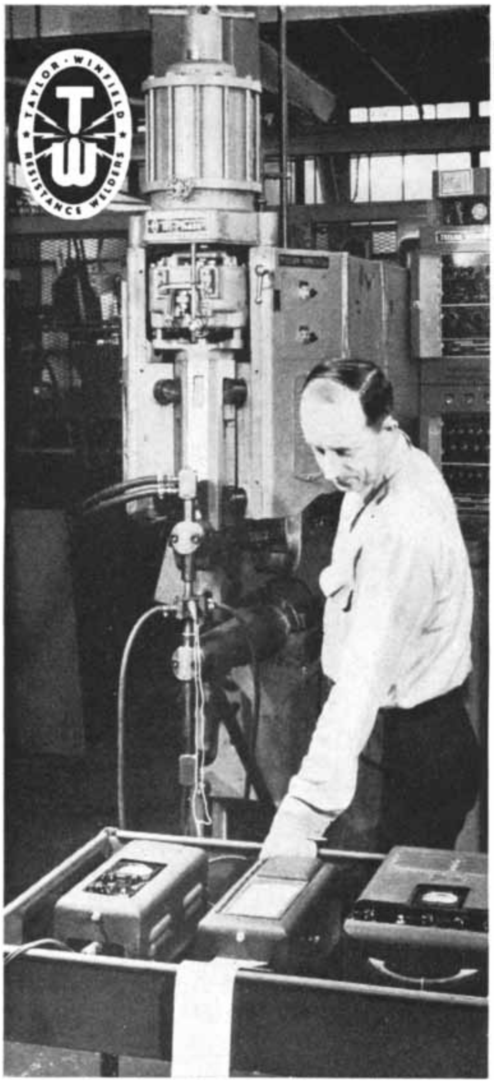

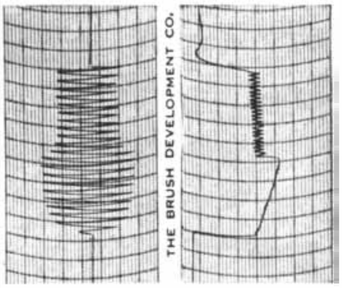

Chart of welding cycle on Taylor Winfield welder shows 60-cycle A-c input current at left, D-c welding current at right. This Brush Analyzer consists of A-c amplifier, D-c amplifier, direct-writing oscillograph.

welding specifications a problem?

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THE COVER

The painting on the cover shows the apparatus required for a typical experiment in the reactivation of microorganisms by light (*see page 22*). At the right is a beaker containing water at constant temperature; immersed in it are a heating element, a thermostat and a stirrer. At the surface of the water near the left side of the beaker is a small glass receptacle containing *Streptomyces griseus*, the microorganism that manufactures the antibiotic drug streptomycin. On this is focused a narrow beam of monochromatic light, cooled by the flask of water at the left. The purpose of the experiment: to study the effect of light on microorganisms that have apparently been killed with ultraviolet radiation. One result of such experiments is to show that these microorganisms are reactivated by light.

THE ILLUSTRATIONS

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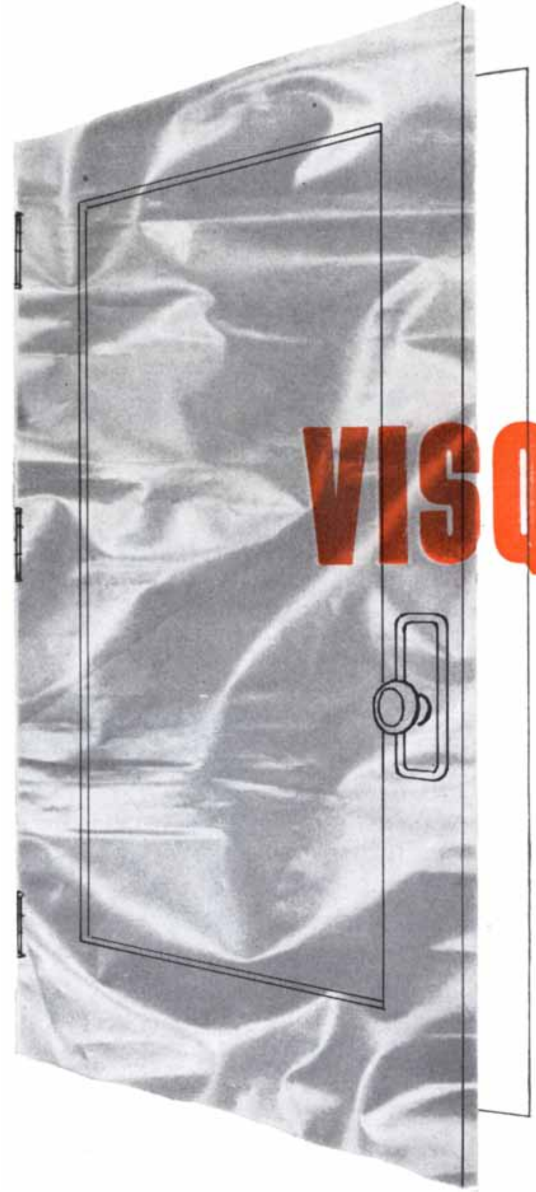

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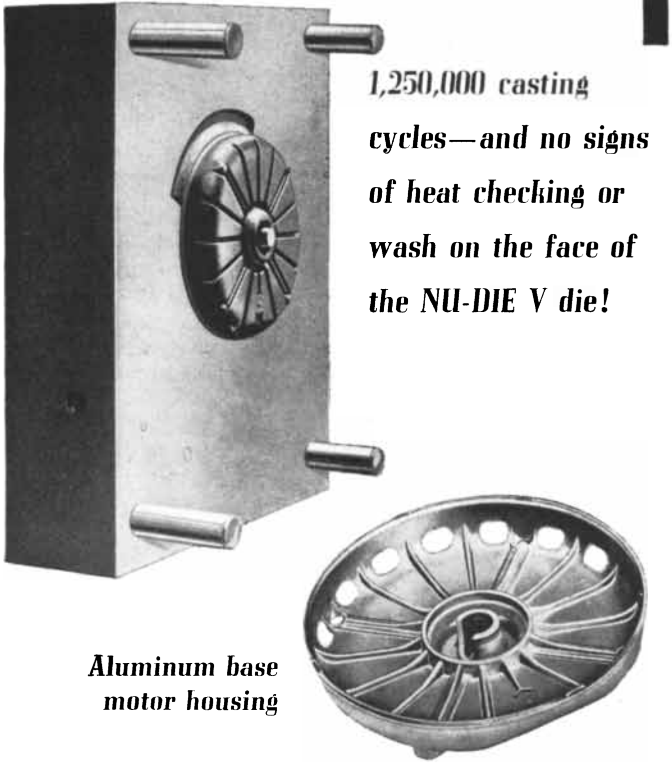

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MAY 1951 VOL. 184, NO. 5

The Earth's Uranium

It is fairly common, yet it occurs in few concentrations that can profitably be mined. A brief summary of the most important deposits, including some that have only recently been revealed

by Paul F. Kerr

THE most important sources of uranium in the world are the Shinkolobwe mine in the Belgian Congo, two mines in northwest Canada, the Erz Mountains on the boundary between Czechoslovakia and East Germany and the Colorado Plateau in the U. S. Two years ago the latter area was not considered in the same class with the first three. But intensive prospecting and new geological knowledge have greatly increased our known resources. Today the U. S. production of uranium is an important factor in the world supply.

Uranium is a fairly common element, present almost everywhere in the earth's crust. The problem is to find it in concentrations that make it worth while to try to mine it. It has been suggested that we could get 70 tons of uranium from every cubic mile of sea water. This sounds impressive until one makes a simple calculation and finds that a cubic mile of sea water weighs about four billion tons—70 tons of uranium in that bulk of "ore" amounts to about one part in 60 million. There are many rock masses in the earth with a uranium content of one part in 10,000, but even this concentration is considered much too thin for mining by present methods. To interest mining engineers a deposit must have a uranium content of at least one part in a few hundred; that is, at least several pounds of uranium per ton of ore.

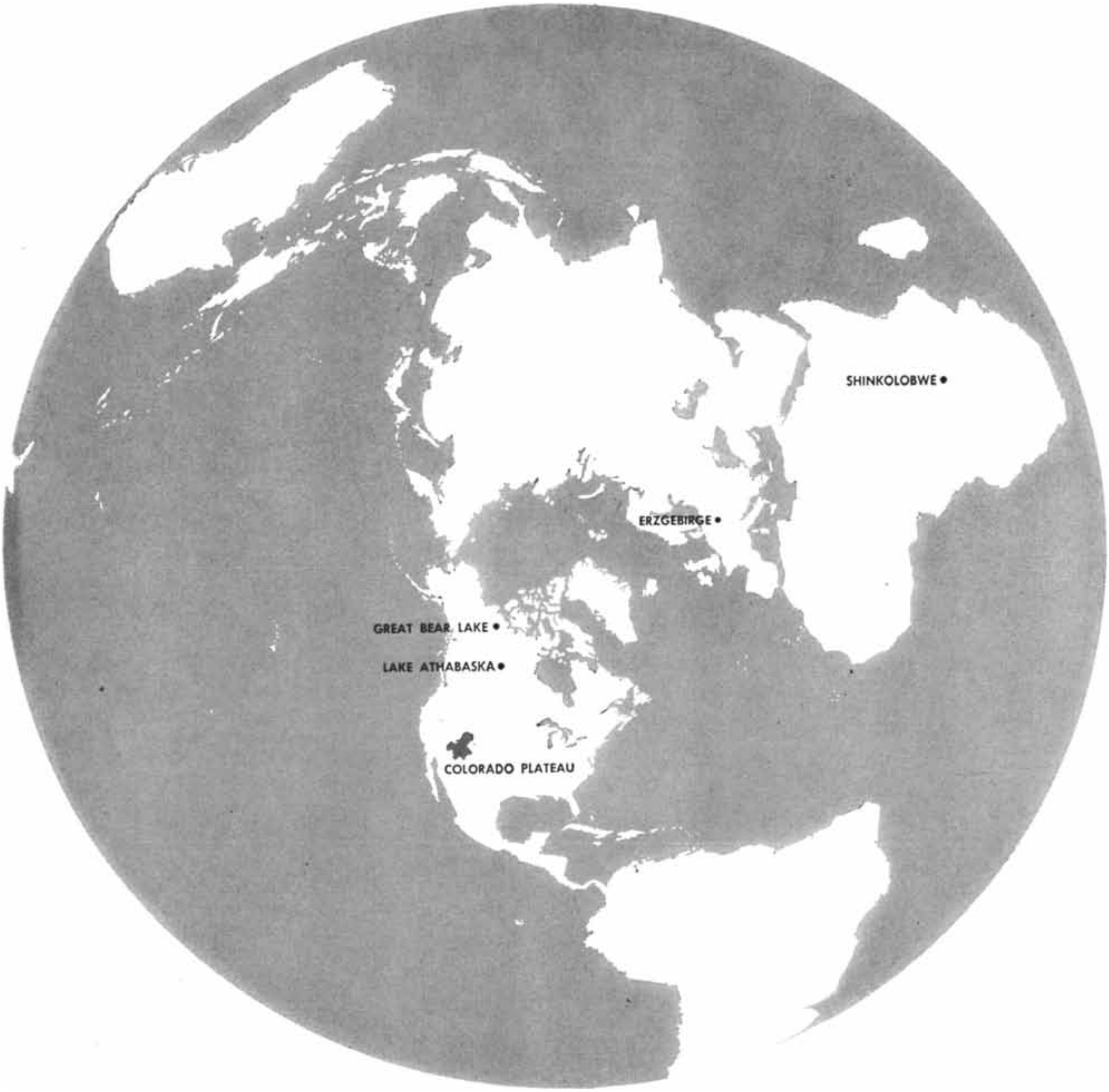
There are more than 80 known minerals that contain substantial amounts of uranium, but less than a dozen are at all abundant in the earth. The richest mineral is uraninite, a combination of uranium dioxide (UO_2) and trioxide (UO_3). This exists in black powdery and solid crystalline forms. Pitchblende is a variety of uraninite. Usually uraninite occurs in relatively deep deposits. The other important uranium minerals ordinarily are found near the earth surface. They are carnotite, a canary-yellow powder in which uranium is combined with potassium and vanadium; torbernite, a green crystal phosphate of uranium and copper; autunite, a yellow crystal phosphate of uranium and calcium; tyuyamunite, a yellow powder containing uranium, calcium and vanadium; thucholite, a black organic material in which uranium is combined with a hydrocarbon, and kolm, another uranium-hydrocarbon combination.

Carnotite is the most common uranium mineral in the Colorado Plateau. Torbernite is found in large masses near the surface in the Belgian Congo, where the richest deposits of uraninite are located. Good deposits of autunite are found in Portugal. Tyuyamunite is named for a city in a region of the U.S.S.R. where it is particularly abundant.

In looking around the world for likely sources of uranium minerals the geologist has certain general principles to guide him. He will look, of course, to faults, fissures and pockets in the earth's crust, where minerals in general are concentrated, and he will search for chemical and physical conditions that particularly favor the precipitation of uranium. He knows that concentrations of uranium often occur in veins cutting the granitic igneous rocks. Uranium (with its companion radium) tends to be associated in veins with certain other minerals, notably cobalt, nickel, bismuth and a few others, including small amounts of silver and gold. During the recent worldwide hunt for uranium another apparently significant fact has emerged: many of the uranium deposits have been found in ancient Pre-Cambrian rocks. It is believed to be more than a coincidence that the chief uranium locations in the Belgian Congo, the Erz Mountains, Canada, eastern Colorado and at several other places are all in Pre-Cambrian formations.

We can see the uranium picture most conveniently by reviewing briefly the history of each of the principal locations.

THE town of Joachimsthal in the Erz Mountains has been a mining center since the 15th century. For centuries the only metal mined was silver. The American word "dollar" is derived from the name of silver coins struck there, first called *Joachimsthaler* and later abbreviated to *thaler*. In the middle of the 19th century the element uranium was discovered in the Joachimsthal ores, but the only use then found for it was as a pigment for porcelain and glass. When in 1898 the Curies isolated radium, a product of the radioactive decay of uranium, from the uranium residues of Joachimsthal, the mines rose in importance; for many years they were the world's sole source of radium. Up to



THE FOUR MOST IMPORTANT uranium regions are in northwestern Canada, the western U. S., the southern Belgian Congo and the Erz Mountains, or Erzgebirge, of Czechoslovakia and the Russian zone of Germany.

World War II they had yielded a total of 100 grams of radium.

The uranium-bearing formations of the Erz Mountains lie along two mountain belts which intersect at Joachimsthal. The mountains, once the boundary between Saxony and Bohemia, now are on the border between the Russian zone of Germany and Czechoslovakia. The principal uranium mineral in these deposits is uraninite. It lies in veins ranging from less than an inch to several feet in thickness. The veins also contain minerals of silver, cobalt, nickel and bismuth. They represent old fissures in the earth's crust that were partly filled by the precipitation of metallic minerals from ascending solutions. The wall rock consists of recrystallized sediments of Pre-Cambrian age.

Uranium is reported as U_3O_8. The total amount of U_3O_8 mined in the Erzgebirge region up to 1940 is estimated at 690 tons. We can only guess at how much the Russians may have obtained from their intensive mining of the area since the end of the war. In all likelihood the amount is at least several hundred tons.

To estimate the total extent of the uranium resources available to the U.S.S.R. we must extrapolate from what was known about them before 1944, for little information has been revealed from behind the Iron Curtain since that time. The principal uranium deposits in the U.S.S.R. before 1944 were considered to lie in the black shales and slates of the desert area of Asiatic Russia between Lake Balkhash and the Afghanistan border. This is the region where the mineral known as tyuyamunite is found. The Alai Range in the same general area also is reported to possess large amounts of black shales or slates containing on the order of a pound of uranium per ton of rock, but the labor required to work these deposits would be great indeed. Near-surface deposits of a uranium mineral are known to exist in Bulgaria. In addition the U.S.S.R. was known to possess scattered deposits of uranium minerals such as occur in other parts of the world; probably these are numerous enough to yield significant quantities of fissionable material.

According to press accounts some 3,000 geologists are exploring for uranium in the U.S.S.R. It must be assumed that they have made considerable progress. Whether the state-operated Soviet effort will ultimately produce more and cheaper uranium than will the cooperative efforts of government and private industry in the U. S., time alone will tell. But if any credence may be placed in the newspaper reports that hundreds of thousands of Russian workers are engaged in mining and hunting uranium, with digging and prospecting going on in 230 locations in eastern Germany alone, we may well conclude that the present uranium production available to the U.S.S.R. is seriously large.

OUR first source of supply is the Shinkolobwe mine in the Belgian Congo. Shinkolobwe is in the heart of Africa, about midway between the continent's east and west coasts and near the southern margin of the Congo Basin about 11 degrees south of the Equator. It lies in the center of a great mineral province long famous for its production of copper, cobalt, tin and diamonds; the province produces most of the world's industrial diamonds and leads the world in the production of cobalt.

In 1915 a Major Sharp, prospecting for minerals as an employee of the Tanganyika Concession, noticed some unusual bright yellow fragments of rock in the soil at Shinkolobwe. Analysis showed that they were rich in uranium. The concessionaires dug trenches and soon exposed veins of black uraninite. Later explorations disclosed masses of rock containing the highest percentages of uranium found anywhere. Near the surface above these veins lie brightly colored uranium minerals—yellow, orange or green—some of which have been found nowhere else in the world.

The Shinkolobwe area is one in which Pre-Cambrian rocks of varying ages are exposed at the surface. Curiously, in some places an older Pre-Cambrian rock lies on top of a younger; the layers apparently were overturned by faulting and deformation of the crust. It is in the older rock that the most important uranium deposits have been found. How the uraninite was deposited in this rock is a matter of conjecture. Originally the uranium came from deep in the earth crust. It rose in heated solutions and was deposited in spaces in the shattered rock of the old Pre-Cambrian strata as uraninite. The deformation that thrust the old layer upward then raised the veins of uraninite close to the surface. Some such explanation seems necessary to ac-

URANIUM PROSPECTORS' ROADS make a distant network in the hills near Marysvale, Utah. Veins of uraninite have been found in this region.

"HAPPY JACK" URANIUM PROSPECT is in the rugged country of southeastern Utah. In this region the uraninite is found not in veins but in strata.

count for the emergence of so rich a concentration of uranium at Shinkolobwe—unmatched, as far as we know, anywhere else on the surface of the earth.

THE uranium deposits of Canada are in another great area of exposed Pre-Cambrian rocks, but in this case the ancient rocks have been laid bare by erosion of the younger rocks that covered them. Anyone who flies over the Canadian Shield can hardly fail to be impressed by the great number of scattered lakes, seemingly always extending to the horizon. The land areas between the lakes have been so swept by the great ice sheet which once covered the entire area that when viewed from the air they appear to have been planed. The surface is furrowed, however, with a network of fault lines that show up in the topography as long narrow depressions filled with trees, bushes and muskeg. It is along such fault lines or other fractures parallel to them that the Canadian uranium deposits were found and much of the uranium prospecting in the northland has been carried on of late.

The original Eldorado deposit was discovered in 1930 by the Canadian prospector Gilbert LaBine. On the east shore of Great Bear Lake, in a wilderness only a short distance south of the Arctic Circle, he spotted from the air a vein which proved to contain uraninite. It was later traced for several thousand feet and found to belong to a group of five neighboring veins. The original vein, named "No. 1," in places is as much as 30 feet thick.

Intensive mining began during the war, when the need for uranium for the Manhattan Project developed. Since the Eldorado mine is 1,380 miles by boat and 800 miles by air from the nearest railhead in the province of Alberta, transportation is a problem. The uranium oxide is shipped to the railhead over a circuitous route by way of several lakes and rivers. The Eldorado Mining and Refining Company, Ltd., operator of the mine, also runs its own airline from Eldorado to Edmonton. The company is controlled by the Canadian Government.

Since the end of the war the great Canadian Shield has been extensively prospected. Uranium has been found at various places in a zone which extends from Great Bear Lake southward through Great Slave Lake and Lake Athabaska and finally eastward along the northern shore of Lake Superior. Near the eastern arm of Lake Athabaska the Eldorado Company has recently found a group of veins along what is known as the St. Louis fault. On the basis of extensive drilling and tunneling into the shattered rock the engineers have concluded that this deposit will yield an amount of uranium comparable to that from the Eldorado site. It is expected to begin producing before the end of this year.

IN the U. S. the main center of prospecting has been the Colorado Plateau, which covers parts of the four states of Colorado, Utah, Arizona and New Mexico. The ore here, as we have noted, is carnotite, a vanadate of potassium and uranium. It occurs in old sandstones formed in what seems once to have been a shallow fresh-water sea. The sandstone contains a great many fossil logs and other plant remains. In some of the logs carnotite has replaced part of the original material. One such log, four feet thick and 100 feet long, yielded 105 tons of uranium-vanadium-radium ore. The market value of this log at the time it was mined is reported to have been about $230,000.

The logs and other vegetable matter appear to have been important factors in the accumulation of the concentrations of uranium and vanadium. Presumably the organic matter played a part in the chemical reduction and precipitation from solutions of dissolved salts containing uranium.

Deposits of carnotite underlie large areas in Colorado, Utah, Arizona and New Mexico. The U. S. sources of uranium are not restricted to carnotite. Near Marysvale, Utah, significant veins of uraninite have been found. Another encouraging discovery of uranium ore has recently been made at the old Sunshine silver mine in the Coeur d'Alene district of Idaho. There are also promising veins bearing uranium in the granitic rocks of western Montana. The Pre-Cambrian formations of the northern Michigan Peninsula have shown possibilities, but no workable deposits as yet.

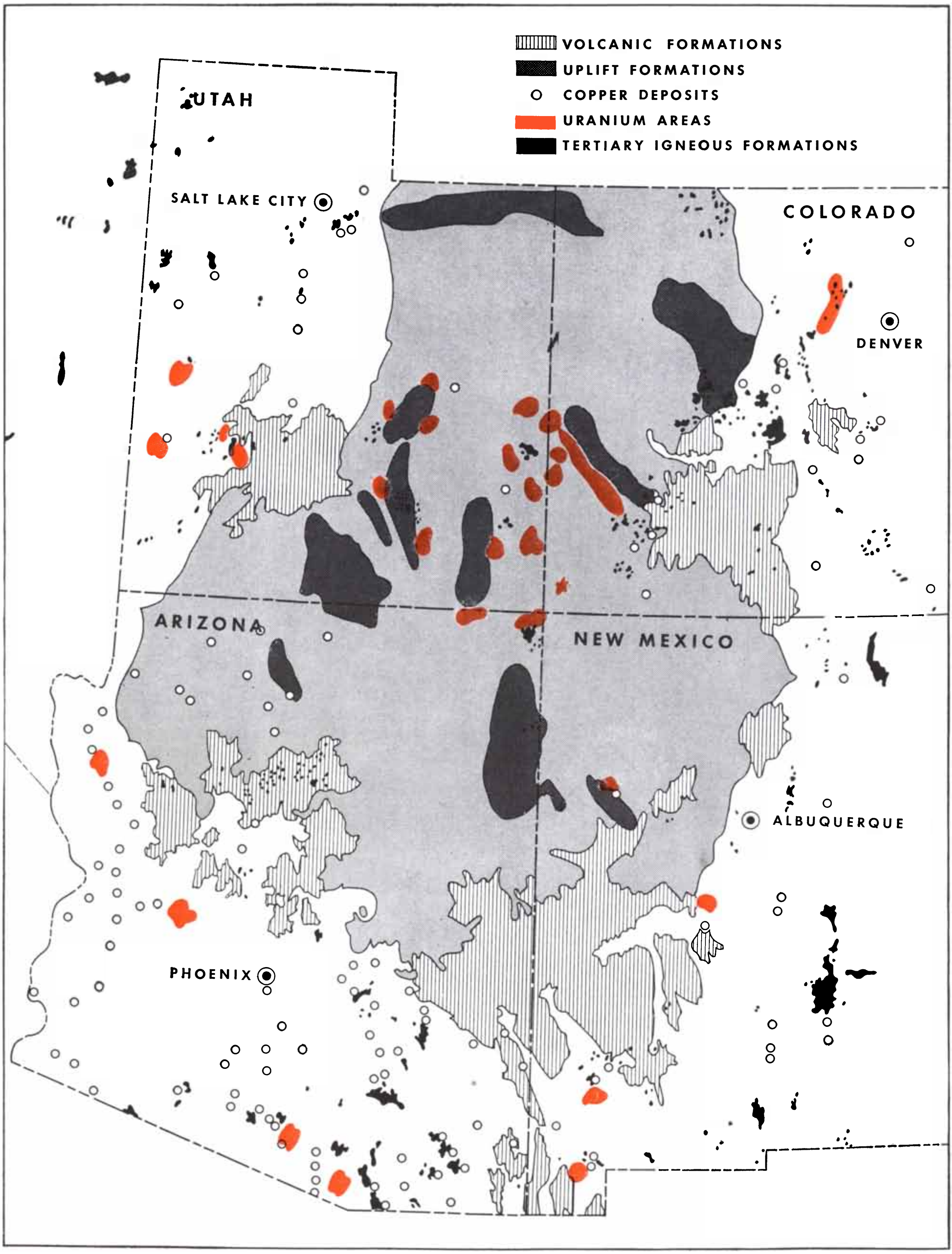
Throughout much of the western U. S. an army of prospectors is searching for uranium with an enthusiasm that must be witnessed to be appreciated. The "uranium rush" is producing new types of prospectors. Radio technicians, businessmen and people of many other occupations who have never had any interest in mining have equipped themselves with Geiger counters and assailed the hills in search of radioactive rocks. They have reported many usable prospects, and some of these are already being mined. One interesting deposit was discovered accidentally by a plumber on a picnic. He was amusing himself with a portable Geiger counter and happened on some loose rocks that showed unusual radioactivity. He then traced the rocks to the uranium deposit. An attractive feature of uranium-hunting is that it can be carried on with little more equipment than a Geiger counter; anyone can be a prospector, even if he does not know much about rocks. And a search of the terrain with a Geiger counter is a fascinating experience.

It appears that it may also become possible to explore for uranium from the air. The U. S. Geological Survey, working with the Atomic Energy Commission, has made tests of this possibility with low-flying planes carrying specially built counters. Some planes fly slowly over the terrain at an altitude of about 500 feet. They have been able to locate rock deposits of unusual radioactivity within about a quarter of a mile. Such a survey is very crude, of course, and it must be followed up with a more intensive exploration on the ground, which may eventually come to naught. But the survey can cover a great deal of terrain in a relatively short time.

FROM the finds of the prospectors and from geological studies we are steadily enlarging our knowledge of the occurrence of uranium in the earth. The deposits found are being scrutinized by geologists; the minerals taken from them are being studied in the laboratory. These analyses provide further clues as to the types of formations where uranium is likely to exist. The studies are not restricted to high-grade sources of the metal. Recently attention has been directed to the fact, previously overlooked, that the gold ores of the Witwatersrand in South Africa contain some uranium. The average uranium content of these rocks is small, but with 60 million tons of gold ore passing through the Witwatersrand mills each year, the salvage of even a small amount of uranium from each ton may well be worth while. In our own country there are known to be large deposits of uranium-bearing phosphate rock in Florida, Idaho and western Wyoming, black shale in Tennessee and pegmatites scattered through many parts of the nation. These ores are of very low grade—one pound of uranium in several tons of rock—but in the aggregate they constitute an enormous potential reserve.

As our information accumulates, it appears more and more evident that uranium is deposited in the earth in much the same way and by much the same processes as other metals, such as copper, lead, silver, cobalt and nickel. In fact, uranium is often associated with those metals, as we have seen. Hence we should increasingly be able to apply our long-established knowledge of the older minerals to the newer problem of uranium prospecting. Given unrestricted peacetime publication of geological information, and the incentive of industrial demand, man should learn a great deal more about the earth's uranium resources.

Paul F. Kerr is professor of mineralogy at Columbia University and a consultant to the Atomic Energy Commission.



COLORADO PLATEAU covers a large part of four western states. In the uranium areas near the center of the plateau the uranium minerals tend to occur in strata; in the areas around the edge of the plateau, they tend to occur in veins. The distribution of copper deposits is roughly similar to that of the uranium veins.

Revival by Light

Concerning the remarkable discovery that visible radiation is able to resuscitate microorganisms that have apparently been killed by ultraviolet

by Albert Kelner

FROM the sun there streams to our earth a tremendous amount of invisible ultraviolet radiation. It is lucky for life on our planet that not all of this energy reaches the earth's surface. The shorter ultraviolet wavelengths below 2,900 Angstroms are intercepted and absorbed by a layer of ozone high in the stratosphere. If these short-wave ultraviolet rays got through to the earth, they would kill or seriously injure all unshielded cells.

Laboratory experiments have shown that when ultraviolet light in the neighborhood of 2,600 Angstroms penetrates an unprotected cell it can do one or more of several things: kill the cell, delay its growth or change its heredity by causing mutation of genes. Ultraviolet light is therefore a valuable tool for studying the growth and heredity of cells. There are other agents, such as chemicals, X-rays and atomic nuclear radiations, that can produce similar effects on the cell, but the ultraviolet is especially useful because it is known to act on certain specific structures and compounds in the cell. Unlike X-rays, whose absorption by a cellular substance is dependent only on the mass of the atoms in it, the absorption of ultraviolet is dependent on the structure of the molecule. Hence the ultraviolet is highly selective. Ultraviolet wavelengths near 2,600 Angstroms are absorbed specifically by nucleic acids. These important substances, combined with proteins as nucleoproteins, are found in the cell nucleus' chromosomes, in the cytoplasmic particles known as mitochondria and in other vital structures of the cell.

There are various evidences for this. When living, unstained cells are photographed with ultraviolet light of wavelengths near 2,600 Angstroms, the cell structures that absorb the ultraviolet and appear black in the photograph are chiefly chromosomes, nucleoli and mitochondria. Furthermore, cells that are particularly rich in nucleoproteins, such as spermatozoa and certain virus particles, are particularly sensitive to ultraviolet light. Finally, the best evidence that absorption by nucleic acids is chiefly responsible for the lethal and genetic effects of ultraviolet radiation is that those wavelengths of ultraviolet light which are known to be most highly absorbed by nucleic acids are also the ones that are most effective in causing death or mutation in a cell.

Because of this highly selective action of ultraviolet light on nucleic acids, biologists have felt for some time that the ultraviolet method offers great hope of leading us to the explanation of the functions of nucleic acids in the cell and the mechanism of mutation. The chief questions to which investigators in this field have been seeking answers are: What is the nature of the change induced in nucleic acid by ultraviolet light? How does this change cause mutation of a gene? How does it produce death or a delay in the growth of the cell?

THE subject of this article is a recent discovery that has opened a new lead in the investigation of these problems. The discovery is that the lethal action of ultraviolet light can be reversed or prevented by exposure of the "killed" cells to visible light.

About three years ago in the Carnegie Institution Laboratory at Cold Spring Harbor, N. Y., we were irradiating bacteria and the group of soil microorganisms known as the actinomycetes with ultraviolet light and X-rays. The purpose was to produce mutants with antibiotic activity. The radiation dose necessary to induce maximal mutation killed most of the cells (mutants were found among the few survivors). We noticed that when a culture of the actinomycete *Streptomyces griseus* was stored in the icebox for a few days after being irradiated with ultraviolet, the number of survivors would increase, sometimes as much as 10-fold. Some of the cells that had been thought "killed" had recovered.

Now a phenomenon similar to this had been observed a number of years before by Alexander Hollaender and Chester W. Emmons at the National Institute of Health. They had noticed that fungus spores irradiated with ultraviolet recovered after being stored in salt solution for several days. It was also known that X-rayed organisms sometimes partially recovered from radiation injury when they were kept cold after irradiation. It seemed to us that the phenomenon was eminently worth studying, because it might tell us something about the lethal and genetic effects of ultraviolet.

We set out to investigate more closely the possible role of temperature in the recovery of damaged cells. In an early experiment in this test we compared the survival rates of organisms (actinomycete spores) at icebox temperature and at room temperatures. After irradiation with large doses of ultraviolet, some suspensions of the spores were stored in the icebox at 5 degrees Centigrade and some in a glass bottle on a shelf in the laboratory. This produced a surprising result. While the organisms in the icebox showed the usual slight recovery (a 2- to 10-fold increase in survival), the survival rate of those stored at room temperatures increased 10,000 times!

Obviously cold *per se* had nothing to do with recovery. Indeed, it was a handicap. We began a systematic study of survival rates at various temperatures. There was considerable variation in the results of these experiments, even at the same temperature. We had stored some of the irradiated organisms in a thermostatically controlled water bath on a table in front of a window. The organisms in this bath consistently showed high recovery rates. After a systematic study of various environmental factors that might be influencing recovery, we came to the conclusion that the recovery factor must be the light coming in the windows. We tested the light hypothesis by storing some irradiated spores in darkness and some in light. The result was clear-cut and conclusive. In the light there was a 10,000-fold increase in survival; in the dark there was none. The reason for the original observations—the recovery of organisms that had been stored in iceboxes or other places—was now plain: because of the extra handling they received, stored samples were generally exposed to more light than would otherwise have been the case.

We explored the effect of visible light further, and found that by exposing irradiated cells for a few minutes to bright artificial light we could increase their survival rate as much as 300,000 times. Such a tremendous recovery, 30,000 times greater than achieved before, put a completely new face on the problem of ultraviolet effects. The magnitude of the recovery convinced us that we were dealing here with the key mechanism of ultraviolet action.

IT seemed incredible that no one had ever before observed this effect of visible light. We searched the literature and found that such phenomena had been noticed, but their significance had not been recognized. Back in 1904 the German botanist E. Hertel had shown that ultraviolet light inhibited the movement of protoplasm in an Elodea leaf cell more strongly in darkness than in light. Two German biophysicists named Hausser and Oehmke had reported in 1933 that visible violet light and neighboring wavelengths inhibited the browning action of short-wave ultraviolet on banana skin. In 1941 the Stanford biologist Douglas M. Whitaker had reported that "white" light counteracted the growth-inhibiting action of ultraviolet light on the alga Fucus.

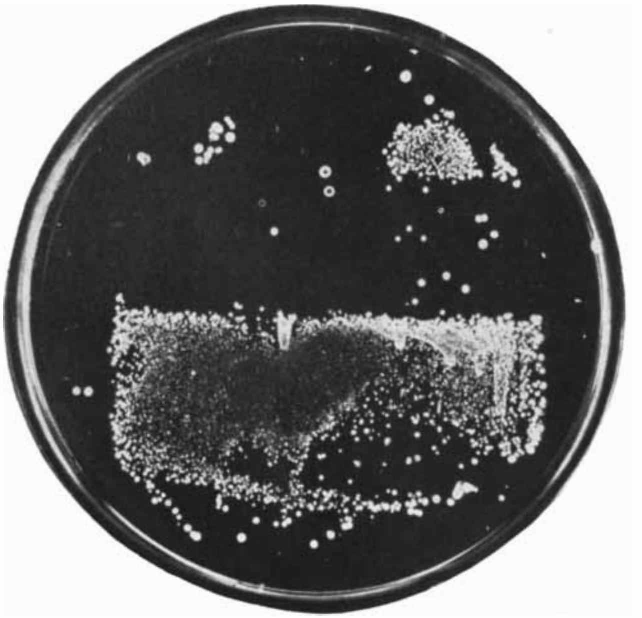
We soon found that visible light could revive not only actinomycete cells but other microorganisms as well, including the colon bacterium, baker's yeast and the penicillin-producing mold *Penicillium notatum*. These results suggested that the phenomenon was a general one.

Let us perform an experiment. We prepare a suspension of colon bacteria containing eight million cells per cubic centimeter of fluid. Each of these cells is fully viable, *i.e.*, is capable of growing if placed in a suitable nutrient medium at a favorable temperature. We put aside part of the suspension as a control and irradiate the rest under a low-pressure mercury lamp which emits chiefly ultraviolet light at the short wavelength of 2,537 Angstroms. Now we assay the viability of the irradiated suspension. We do this by taking out a sample and determining what proportion of the cells can grow sufficiently to form a visible colony of bacteria on the surface of nutrient agar jelly. We find that only 100 of the eight million viable cells per c.c. we started with are still capable of growing. The rest, to all intents and purposes, are "dead."

We then expose another sample of the same irradiated suspension for 30 minutes to sunshine, to a bright tungsten lamp, or, better yet, to a high-pressure mercury lamp whose emission is rich in violet and neighboring wavelengths. Now a large number of the inactivated cells will recover. We find that instead of 100 viable cells per cubic centimeter there are two million. It is evident that 1,999,900 of the 7,999,900 inactivated cells have recovered from their injury and can grow more or less normally. A control which we have placed in the same water bath, but protected from light, still has only 100 viable cells per cubic centimeter. The control that we removed originally and did not irradiate with ultraviolet is not at all affected by visible light.

The degree of recovery possible for irradiated cells is dependent on the original ultraviolet dose: the greater the dose, the greater the proportion of inactivated cells that cannot be revived. Given a sufficiently high dose of ultraviolet, probably not a single cell will recover, no matter how great the amount of reactivating light. Whether this fact indicates that ultraviolet light has two effects, one of which is sensitive to light and the other not, as the University of Chicago biophysicists Aaron Novick and Leo Szilard recently suggested, is not yet known.

AS in most photochemical reactions, the degree of recovery is proportional to the dose of light. There is also a temperature effect: the warmer the cells are while they are exposed to visible light, the greater the amount of photoreactivation, up to a temperature of 45 to 50 degrees Centigrade, where they become subject to heat injury. This indicates that in addition to the light reaction a secondary reaction sensitive to heat, perhaps an enzymatic one, is essen-



STREPTOMYCES GRISEUS cells on agar jelly plate were first exposed to ultraviolet, then covered with tape in the shape of an inverted T and finally exposed to light. New colonies grow in area not masked by tape.

ESCHERICHIA COLI cells on agar plate were exposed to ultraviolet and covered so that only a small window remained open. When projector was focused on window, bacteria were revived in pattern of lamp filament.

tial for recovery. Such a reaction, for which light is unnecessary, may be called a "dark reaction," analogous to the dark reaction of photosynthesis. On the other hand, in the inactivation process ultraviolet light apparently needs no assistance from heat.

If ultraviolet-irradiated bacteria are kept cold and dark, they can be photoreactivated many hours or even days after irradiation. If, however, they are put immediately after irradiation into what for a normal bacterium would be an ideal environment—a warm temperature and a rich meat-extract broth—and are incubated there for two to three hours, they can no longer be revived by any light treatment. This gives us a means of determining approximately the moment at which whatever change was induced by ultraviolet radiation becomes irreversible by light. This is the point where we can consider the cells to have died.

As a definition for death at this single-cell level, we might say it is the point at which any property we choose to employ as a sign of life—in the bacterium, the ability to grow is the best one—can no longer be restored by any known means. Of course with this definition the point at which life ends is a shifting one, depending on the state of our knowledge. Before photoreactivation was discovered, the point at which an ultraviolet-irradiated bacterium died might have been taken to be immediately after irradiation, at least for all but a minute fraction of the cells. Now, with our new knowledge of the phenomenon of photoreactivation, the point of death for the irradiated bacterium has been pushed back a little. Perhaps in the future the point of no return can be pushed back still further by the discovery of some other revival process. Conceivably biologists' knowledge of how to reverse the disorganization of the cell may be carried further and further until the cell is reduced to some simple state that is capable of artificial synthesis and subsequent organization into a living cell. That may be the way the first creation of life will be achieved. But such fascinating speculations take us from our story.

HAVING found that visible light could resuscitate cells "killed" by ultraviolet, our next step was to investigate whether it could counteract the effects of ultraviolet on genes. Would it reduce ultraviolet-induced mutations? Our early experiments, carried out on colon bacteria, indicated that light did have this effect, but the results were not as conclusive as we would have liked. By now, however, the ability of visible light to check mutation has been fairly well established, by Novick and Szilard at the University of Chicago; by Richard F. Kimball, working with paramecia, at the Oak Ridge National Laboratory; by S. H. Goodgal, with the fungus *Neurospora,* at Johns Hopkins University, and by Howard B. Newcombe, with colon bacteria, at the Canadian Chalk River atomic energy research laboratory. In extensive studies Newcombe showed that reactivating light lowered the frequency of several types of ultraviolet-induced mutants. These results in microorganisms have not yet been confirmed in higher forms. If they are, it will be the first time so drastic a reduction in mutation has been achieved in animals by a treatment *after* their exposure to a mutagenic agent.

Does light exert its effect by reversing mutation after it has already occurred? Or does it prevent the mutation by interfering with some process started by ultraviolet radiation? It is too early to say, but the latter explanation is less radical and more likely.

The task of determining how photoreactivation takes place has only just begun. The first step is to identify the substance in the cell that absorbs the reactivating light. In the case of ultraviolet radiation, it will be recalled, investigators identified nucleic acids as the absorbing substance by comparing the relative effects on the cell of various wavelengths of ultraviolet light, in other words, by determining the activity spectrum of ultraviolet, which was then matched with the ultraviolet-absorption spectrum of nucleic acid. A similar comparison of the activity of various wavelengths of visible and near-visible light should indicate what substance is absorbing reactivating light.

Studying the colon bacterium and *Streptomyces griseus* in this way, we found that the spectra for photoreactivation were distinctly different in the two species. The substance responsible for photoreactivation in the colon bacterium absorbed reactivating light in the range from 3,650 Angstroms (in the long-wave ultraviolet) to about 4,500 Angstroms in the visible blue; it absorbed most strongly at about 3,700 Angstroms. On the other hand, the active spectral region for the actinomycete extended up to about 4,900 Angstroms in the blue, and its peak of strongest absorption was near 4,360 Angstroms. This difference in spectra was surprising; it suggested that although the photoreactivation effect was the same in both species, the absorbing substance was not the same in both cases. The spectrum for reactivation of the actinomycete resembled the absorption spectrum of a porphyrin, an important type of compound found in many enzymes and in the hemoglobin of animals and the chlorophyll of plants. The colon bacterium's spectrum was probably not that of a porphyrin; indeed, it did not unmistakably resemble the absorption spectrum of any well-known cellular substance. Incidentally, these experiments showed that green, yellow or red light has little or no photoreactivating effect.

ONE of the striking characteristics of photoreactivation is its generality. It affects many types of organisms and can reverse various kinds of damage. For example, the Indiana University bacteriologist Renato Dulbecco has shown that visible light can "revive" ultraviolet inactivated bacterial viruses (bacteriophage). These virus particles—they cannot be called cells—are composed of almost pure nucleoprotein and multiply only when inside a living host, the bacterium. Let us irradiate free virus particles (away from the host) with 2,537 Angstrom ultraviolet. Now the irradiated virus can still attach itself to a host cell, but it has lost its ability to multiply. It is inactivated—or, if we wish to regard viruses as a form of life, it is "dead." If it is subjected to reactivating light before it attaches itself to a host, nothing happens: the virus remains inactivated. But, Dulbecco showed, if irradiated virus and a host cell to which it has attached itself are exposed to light together, many of the virus particles are reactivated and regain their ability to multiply. In other words, the virus-host complex, rather than free virus alone, must be illuminated for photoreactivation to take effect. This suggests that perhaps some structure of the host is necessary for the resuscitation of the virus. Dulbecco also found, incidentally, that viruses which are "killed" by X-rays, rather than by ultraviolet, are not reactivated by light.

The photoreactivation of viruses is remarkably similar in many ways to that of bacteria. In both cases only a certain percentage of the irradiated organisms can be "revived" by light, and the percentage decreases with the severity of the original inactivating ultraviolet dose. In both, recovery is favored by warmer temperatures. Bacterial viruses even have much the same reactivation spectrum as the colon bacteria they attack, which indicates that perhaps the same absorbing substances are involved.

The demonstration of the photoreactivation of bacterial viruses raises another very interesting question: Is this phenomenon related to the type of reactivation demonstrated by S. E. Luria in his brilliant studies at Indiana University? He found that after bacterial viruses are inactivated by ultraviolet, two or more virus particles sometimes apparently combine within the host to form one active, normal particle. This phenomenon has nothing to do with light; it can proceed equally well in the dark. It has been given a purely genetic explanation: the new virus is believed to be formed by combination from a pool of undamaged "genes" of the virus particles.

The list of types of cells that have

been photoreactivated now includes various bacteria, molds, yeast, protozoa and the sperm and eggs of the sea urchin.

One of the finest demonstrations of the versatility of photoreactivation was provided by Kimball in his experiments with paramecia. In this animal exposure to ultraviolet produces a wide variety of damage: 1) a delay in division of the cell, 2) a visible change in the cell's large nucleus, 3) death of some of the cells, 4) a gene mutation, and 5) a partially hereditary defect, causing delay of cell division, which is transmitted to progeny through the cytoplasm. Kimball showed that every one of those effects can be reversed or prevented, at least partially, by reactivating light.

The ability of light to reverse such diverse ultraviolet effects is surprising. It suggests that there is some common factor in all the effects which can be influenced by visible light. Presumably this factor would be nucleic acid, which is known to absorb ultraviolet radiation. But it is difficult to see how nucleic acid can be involved in all the varying ultraviolet effects—how, for example, a physiological effect such as delay in cell growth can have any close relation to the mutation of a gene. Perhaps the nucleic-acid hypothesis is faulty; perhaps some other compound absorbs the damaging ultraviolet radiation. But if the latter be true, how explain the unquestionable similarity of the spectra of ultraviolet action to the absorption spectra of nucleic acids, as well as other indirect evidence for the nucleic-acid hypothesis? Our own feeling is that the nucleic-acid theory is correct. It cannot be discarded until better evidence than anything we have comes along. Perhaps the real stumbling block is that we do not yet understand at all well the biological role of that omnipresent and important substance—nucleic acid.

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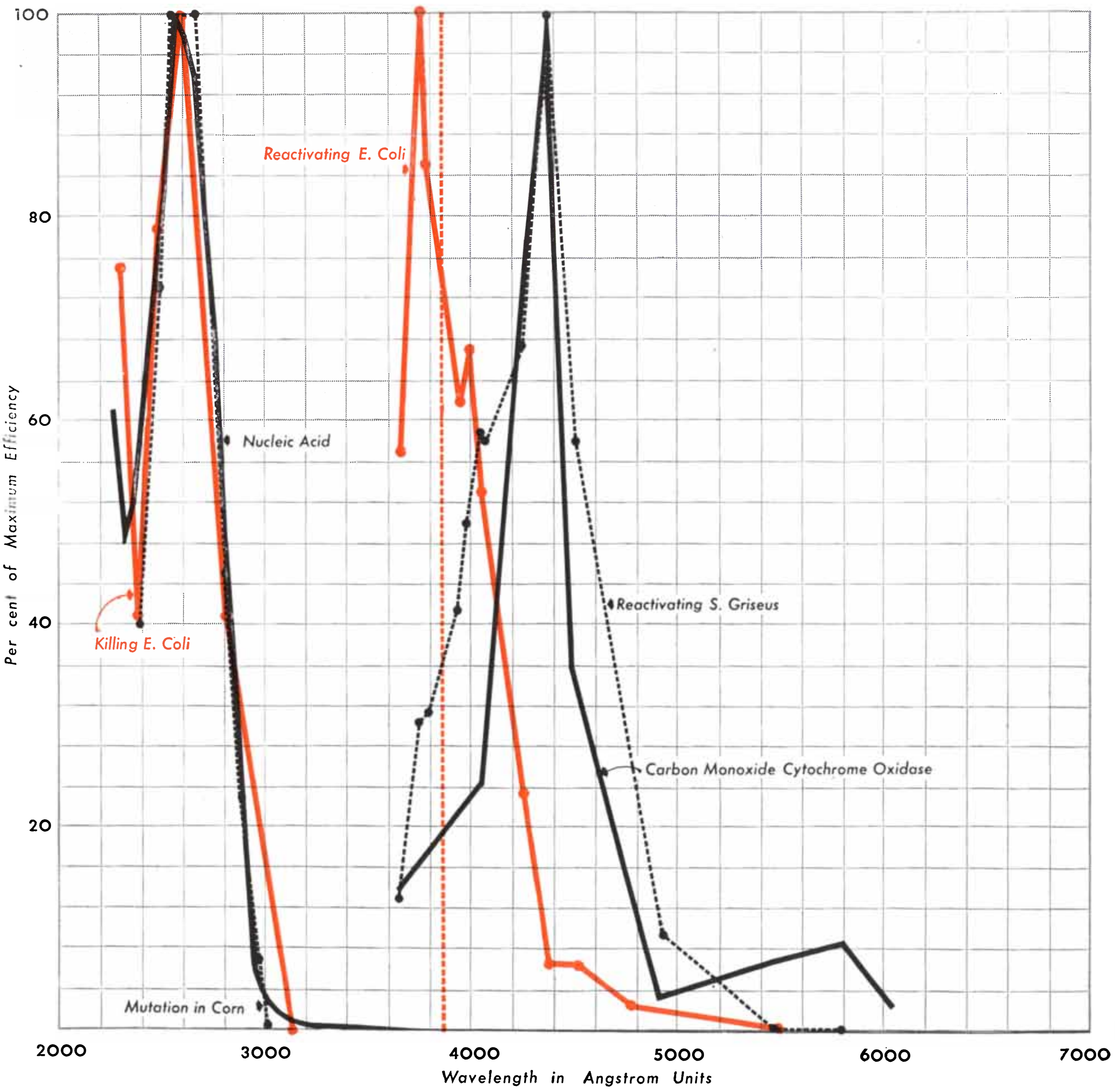


CURVES plotted on the basis of wavelength and the efficiency of the effect show a possible relationship between three biological radiation phenomena and the absorption spectra of two biological molecules. To the left of the dotted line running down the center of diagram radiation is ultraviolet; to the right, it is light.

UNINFLATED BALLOON begins its ascent with a payload of cosmic-ray instruments. When the balloon reaches its ceiling altitude, it is entirely filled by the bubble of gas at the top (*see photograph on opposite page*).

HEAVY ELEMENTS FROM SPACE

By sending special balloons to great altitudes physicists have learned that primary cosmic rays are not only the nuclei of hydrogen but also those of more massive atoms

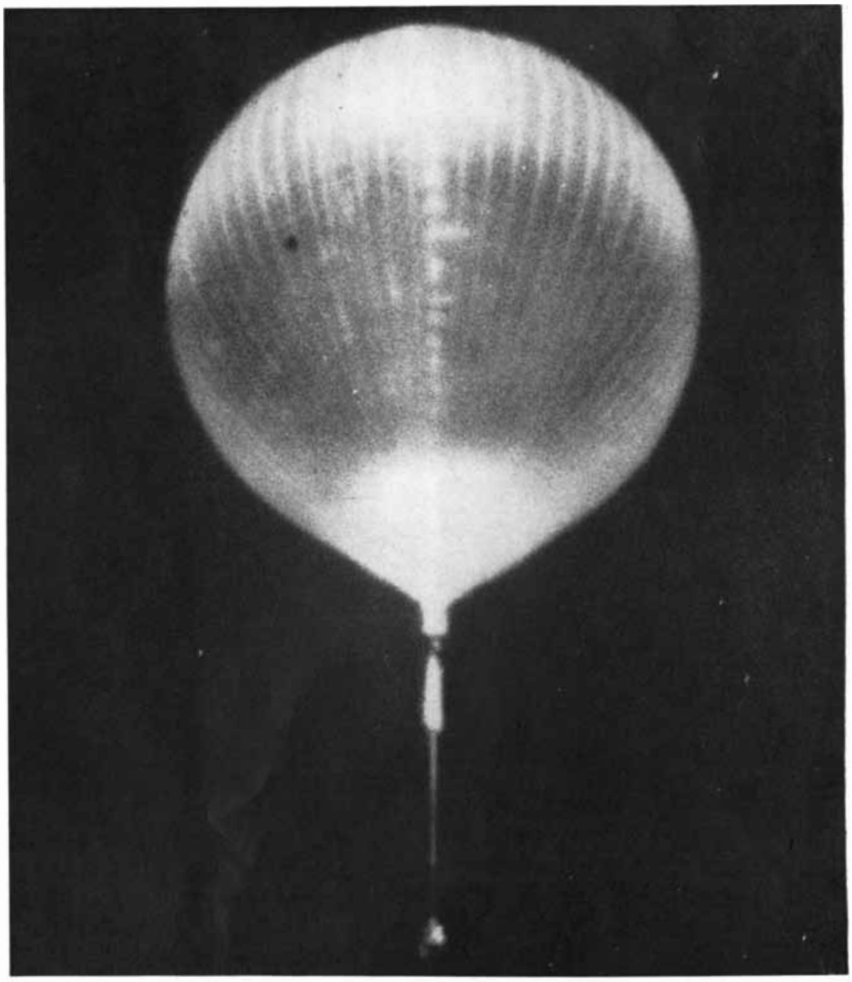
by Edward P. Ney

IN the year 1911 the Viennese physicist Victor Hess ascended high into the atmosphere in a free balloon carrying an ionization chamber, a device for detecting charged radiations. His purpose was to test a theory as to the source of certain mysterious radiations that had been observed for some time at ground level. Most of Hess' contemporaries believed that this radiation came from radioactive rocks in the earth. But Hess had a different idea. He was of the opinion that at least part of the radiation came from cosmic space outside the earth. He rose in his balloon to about 15,000 feet, recording the intensity of radiation at various levels, and when he returned to earth he had proved that his idea was correct. The mysterious radiation, he found, steadily increases in intensity as one goes higher and higher in the thinning atmosphere. Other balloon flights confirmed this discovery, and within two years physicists were convinced that some very energetic and penetrating form of radiation was coming into the atmosphere from outer space. Robert A. Millikan, one of its investigators, named the phenomenon "cosmic rays."

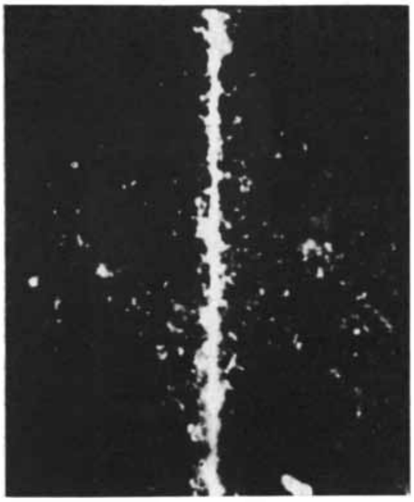
In a beautiful series of experiments Millikan determined the intensity of the ionization at various altitudes from the bottom of the deepest lakes to the top of the atmosphere. From this he was able to calculate that the total energy of the primary cosmic rays which are constantly bombarding the earth is about equal to that coming to the earth from all the stars, excluding our sun.

Today, 40 years after Hess' history-making experiment, scientists are more interested than ever in this extraterrestrial radiation, and they are still arguing heatedly about its nature and properties. We know now that the primary cosmic rays that enter the atmosphere consist of nuclei of atoms traveling at very high speeds. Within the atmosphere, through collisions with the nuclei of atoms in the air, this primary radiation is transformed into showers of secondary particles and gamma rays. These transformations are very complex, and they have given rise to a whole new special field of physics in their own right. But our chief interest in this article is in the primary rays themselves—the cosmic projectiles that are being fired at the earth from somewhere in space.

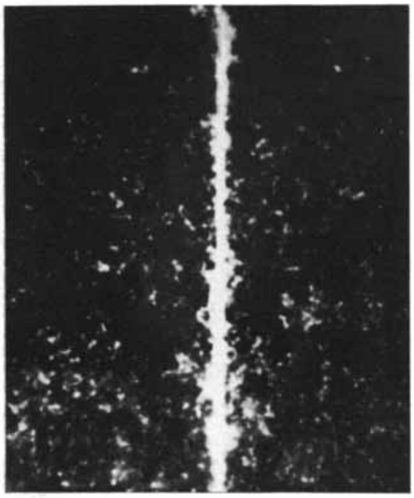
Obviously the primary cosmic rays are



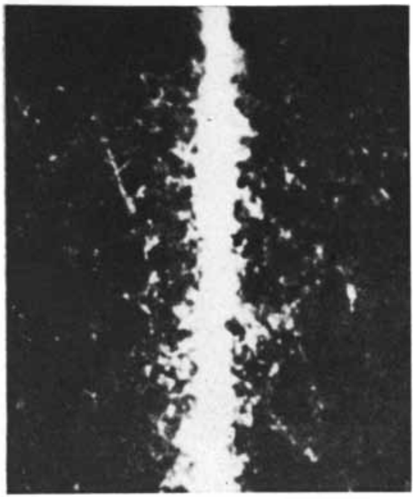
INFLATED BALLOON, photographed at its ceiling altitude by the 10½-inch telescope at the University of Minnesota, is some 100 feet in diameter.



TRACK of heavy cosmic-ray nucleus is shown by a photomicrograph at point it entered photographic plate.



HEAVIER TRACK was left by same nucleus after it had proceeded farther through the special emulsion.



STILL HEAVIER TRACK was left by nucleus farther along. Atomic number is about 40, that of zirconium.

not easy to investigate; to observe them directly we must go up near the top of the atmosphere, for once they enter the earth's envelope they do not survive long in their original form. Physicists were able to obtain some information, however, by indirect methods. By 1933 Arthur H. Compton and his collaborators had established that primary cosmic rays consisted of charged particles. They proved this by showing that cosmic radiation is less intense at the Equator than at the poles of the earth, which was interpreted to mean that the magnetic field of the earth deflects the radiation and it must therefore have an electrical charge. It was also possible to calculate that some of the particles must have an energy of at least 20 billion electron volts, because to get through the magnetic field and reach the earth at the Equator they would require that energy. This was far beyond any energy available to man on the earth; to appreciate what it means one must remember that the electrons in the vacuum tubes of a radio receiver have an energy of only 300 electron volts, those that strike the screen in a television receiver have about 8,000 electron volts and the largest particle accelerator being planned on earth will accelerate protons to a maximum energy of six billion volts.

The primary cosmic rays, then, were charged particles. Was their charge positive or negative? In 1939 the physicist Thomas H. Johnson (now head of the physics department at Brookhaven National Laboratory) determined that most of them were positively charged, for they came into the earth mainly from west to east, the direction in which positive particles would be deflected by the earth's magnetic field. Presumably the particles were protons. But their identification had to wait for the development of a better method than the ionization chamber for recording them and for research balloons that could rise higher.

These advances were both accomplished by 1948. A cosmic-ray research group under C. F. Powell at the University of Bristol in England, collaborating with Ilford, Ltd., produced photographic plates capable of reliably recording the tracks of singly charged particles with speeds up to about one-third the speed of light. Meanwhile the General Mills Corporation in the U. S., under a contract with the Office of Naval Research, developed light, strong plastic balloons that could carry as much as 200 pounds of instruments to altitudes of 100,000 feet or more. At that height the atmospheric pressure is less than one centimeter of mercury, that is, 1/76th of the pressure at sea level. There primary cosmic rays can be observed almost without contamination by secondary radiation.

On one of the first of these balloon flights two collaborating groups of cosmic-ray workers, those of the University of Rochester and the University of Minnesota, made a somewhat unexpected discovery. The instruments sent up in the balloon recorded not only the presence of protons, or nuclei of hydrogen, but also the tracks of considerably heavier particles. They were tracks such as would be made by the charged nuclei of elements heavier than hydrogen. Cosmic-ray investigators were quick to explore this lead, and they soon found evidences of a number of different nuclei at these high altitudes. In fact, by now it has been shown that the primary cosmic rays are composed not merely of protons and a few other species but of nuclei of all the elements up to about atomic number 40, in about the same relative abundances as these elements are present in the sun and in large planets such as Jupiter. In general, the heavier the element the smaller is its abundance, but there are exceptions to this rule; for example, iron is disproportionately abundant.

The actual number of primary cosmic-ray particles striking our atmosphere is not large. At the latitude of Minnesota about 4,000 protons, 500 to 1,000 alpha particles (helium nuclei), 20 carbon nuclei and one iron nucleus pass through each square centimeter at the top of the atmosphere per hour. This "rain of matter" is nothing to worry about, for it increases the mass of the earth only at the rate of one hundredth of a millionth of a millionth of one per cent in a billion years.

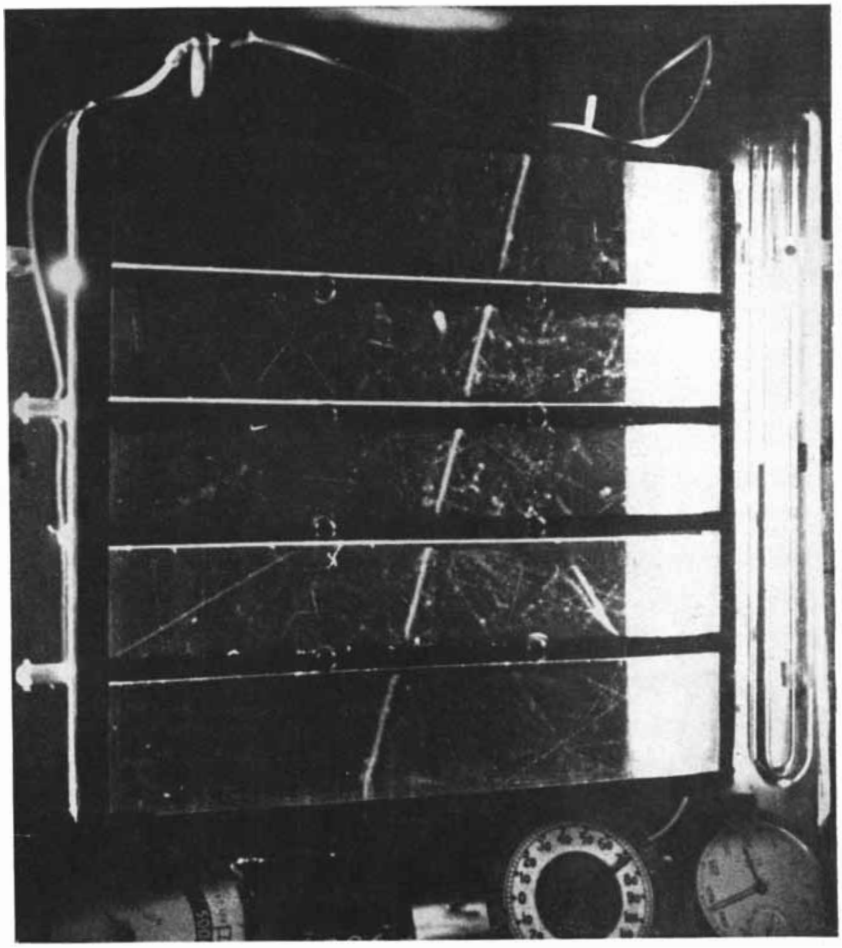
THE most striking characteristics of the heavy nuclei are their large energies and their dense ionization. The density of ionization means the density of the track produced by a particle in an ionization chamber or photographic emulsion. Paradoxically, high energy and dense ionization do not as a rule go together; in general, the more energetic the particle, the less the ionization. The definition of ionization makes clear why this is so. Ionization is the result of the interaction of a charged particle's electrical field with the electrons of the atoms through which it passes. The effects are twofold: the charged particle loses energy and it strips electrons from the atoms in its path. These ionized atoms form the track that is visible in the cloud chamber or in the emulsion of a photographic plate. Now obviously a very fast particle will have less opportunity to interact with electrons, will lose less energy and will produce less ionization per unit of distance than a somewhat slower particle of the same charge. On the other hand, a particle carrying a greater charge will interact more strongly and yield more ionization at a given speed. The charge of any nucleus is the same as its atomic number. In general, the ionization produced by a fast charged particle is approximately proportional to the square of its charge divided by the square of its velocity—that is, Z^2/v^2.

Let us illustrate this with an example. Suppose a proton (hydrogen nucleus) and an iron nucleus are both traveling at the same speed. The charge of a proton is 1; that of an iron nucleus is 26. The squares of these numbers are 1 and 676, respectively. Therefore, the speeds of the two particles being the same, the iron nucleus will produce 676 times as much ionization, and 676 times as dense a track in a cloud chamber or photographic plate, as the proton. It is clear, however, that an iron nucleus traveling at one speed and a proton traveling at 1/26 that speed will both show the same ionization. How, then, are we to distinguish one from the other?

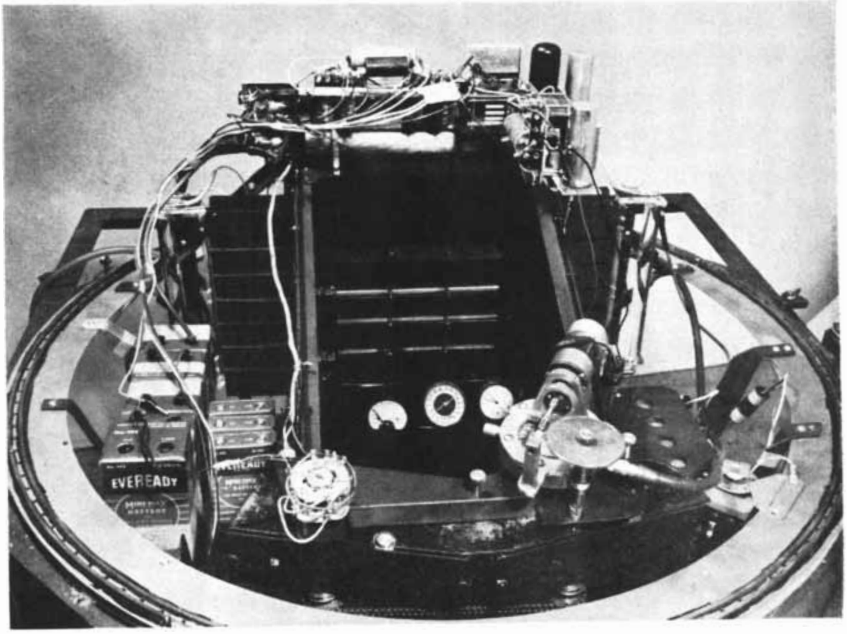
The answer lies in the fact that though the ionization is the same, the penetrating power of the two particles is very different. Because of its higher speed and greater mass the iron nucleus will have a much higher kinetic energy. At a speed close to that of light the kinetic energy of an iron nucleus is at least 50 billion electron volts, while that of a proton traveling at 1/26 this speed is only about one million electron volts. As a result the iron nucleus will penetrate 10,000 times as great a thickness of absorbing matter as the slow proton will.

Many of the primary particles at the top of the atmosphere travel essentially at the speed of light. They are not quite at this speed (if they were, they would have infinite mass and energy), but so close to it that any increase in their energy would not appreciably change their ionization. One may ask: If the heavy nuclei have such great energies at the top of the atmosphere, why are they not observed farther down? There are two reasons. The first is that the energy of a heavy nucleus is rapidly dissipated by its ionization of atoms in the atmosphere. An iron nucleus traveling at the same speed as a proton will penetrate only 1/13 as far into the atmosphere as the proton. The other reason is that because of their large size heavy nuclei are in grave danger of suffering catastrophic collisions with the nuclei of air atoms. Such collisions have been observed in emulsions and cloud chambers. In one case a carbon nucleus (consisting of six protons and six neutrons) was broken into an alpha particle, four protons and presumably four neutrons—the latter, being uncharged, are not detectable as tracks. All of the observable fragments of this carnage proceeded with high speeds in the initial direction of the heavy particle.

THE heavy particles that enter our atmosphere are all bare nuclei completely stripped of their atomic electrons.



CLOUD CHAMBER photographed as it was suspended from a balloon shows the passage of a cosmic-ray nucleus with an atomic number of about 6, that of carbon. The nucleus has penetrated four quarter-inch lead plates.

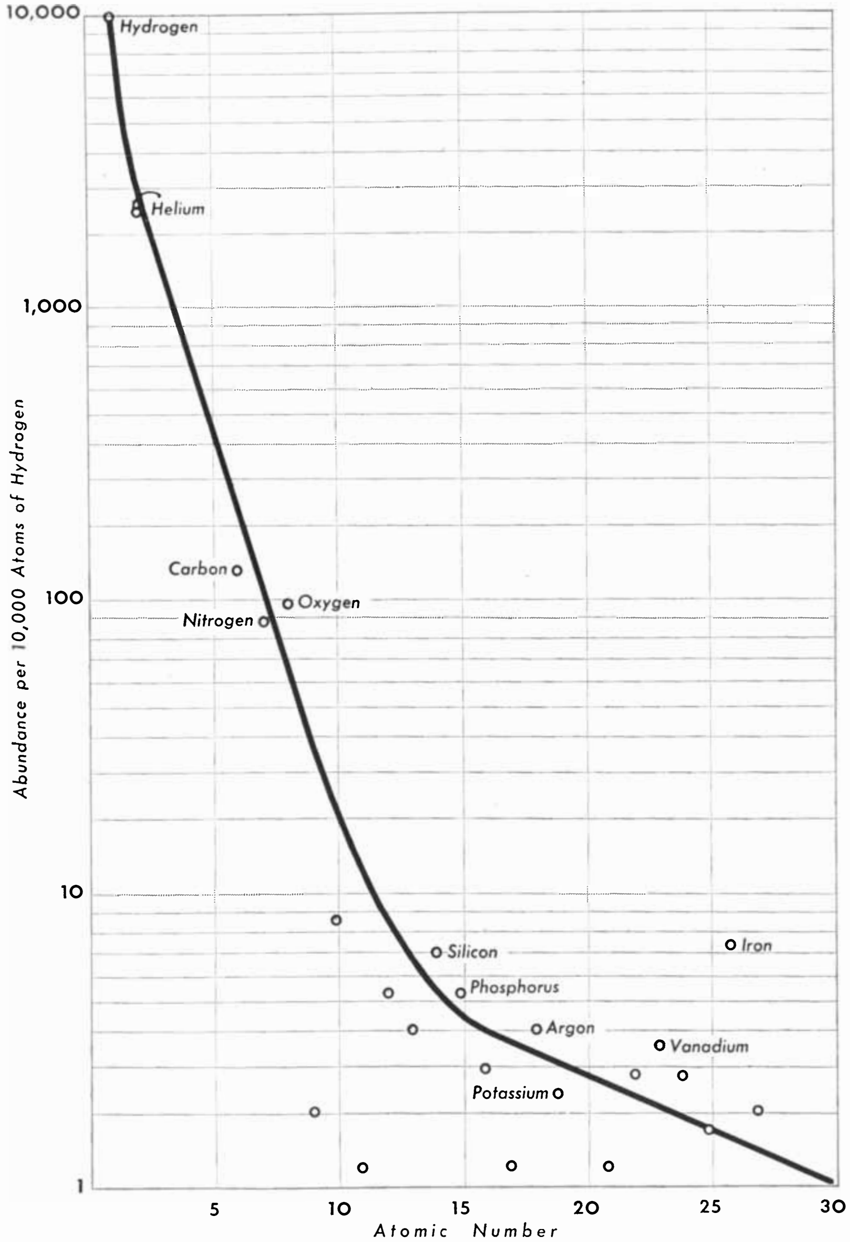


GONDOLA of a cosmic-ray balloon contains a cloud chamber and other apparatus. The chamber is in center; the camera that photographs it in foreground. When aloft, the apparatus is enclosed in an aluminum sphere.

What is the explanation? This is a key question, for if we knew the answer we would be a long way toward knowing where the cosmic rays come from. We have two important clues. First, the very fact that the nuclei are stripped indicates that they originated in some region where there was sufficient surrounding matter to rub off their atomic electrons when they were accelerated and shot into space. Second, we find that the energies of the heavy particles are roughly proportional to their atomic numbers. An average iron nucleus in the cosmic rays has approximately 13 times the energy of an average alpha particle. Individually both heavy nuclei and protons may vary in energy from the lowest to the highest values, but on the average the energy of a heavy nucleus tends to be proportional to the number of protons it contains, that is, its charge. This situation suggests that the nuclei gain their energy by virtue of their charge, as particles do in a Van de Graaff accelerator or an electromagnetic accelerator such as a cyclotron.

Theories about the origin of cosmic rays are even more numerous than good experiments on them. All of them, however, can be lumped into three classes.

One school of thought argues that the cosmic rays have been roaming in space since the beginning of the universe. The Belgian astrophysicist Georges Lemaître, who first proposed this theory, suggested that they may have been created with everything else at the beginning and that they have been slowly dying away because of collisions with planets and with other particles in space. A strong objection to such a theory is the fact that cosmic particles as heavy as iron still seem to be present in space in approximately the same abundance as in the stars. The average lifetime of an iron nucleus before it is broken up by collision with a proton in interstellar space is about one million years. The universe is believed to be about two billion years old. In that length of time, assuming they were present from the beginning, virtually all the iron nuclei should have disappeared.



ABUNDANCE OF ELEMENTS in cosmic rays at 55 degrees geomagnetic latitude is plotted logarithmically. Hydrogen is by far the most abundant element; iron is more abundant than elements of adjacent atomic numbers.

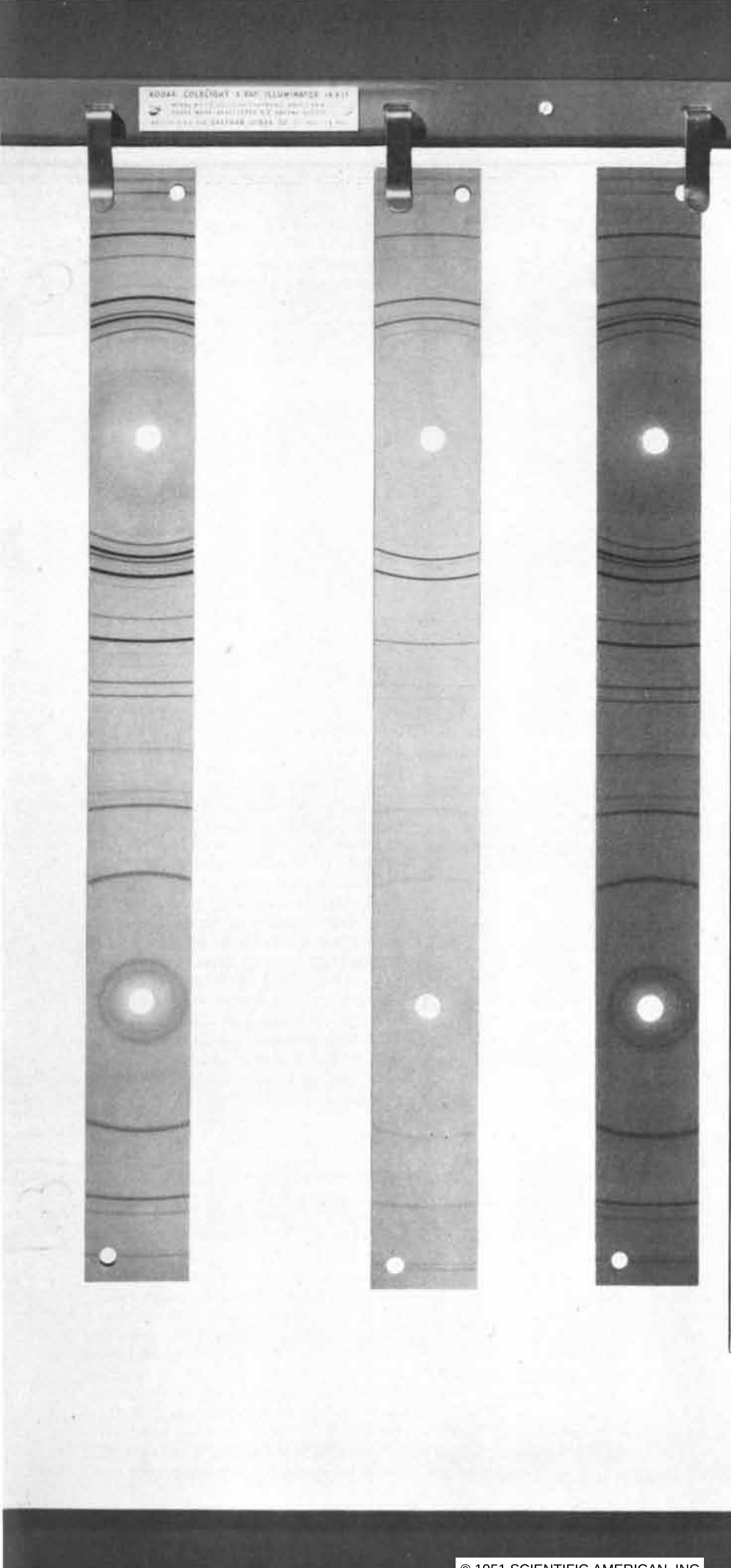
The second group of theories suggests that cosmic rays come from the sun or from other stars. It seems very unlikely that they originate only in stars other than our sun, because not even the vastly energetic exploding stars called supernovae give off enough energy to account for the amount of cosmic-ray energy intercepted by the earth. If the cosmic rays come from the sun, there should be a considerable difference between the daytime and night-time cosmic radiation on the earth. This possibility is now being investigated by means of day and night recordings of heavy nuclei. As yet the results are not conclusive, but an apparent diurnal effect has been observed. It appears that the intensity of heavy nuclei does decrease at night.

The third general view is that cosmic rays are continually being produced by some agency other than stars. Many theories as to possible sources of acceleration of the particles in space have been proposed. One of the most recent was suggested last year by the physicist Enrico Fermi. He investigated theoretically the possibility that the particles might be accelerated by collisions with nonuniform magnetic fields. The type of collision is assumed to be much like the collision of relatively slow-moving billiard balls (magnetic fields) with light, fast marbles (particles). Fermi was able to show that if very small magnetic fields moved through space, they might indeed accelerate protons to the required energies. Unfortunately this mechanism would fail for heavy particles: they would lose energy faster than they gained it.

Whatever the heavy nuclei may eventually tell us about the origin of cosmic rays, at the present time the most significant and exciting fact is that they are present at all. As Karl K. Darrow has remarked, "Millikan used to think cosmic rays were the death-cries of the elements, and now we find they are the elements themselves."

* * *

Edward P. Ney is associate professor of physics at the University of Minnesota.



Kodak
TRADE-MARK

To Make the Most of Short Exposure Time . . .

The story behind these x-ray diffraction films may save you a lot of time and make your work much easier. While they were all made on Kodak Industrial X-ray Film, Type K, and all show the same Debye-Sherrer-Hull pattern of lithium fluoride, the one on the far left was given a normal exposure of one hour, and *the other two only 15 minutes.*

Although all three films were processed for 5 minutes at 68°F. in Kodak Rapid X-ray Developer, the 15-minute exposure under the third clip was intensified by a recently developed technique—*is usable despite the short exposure.*

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Now available: For your convenience, your Kodak X-ray Dealer now supplies Kodak Industrial X-ray Film, Type K, and Kodak No-Screen X-ray Film in 1⅜″-wide unperforated 25′ rolls. Eastman Kodak Company, X-ray Division, Rochester 4, N. Y.

X-RAY DIFFRACTION

. . . another important function of photography

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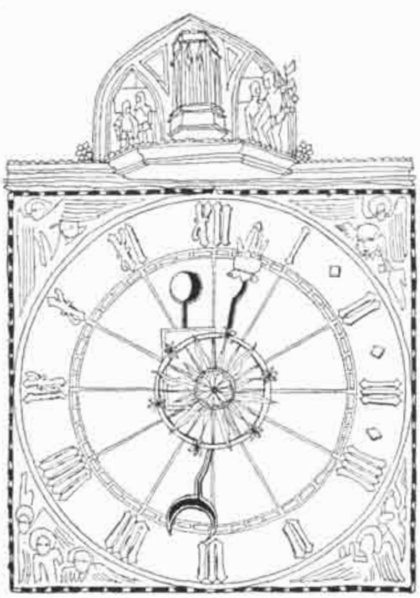
SCIENCE AND



The Wages of Science

DOES science pay? A debate on this subject has been going on in the magazine *Science.* It was started by a bitter letter from a German mathematician named E. Bodewig. He wrote: "If a lawyer had to do as much work as I had to do in reviewing the papers of von Neumann or Reicheneder, he would demand 1,000 gulden and get it. What do I or anyone else get for this? Nothing. I heard of a camp for German prisoners of war in Australia. The prisoners were allowed to work and were all paid. But there were also teachers and professors there who were giving valuable instruction to the other prisoners. These teachers were the only ones who were not paid. In fact, at the end of the class they had to sweep out the classroom, since the students didn't do it.

"Do I have to remind you of the disgraceful fact that a bookseller gets 30 per cent commission, often 40 per cent, for each book he sells, he who often cannot read a single line of the book? While the learned man who wrote the book gets 10 per cent? Professor X invited me to take a position at the Mathematical Center at Amsterdam—for 300 gulden a month. I wrote to him that for that he could get a plumber. The exploitation of the scholar is one of the worst in the world. It is the modern social problem! Nobody bothers about it, not even the scholars themselves. It would be a job for the United Nations, but they don't do anything either. Under the circumstances I can only act for myself. I want my work to be well paid, like that of a doctor, a chemist or a lawyer. If the world won't do that, I shall not work any more for the 'Society of Mankind.' I strike."

This outburst provoked a wide variety of comments from U. S. scientists. Many agreed that scholars were exploited and it was time something be done about it. But one reader argued: "Scientific work is a calling such as the ministry or teaching, where satisfaction in the work is as important as monetary compensation." A letter from an anonymous "Moneyed Man" pointed out that scientists are more likely than businessmen to have streets named after them and to have their busts exhibited in the Hall of Fame.

Science published a report by M. H. Trytten and Theresa R. Shapiro on the earnings of U. S. scientists. It was based on a study of a sample of the persons listed in the 1949 *American Men of Science*, conducted by the National Academy of Sciences and Government agencies. It showed that the average salary of all scientists with Ph.D.'s in 1948 was $5,720. The lowest paid were those in schools and universities: their average income was $4,860. Scientists in private industry averaged $7,070, and those in Government employment, $6,280. The spread between incomes of scientists in private industry and in academic life was greater at the older ages: *e.g.*, in the age group between 50 and 54 the average salary was $9,980 in private industry and $5,460 in educational institutions. At the peak of earning power (between the ages of 45 and 65) incomes of $10,000 or more a year are attained by 47 per cent of the scientists in private business but only by 4 per cent of those in schools and universities.

The best paid group are the engineers, the lowest paid the biologists. Biologists in private industry, however, are better paid than engineers in teaching. Paradoxically, as a group those persons listed in *American Men of Science* who have only a bachelor's degree receive a higher average income ($6,450) than the M.A.'s or Ph.D.'s. This is due in large part to the fact that the bachelors are employed predominantly in private industry.

The Perónist Atom

SELDOM has the announcement of a scientific achievement been greeted with such a chorus of skepticism and derision as was the statement by Argentine President Juan D. Perón last month that scientists in his country had succeeded in obtaining the release of atomic energy by a new method. Perón claimed that a "controlled" thermonuclear reaction identical with that in the sun had been achieved without the use of uranium fission for the triggering temperatures, or of tritium for the reaction itself; that particles had been emitted in this reaction which led to the conclusion that "at least a part of so-called cosmic rays" originate in the sun, and that "we were able to prove that the writings of most authoritative foreign scientists show they are enormously far from their goal" of creating a hydrogen bomb. The Argentine dictator said the first successful tests of the Argentine reaction had been made "on a technical scale" in a "pilot plant" on an island in a lake on February 16. The head of the project was an Austrian-born refugee physicist, Ronald Richter.

In the U. S. the physicist Enrico Fermi commented: "The whole claim would seem rather strange." Werner Heisenberg in Germany remarked that he did not believe the Argentine workers had developed anything "which U. S. scientists did not know long ago." Richter himself soon tempered Perón's claim considerably. He said that the reaction had been produced only on a laboratory scale. He added that it had taken place in a "furnace," not a particle accelerator. He would not discuss how he had created or controlled the temperature of "millions of degrees" of which Perón had spoken.

Some scientists thought that Richter might have carried out on a laboratory scale experiments which had already been performed elsewhere but thus far had shown no promise of any large-scale release of energy. A leading French physicist, François Gunet-Caplin, said that in laboratory experiments last year he had succeeded in fusing atomic nuclei without the use of uranium fission and without "vast installations like those at Los Alamos." The French magazine *Sciences et Avenir* reported last November a claim that the U.S.S.R. physicist Peter Kapitza had created high enough temperatures by electromagnetic means to fuse deuterium nuclei.

The physicist Lloyd Motz of Columbia University has suggested a theoretical method for producing a thermonuclear reaction without an explosion. He suggested that the necessary temperature and pressure might be achieved by compressing deuterium gas rapidly without loss of heat to 200,000 times atmospheric pressure. The reaction might be controlled, he thought, if it were made discontinuous: deuterium would be converted to helium in tiny batches and allowed to expand and cool before it melted or vaporized the container.

Secret

HISTORY'S most elaborately guarded secret—how to make an atomic bomb—was casually let out of the bag in a courtroom last month. Or was it?

Government witness David Green-

glass, once foreman of a machine shop at Los Alamos, was on the stand in U. S. District Court in the espionage trial of Julius and Ethel Rosenberg and Morton Sobell. Greenglass had testified that he had delivered a description of the Nagasaki A-bomb in 1945 to Julius Rosenberg as a courier for the Soviet Government. The Government prosecutor asked him to tell what information he had given away.

Defense attorney Emanuel Bloch asked that "in the interests of national security" the courtroom be cleared of all but the court officials and the jury. Judge Irving R. Kaufman "reluctantly" did so. Ten minutes later the judge called the newspaper reporters covering the trial into his chambers. He told them that U. S. Attorney Irving Saypol and several officials of the Atomic Energy Commission who were present had agreed to let them hear the testimony. The judge asked the reporters to use discretion in what they printed, and ordered the court stenographer not to transcribe the testimony but to read it from his notes to any defense attorney who requested it. Spectators were to be barred during the testimony.

Greenglass proceeded to give what seemed to be a detailed description of the bomb. At its center, he said, was a beryllium sphere emitting neutrons; around this was a sphere of plutonium, and this in turn was enclosed in a plastic sphere. The detonating mechanism consisted of 36 "lens molds" of explosive arranged around the bomb. These shaped charges were detonated to produce an "implosion" toward the center that collapsed the plutonium sphere and rapidly created a critical mass.

The next day newspapers published parts of Greenglass' testimony, and news magazines followed up with diagrams of the Greenglass bomb and interpretations to clarify and fill in gaps in his testimony. The prosecution then brought to the stand John A. Derry, special assistant to the director of production of the Atomic Energy Commission. The courtroom was again cleared of spectators, and the judge told the newspapermen: "I do hope you exercise the same good judgment as you exercised when this information came from the lips of the witness Greenglass." Derry heard the Greenglass testimony reread, examined a sketch made by Greenglass in 1945, and said: "It was the bomb dropped on Nagasaki."

"Would you say," asked the defense attorney, "that the Government's exhibit reflects a sketch of the atom bomb when it had already been perfected?"

"Substantially," answered Derry.

To naive newspaper readers who have gained the impression that the secret of the atomic bomb is a neat little blueprint that any mechanic could steal or even reconstruct in his basement, this performance must have seemed curious indeed. What the newspapers failed to note was that without quantitative data and other necessary accompanying technical information the Greenglass bomb was not much of a secret. The principle of "implosion" by means of a shaped charge has often been suggested in speculation on a possible mechanism for detonation of the atomic bomb.

The relative unimportance of Greenglass' disclosure was confirmed after the trial by the Joint Congressional Committee on Atomic Energy in a report on Soviet atomic espionage. The Committee said that by far the most damaging spy was Klaus Fuchs, the German-born British physicist who had access to and understood all phases of the atomic bomb program. Greenglass' diagrams, said the Committee, "have a theatrical quality and at first glance may seem the most damaging single act committed by any of the main betrayers." But because he was not a scientist "the bomb sketches and explanations that Greenglass could prepare must have counted for little compared with the quantitative data and the authoritative scientific commentary upon atomic weapons that Fuchs transmitted." There was evidence, said the Committee, that after Soviet agents had learned what kind of information "Greenglass was capable of telling them, they lost some of their interest" in him as an informant.

Greenglass was sentenced by Judge Kaufman to 15 years in prison, Sobell to 30 years, Julius and Ethel Rosenberg to death—the first U. S. spies ever to receive the death penalty.

Atomic Plants

A NEW secret $45 million atomic production plant is to be built northwest of Denver, Col., the Atomic Energy Commission announced last month. It will handle radioactive material and will have only moderate water, gas and electric requirements. "No further description of the nature of the operation is permitted under security provisions of the Atomic Energy Act," said the announcement. The plant will be operated by the Dow Chemical Company.

The Commission will also build a new Feed Materials Production Center costing some $30 million in Ohio 19 miles northwest of Cincinnati. This plant will refine and process uranium ore.

Channels for Education

THE Federal Communications Commission rendered a decision last month on the question of the reservation of television channels for education. Striking a compromise between the demands of educators and the opposition of commercial broadcasters, it assigned 10 per cent of the unused channels for noncommercial use, instead of the 25 per cent the educators had requested.

The 209 channels granted to educa-

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tion would permit a total of about 2,000 TV stations in 1,200 communities. Most of the channels are in the ultra-high-frequency range, now used only for experimental purposes. To receive broadcasts from such stations present receivers would need special adapters. The FCC's decision does not mean that any new stations will soon be built, since broadcasting equipment is severely restricted and there is a current FCC ban on the opening of new stations.

The Commission specified that one channel be reserved for education in any locality with three or more frequencies. Commissioner Frieda B. Hennock thought the allocations to education were too limited. She objected that the new plan does not provide enough channels for a nationwide system, nor any assurance as to when the ultra-high-frequency equipment will be available.

The New York County Medical Society has announced plans for a three-year series of weekly programs of medical education on commercial stations. Leading specialists will discuss such topics as cancer, poliomyelitis and peptic ulcers. The physicians hope that the program will be carried on a nationwide hookup.

Hormones from Tomatoes

THE leaves and roots of the tomato plant may provide a cheap and plentiful source for sex hormones, three workers at the National Institutes of Health have discovered. They found that tomatidine, a substance in the plant, can be converted into allopregnenolone, which in turn is readily transformed by well-known methods into either the female hormone progesterone or the male hormone testosterone. Some investigators hope that it may also be possible to use the plant as a source of cortisone, which has a structure similar to that of pregnenolone and the sex hormones.

The World's People

THE human race has increased by 544 million in the past 30 years and now totals 2,378 million, United Nations statisticians report. At this rate of growth, nearly one per cent a year, the present world population would be doubled in less than a century.

The fastest-growing part of the world is Latin America, with an annual rate of increase of about 2 per cent. As of June, 1949, there were 321 million people in the Americas, 593 million in Europe, 1,254 million in Asia, 198 million in Africa and 12 million in Oceania.

Population density is greatest in Asia, with an over-all average of 47 persons per square kilometer. The range in Asiatic countries is from 223 per square kilometer in Japan to 12 in the Near East. Europe's average density is 22 per square kilometer; the Americas', 8 per square kilometer. Africa and Oceania, with relatively large areas of uninhabited desert, have seven persons and one person per square kilometer respectively.

Blood-Vessel Bank

NEW YORK Hospital has established the world's first blood-vessel bank. Sections of living blood vessel are being used more and more as grafts to replace diseased veins and arteries, particularly in operations on tumors, but the available supply is very limited, since the transplant must be obtained from the corpse of a young person with healthy blood vessels immediately after death. The New York Hospital's bank will be supplied from all hospitals in the city and will assure a ready supply on which any surgeon in the city can draw.

Awards

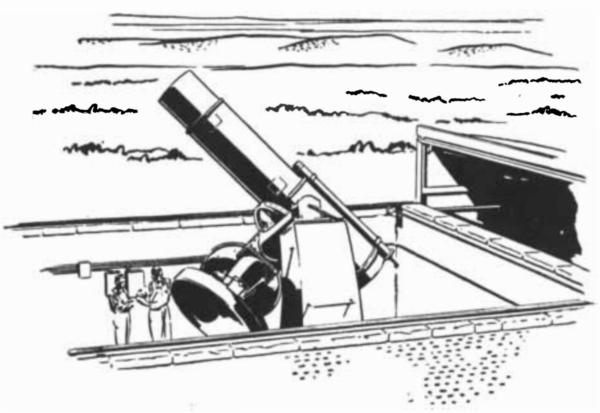
THE first award of the $15,000 Albert Einstein prize for achievement in the natural sciences, probably the largest scientific prize in the U. S., has been made to Julian Schwinger of Harvard University and Kurt Goedel of the Institute for Advanced Study. Schwinger was recognized for his theoretical work on the interactions between light and matter and Goedel for a revolutionary proof in mathematical logic. They divided the prize equally. It was established in Einstein's honor by Lewis L. Strauss, banker and former member of the Atomic Energy Commission. The award committee consisted of Einstein, J. Robert Oppenheimer, John von Neumann and Hermann Weyl, all of the Institute for Advanced Study. Einstein presented the awards at a luncheon celebrating his 72nd birthday. The prize will be awarded every three years.

Also announced last month were the annual Stalin Prize awards to Soviet scientists. Eighty-two awards, including eight 200,000-ruble first prizes, were made in a wide variety of fields. The winners in physics were Dmitri Skobeltsyn, Nikolai Dobrotin and Georgi Zatsepin, for study of "electronic-nuclear showers and the nuclear-cascade process in cosmic rays," and a group led by Leonid Brekhovskikh, for work on acoustics. Skobeltsyn is a member of the Soviet delegation to the UN Atomic Energy Commission. The Moscow *Literary Gazette* said his work had brought "close to a successful solution" the problem of nuclear binding forces.

There were other first prizes for work on the geochemistry of rare elements, in organic chemistry, on a *Marine Atlas*, on fresh-water fish, on "diatomic analysis" and on activity of the higher nervous system. Among the many secondary prizes were awards for studies of low-temperature physics and the enrichment of helium with light isotopes, a quantum theory of the heat capacity of higher

Behind the EYES OF RESEARCH

PUBLISHED IN THE INTEREST OF FURTHERING ANALYSIS AND RESEARCH THROUGH MODERN OPTICAL INSTRUMENTATION



PROBING 30,000 LIGHT YEARS OF SPACE

This Baker-Schmidt telescope was specially designed to explore photographically the 30,000 light years of space between Earth and the center of the Milky Way. Called "a marvel of optical precision," the new telescope is in South Africa with Harvard's "Hub of The Universe" Expedition.

Schmidt telescopes combine the penetrating power of reflectors with the wide coverage of refractors. The Baker modification "sees" three times farther than present similar instruments. In only 20 minutes, it photographs stars 100,000 times fainter than the dimmest glimmer visible to the naked eye.

The optics and mechanical components of this super telescope were designed and executed by Perkin-Elmer.

FINGERPRINTING A MOLECULE

Today, by means of light, the invisible atoms of complex organic compounds can be mapped with the same accuracy as distant giant stars. Infrared spectrometers, developed commercially by Perkin-Elmer, permanently record the "fingerprint" of any organic compound. From this fingerprint its structure can be deduced.

These instruments project invisible infrared radiation through a tiny chemical sample. Minute variations in the radiation intensity are detected, amplified and graphically recorded—constituting the permanent unique fingerprint of that compound. Any organic compound can be identified and analyzed from its spectrometer record.

Infrared has proved to be an ideal tool for industrial research and process control. It has been an important factor in the development and production, among other things, of penicillin, cold rubber and synthetics of all kinds.

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Do you and your research staff know about The Perkin-Elmer Instrument News? *This 8-page quarterly is devoted exclusively to the latest news and technical developments of electro-optical instruments. We will be glad to place any of your staff on our mailing list.*

MEDICALLY SPEAKING

In shock, heat prostration, post-operative care, salt-free diets, physicians must know the salt content of the patient's blood. Formerly such analyses for sodium and potassium levels would take many hours of laborious laboratory routine, delaying vital therapy.

Today the flame photometer, first developed commercially by Perkin-Elmer, enables unskilled personnel to determine *within a few minutes,* the salt content of body fluids with an accuracy of 1 or 2%! Flame photometry is based on the same principle as the classical flame test for sodium, familiar to every high school chemistry student. Results equal or better the accuracies of slower, more tedious classical methods.

Soil, food, cement, water—any dissolved substances—as well as body fluids, can be analyzed for sodium and potassium by this method. Lives which might otherwise have been lost are today saved—thanks to Better Eyes For Research.

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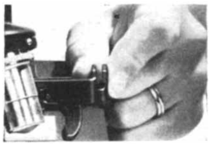
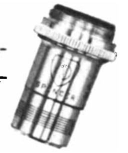
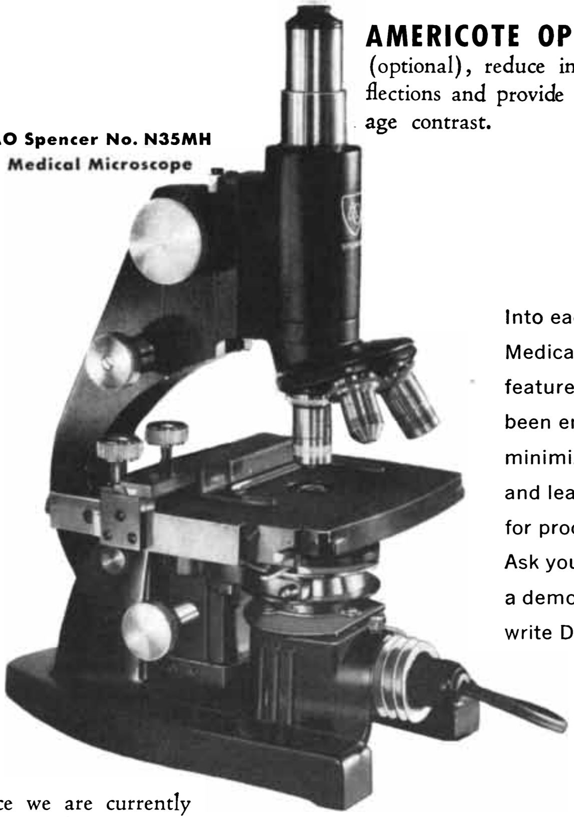






solids, mathematics, aerodynamics, hydrochemistry, "the theory of the automobile" and applications of the Michurin-Lysenko theory of heredity.

Diagnosis by Sonar

A new apparatus being developed at the Massachusetts Institute of Technology may make it possible to locate brain tumors without opening the skull. The device painlessly sends a pencil-sized scanning beam of ultrasonic waves of 2.5 million cycles per second through the patient's head, which is covered with a rubber hood and immersed in water. A sensitive receptor records the transmitted radiation on a shadowgraph. This graph shows the pattern of the liquid-filled ventricular cavities in the brain, since they absorb less ultrasound than the surrounding tissue. If a tumor that distorts the ventricles is present, it produces an abnormal shadowgraph.

The American Cancer Society, announcing the project, said the M.I.T. experimenters had built a preliminary model and hoped to obtain clear enough shadowgraphs to determine both the location and the nature of a tumor. A team of six scientists is collaborating on the device.

Bags Under the Eyes

"WHAT is the cause of 'bags under the eyes,' which often occur in patients with no kidney trouble or other known cause of the unsightly condition?"

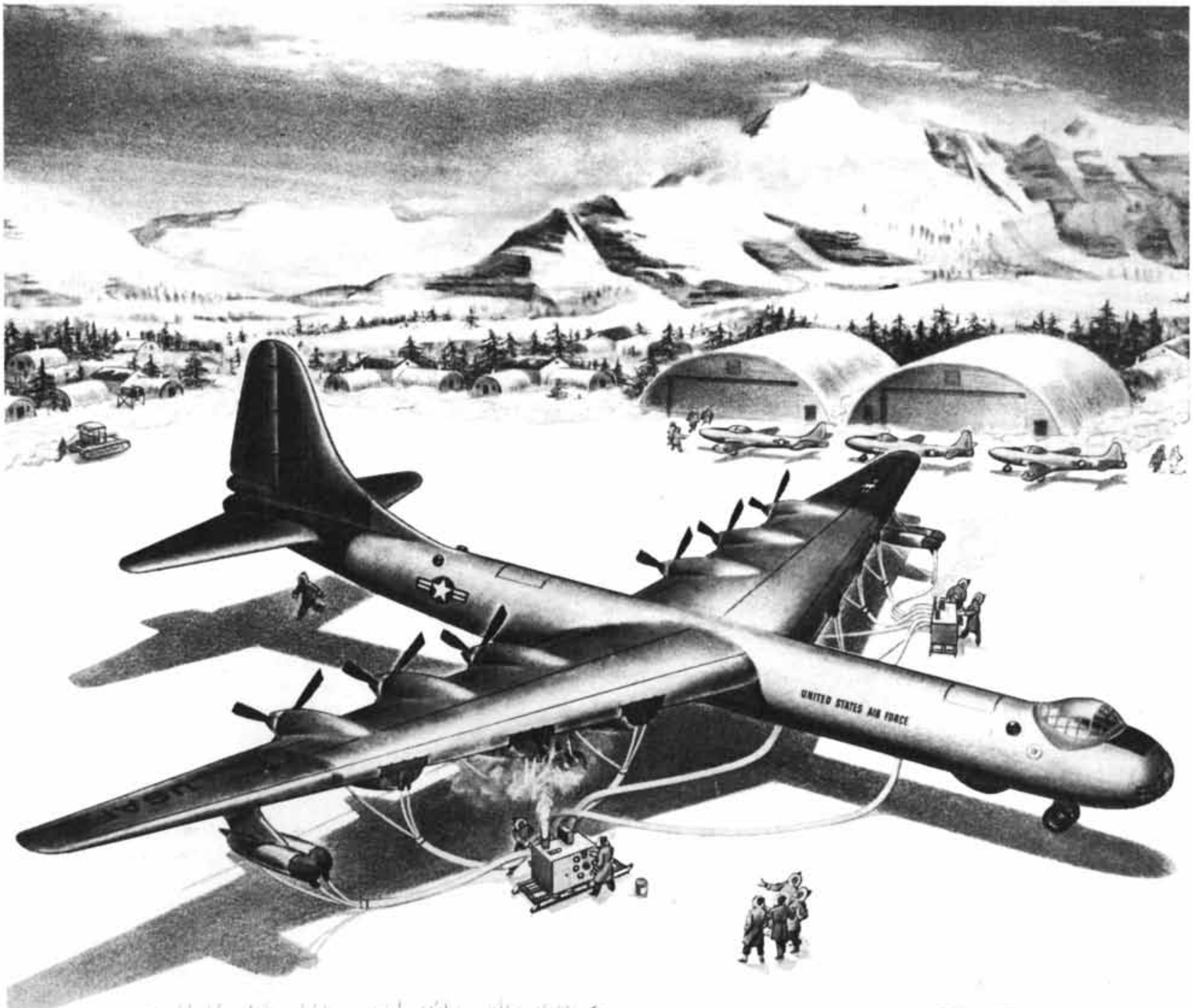
This distressful query was received recently by the *Journal of the American Medical Association* from a Los Angeles physician. The *Journal* editors referred the question to four authorities. The four authorities, whose names were not disclosed, gave four different opinions:

The first contended that the lower eyelids are normally so loose that "even slight changes in muscle tone or elasticity of the skin" can cause bags.

The second listed hypothyroidism, cardiorenal disease, the aging process and five kinds of allergy as possible causes.

The third declared that baggy eyes "is not necessarily an indication of debauchery and dissipation," though it often accompanies cirrhosis of the liver. "No one knows the exact cause of this condition," he said, but it sometimes runs in families.

The fourth observed that "the 'bags under eyes' often seen in elderly persons apparently have not been the subject of a special study, nor has the condition even been given a specific name. The size of the bags may vary at different periods of the year or times of day, suggesting that the patient's general condition is at times an important factor. It is possible, however, that some occult nephropathies [kidney disorders] are responsible for the bags."



"HOT FOOT" for the B-36

In Arctic regions where temperatures often hit 65 degrees below zero, airplanes "freeze up" when engines stop turning over.

To heat up engines and cabins, de-ice wings, control surfaces, landing gear and to free hydraulic lines, AiResearch engineers have designed and built a portable gas turbine powered ground heater—*another AiResearch first.*

The result of a rush development-production order placed by the Air Force several months ago, the new heater will produce clean 280° air from six different outlets on a −65° day, or 4,000,000 BTU per hour. This is more heat than could be produced from 100 large floor furnaces. It is designed to warm up a multi-engine B-36 bomber within 15 minutes in sub zero Arctic weather. It will be used to heat living quarters and all types of mechanical ground equipment.

The compact, lightweight AiResearch gas turbine which powers the ground heater is completely self-contained. Developed as a source of pneumatic power for aircraft, its use in the ground heater is an example of its versatility. It is also being used to start jet and turboprop engines, for operating aircraft accessories and for ground air conditioning. It is ideally suited for any condition where self-contained portable power can be used to advantage.

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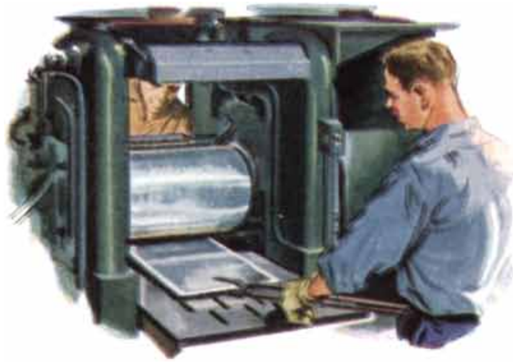

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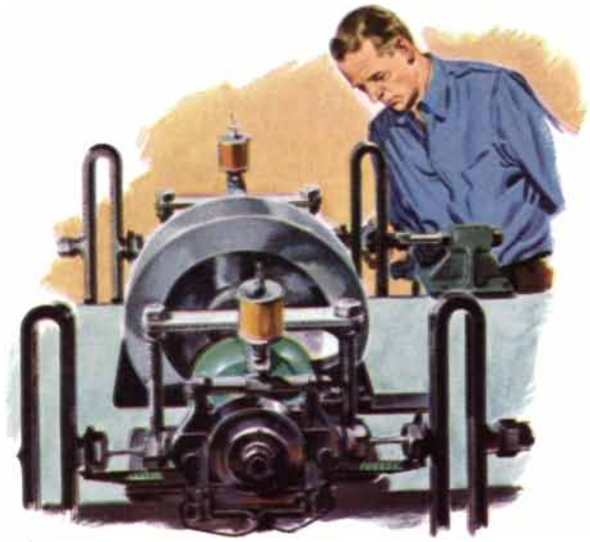

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What GENERAL ELECTRIC People Are Saying

H. A. WINNE

Vice President

Engineering Students: I am much concerned by what seems to be the too general attitude of the young men on our college campuses today. . . . It seems to be a state of mind almost bordering on panic. Often it is an attitude of "what's the use; I'll soon be in the army." Again it is a feeling of rebellion, or of self-pity, because of the uncertainty of the future. Certainly the future is uncertain—and, may I add, *as always.*

My advice, speaking very bluntly, is: quit worrying and put your effort into the job immediately ahead of you, which is to get just as much education as you can. . . .

There is a great need for engineers in industry, particularly in industries which produce defense equipment, and the list of industries so producing is growing at an astounding rate. . . .

Every year our military—as well as our civilian—materiel becomes more complex technically, requiring more scientific and engineering man-hours to develop, build, operate, and service it. I am not aware that any attempt has ever been made to estimate the amount of engineering required on the munitions and materiel needed, on the average, for each military man actually in the field. I would be willing to bet that the ratio of such a figure for World War II to the corresponding figure for World War I would be in the hundreds, and I should not be surprised if it were now in the thousands, and it is still going up. . . .

Industry and our military forces need more and more engineers, but the prospect seems to be that we shall have less and less, and this is most unfortunate. In fact, the immediate and prospective shortage constitutes a serious threat to our national strength.

A survey recently made by Dean S. C. Hollister of Cornell reveals some disturbing figures. A simple straight-line extension of the prewar demand for engineers indicates a need for at least 20,000 technical graduates annually, and this makes no allowance for the requirements of the armed forces. Yet, based on the number of engineering freshmen entering in 1950, we can expect only 12,000 to 15,000 graduates in 1954.

We in industry are plagued on all sides by material shortages. We are restricted in our use of copper, cobalt, nickel, zinc, rubber, aluminum, and many other materials which we need to produce the articles our civilian population wants. But our most critical shortage of all may well prove to be that of engineers and scientists. . . .

Think of our airplanes, our tanks, our guided missiles, our atomic bombs, our naval vessels, our radar. And not only are engineers needed to develop, design, and produce these devices, but the tools and factories which make them must also be engineered. And then the use and servicing of such complicated equipment calls for more engineers in our military forces. . . .

Your country badly needs young men with engineering or other technical training. Most of you young men here tonight have the opportunity to get such training right here at Princeton. I urge you most earnestly to take full advantage of that opportunity, for the good of your country. I wish I could make the same plea to capable young men in the other good engineering and scientific schools. . . .

I know that . . . you do not want to be slackers. Has the thought occurred to you that, if you have the ability and the opportunity to pursue your engineering education, you may well contribute more to your country by doing that than by dropping out of college and going into military service? Remember that engineering is a profession, and that a real professional man's whole career is one of service, service in the highest sense. . . .

Bills now before the Congress on the matter of military service for our young men give recognition to the importance of maintaining a flow of men through our scientific, engineering, and medical educational institutions and into industry, as well as military forces. In World War II we paid little attention to this most important matter, whereas almost all other countries did implement such a program. Perhaps we were lucky that the war did not last longer, for then the shortage of engineers in our reconversion effort would have been much more acute.

Now we face the possibility of a long, long period of heavily armed preparedness, and we dare not stop the flow of engineers and scientists into our economy, even for a year or two. You are a part of that stream. You can help to keep the stream flowing. I hope you will do your part.

Princeton University
March 1, 1951

You can put your confidence in—

GENERAL ELECTRIC

VIRUSES

The very small microorganisms that grow only in cells are studied not only for the treatment and prevention of the infections they cause but also for themselves

by F. M. Burnet

POLIO, influenza and the common cold—probably the three infectious diseases of most interest to the average person—are all caused by viruses. So are smallpox and yellow fever, most of the "childhood diseases" and a host of rarer maladies. Since the days of Jenner and Pasteur the virus plagues have been studied from every angle that might help toward their understanding and control. It is natural that most of the research in this field should have a strongly medical bias. In dealing with disease, as in every important human problem, it is of more immediate value to find some effective answer than to have a clear understanding of the nature of the problem. The history of yellow-fever research provides a good example. Walter Reed's famous experiments in 1900, which proved on the bodies of U. S. Army volunteers that yellow fever was carried by a certain species of mosquito, provided all that was necessary for the control of yellow fever in the West Indies. But the nature of the microbe carried by the mosquito was not discovered until 1928. For a time the culprit was thought to be a bacterium. Then for five or six years, on the authority of the great Japanese-American bacteriologist Hideyo Noguchi, the germ was very widely accepted to be a species of Leptospira, a coil-shaped microorganism in the general class that includes the spirochetes. Finally, as a result of work in West Africa by a Rockefeller Foundation team, it was conclusively proved that yellow fever was due to a virus. Noguchi himself confirmed this finding—and died of yellow fever contracted in the laboratory before his work was completed.

There are similar stories of pragmatic research, with varying failure or success, to be told about all the major virus diseases. But along with this work on prevention and treatment there has been developing in recent years an increasing attention to the fundamental nature of virus infection. There are two excellent justifications for fundamental research. It is the only attack that is likely to open up unexpected new approaches to the practical problems, and it satisfies that almost mystic desire to do something toward seeing the universe "all of one piece." Also, for a variety of reasons which someone might find it interesting to analyze, most scientists worth their salt seem to get more straightforward fun out of basic research than out of anything else.

Quite apart from the problems of human and animal disease, the viruses themselves—their nature, their interaction with the cells they infect, their place in the evolutionary scheme—provide topics of the highest interest. This article is an attempt to give an account of modern experiments and ideas that bear on these matters. It will be based to a considerable extent on the investigations of influenza virus that have gone on in England, America and Australia during the last 17 or 18 years. The influenza viruses are my own chief field of interest, and they are also the field in which fundamental study of animal viruses—as opposed to the viruses that attack plants or bacteria—is furthest advanced.

The Nature of the Beast

A virus can be defined as a microorganism, considerably smaller than most bacteria, which is capable of multiplication only within the living cells of a susceptible host. This definition immediately indicates the important feature that distinguishes the virologist's problem from that of the classical bacteriologist. A bacterium, say the diphtheria bacillus, can be grown on relatively simple mixtures of sterilized nutrients—the tubes of broth and the plates of nutrient agar that are the bacteriologist's tools of trade. For viruses nothing less than the living cell will serve. An influenza virus can be grown in the nasal passages of a ferret, in the lung of a mouse, in the tissues of a developing chick embryo or in a culture of embryonic cells in a flask, but it will not grow in any nonliving material.

There are two general prerequisites for experimental laboratory work with a man-infecting virus. First, the experimenter must find some convenient animal whose cells can be infected by the virus. If chick embryos or mice, which are cheap and available in virtually unlimited number, will serve, so much the better. Second, the experimental host must show some sign or symptom that will allow the experimenter to know when it is infected.

Any good experimental work must be quantitative. In most experiments with viruses the questions we ask usually take the form of an inquiry as to how much virus is present after such and such a manipulation. Suppose we are working with influenza virus in mice and wish to know how much virus is present in an extract from the lung of a mouse that has just died of the disease. Our method of measuring this depends on the amount of consolidation (solidification) of the lungs produced by various doses. If we put a large dose of the virus into the nose of a mouse, it will die in a few days with the entire surface of its lungs consolidated. Smaller doses will produce consolidation of only a portion of its lungs. We can adopt a convention that one unit of virus is the amount which on the average produces consolidation over 50 per cent of the visible surface of the lungs. To measure the strength of our extract from the lungs of the fatally stricken mouse, then, we dilute the extract in varying degrees, so that we have samples diluted to one part in 10, one in 100, and so on. Each of these samples is inoculated into the noses of six mice four to five weeks old. A record is kept of deaths in each group and of the aspect of the lungs when the surviving mice are killed seven days after inoculation. If we find that 50 per cent consolidation occurs, on the average, in mice given a 1-to-10,000 dilution of the extract, while other doses produce more or less consolidation, the original extract is reckoned to have a strength (titer) of 10,000 units of virus. This principle of diluting something down in a series of steps until it produces a certain standard degree of action is very cumbersome in practice and not very accurate. Furthermore, when the titer has to be measured by its effects on monkeys, as in poliomyelitis research, or on human volunteers, as in the study of colds, the process becomes enormously expensive. But so far no more convenient method of measurement has been found, and for most viruses the dilution technique will probably remain the standard quantitative procedure.

The fact that research on influenza virus is much further advanced than research on poliomyelitis is very largely due to the greater facility of measurement. The action of influenza virus can be measured not only in the mouse and the chick embryo but also in the test tube. When the virus is mixed with a suspension of red blood cells in saline, it causes the cells to clump in easily visible fashion. George K. Hirst, then of the Rockefeller Institute for Medical Research (he is now at the Public Health Research Institute of New York City), discovered this agglutination phenomenon in 1941 through a lucky accident. He was examining chick embryos that had been infected by injection of virus into the fluid-containing cavities that surround the embryo. The fluid in these sacs was known to be very rich in virus. During such an examination some infected fluid, mixed with a little blood, usually spills over into the dish. Hirst noticed that the blood cells in the spilled mixture collected into coarse clumps. It is the mark of a first-class investigator to see the implications of an unexpected occurrence. Hirst immediately grasped the potential importance of his observation. If the virus, or something associated with it, could produce this easily visible effect in the test tube, here was a direct means for recognizing the virus' presence and measuring its amount. It was a relatively simple task to devise an appropriate test along these lines. In the course of this work it was established that the virus itself produced the effect on the red cells. Since then various applications of the agglutination technique have made it possible to analyze the qualities by which one type of virus differs from another.

How It Attacks the Cell

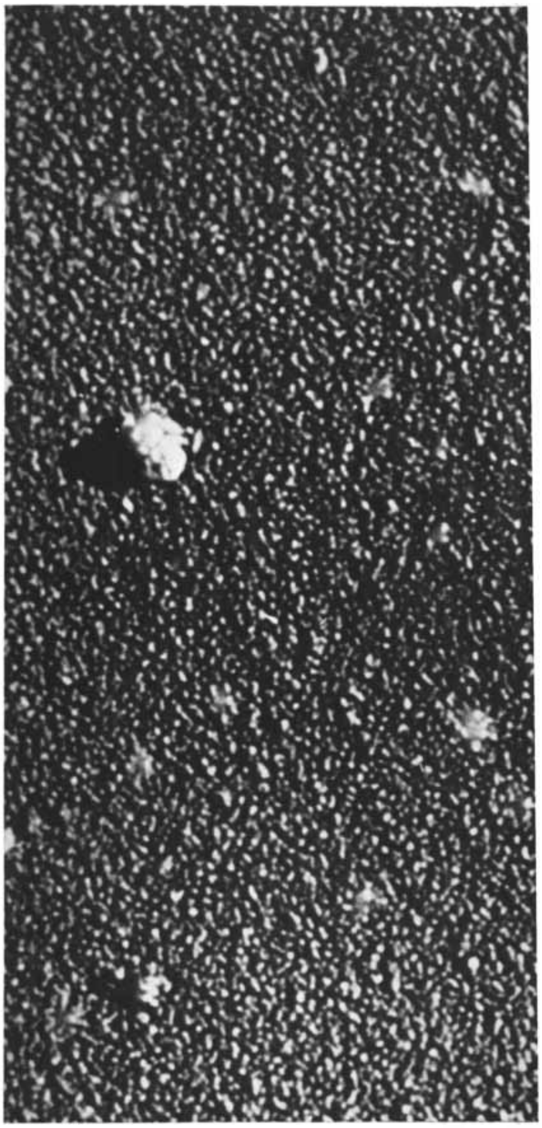
The very fact that the influenza virus agglutinates blood cells has provided the most important of all leads to an understanding of how the virus makes effective contact with the cell it is going to infect. Red blood cells themselves are not susceptible to penetration and infection by influenza or any other virus. But the surface of the red cell seems to have essentially the same complex mosaic of chemical components as any other cell from the same species of animal. There is much direct evidence that the action of an influenza virus on the surface of red cells corresponds closely to its action on the susceptible cells that line the air passages of a ferret or a mouse. Experiments with red cells may therefore provide a convenient model of what happens in the more important but less accessible tissues of the lungs and bronchial tubes.

From large numbers of experiments in many laboratories we have a fairly clear picture of the process by which an influenza virus initiates infection of a cell. The virus seems to approach the cell surface through a reaction closely resembling that between an enzyme and the substance it acts upon. The virus particle has on its surface a number of patches which function as enzymes. These enzyme patches attach themselves to and break down certain molecules of a complex carbohydrate that are built into the surface of the cell. The virus can then sink into the substance of the cell and there begin to multiply.

The points on the cell surface to which the virus attaches are spoken of as receptors, and the complex carbohydrate of which they are composed belongs to the class called mucins or mucopolysaccharides. These are sticky substances like those responsible for the stickiness of egg white and saliva or for the slime track of a snail. The receptor mucin is closely related to the mucins that form a protective film over all the moist air and food passages, provide the chemical basis for the blood groups A, B and O and serve as one of the most important of the sex hormones, gonadotrophin. Influenza virus acting as an enzyme, it has been found, will rapidly destroy the activity of the hormone responsible for the sexual development of the immature female rat or mouse—here surely is a most unexpected crossing of paths between two distinct fields of biology.

In the course of work in my laboratory in Melbourne we found that the organism responsible for cholera produces an enzyme of the same type as the influenza virus enzyme. This enzyme is not part of the cholera germ but is set free in soluble form and can be concentrated and purified by chemical methods. We call it RDE (receptor-destroying enzyme). The isolation of this substance provided an opportunity for a very interesting experiment. If RDE destroys the cell receptors, and if influenza virus can enter cells only through such receptors, then an injection of RDE should make an animal immune to influenza. Joyce Stone of our laboratory performed the experiment both on mice and on chick embryos and found that this was indeed the case. The immunity is very short-lasting, however, for the cells regenerate fresh receptors within two or three days.

So far this mechanism of cell entry by viruses has been definitely established only for viruses of the influenza group. But within the last year somewhat similar observations have been made on two groups of viruses closely resembling, but not identical with, the poliomyelitis viruses; mice have been protected against infection by one of these types of virus by prior treatment with RDE. It is too early to say whether developments in this field will have any significant influence on the prevention or treatment of virus diseases of man. There is nothing of the sort immediately in sight, and for the time being research of this kind must look for its justification more in the interest of the problem itself than in the promise of medical or economic benefit from its solution. But the work done so



INFLUENZA VIRUSES are made visible as small white spheres by an

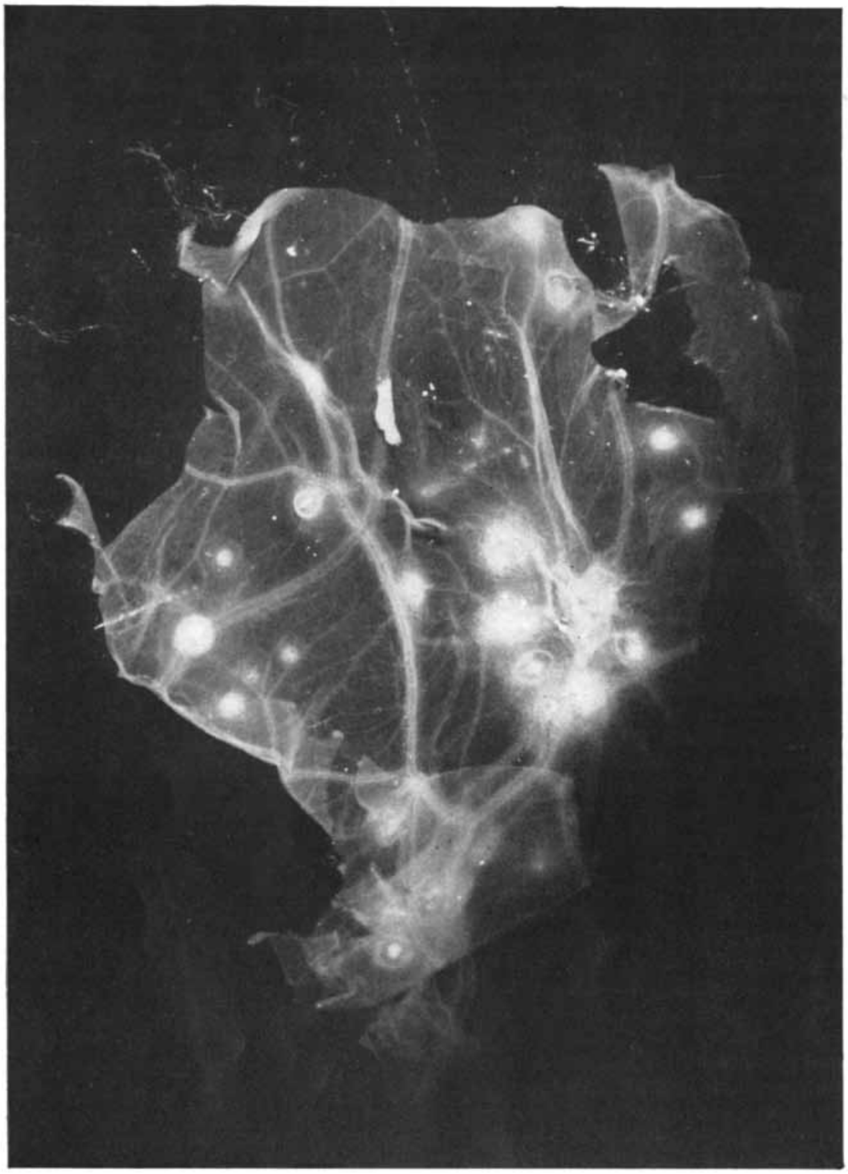
electron micrograph. The rod-shaped particle at top center is a filamentous form of the virus. This micrograph, which enlarges virus particles 47,000 times, was made by R. W. G. Wyckoff of the National Institutes of Health.

far suggests that the chemistry of cell entry by viruses may eventually become of great importance to workers in virus diseases.

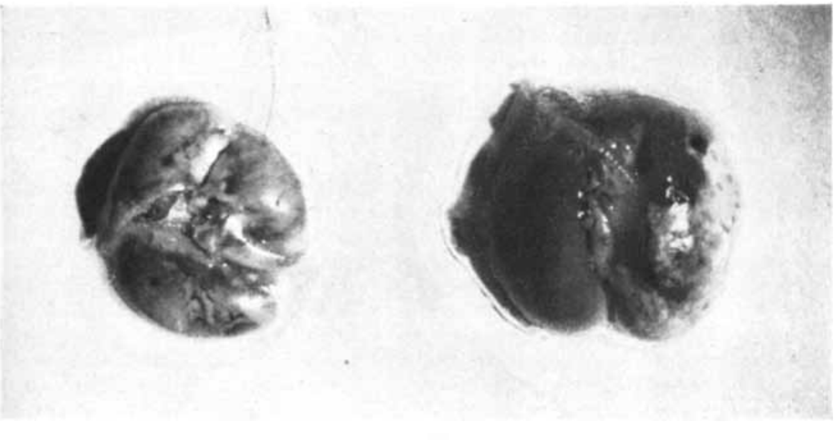
Changes in the Breed

When a virologist undertakes an investigation of a human disease, his first concern is to find some laboratory host for the virus. His next is usually to "hot up" the virus for the new host so that it will regularly produce whatever symptom or lesion is being used as an index for the presence of the virus. Only rarely does fresh virus from a human patient multiply easily in the laboratory animal. Ordinarily it must be adapted to the animal by a series of transfers, or "passages," from one individual to another in the new host. It follows, therefore, that what the virologist works with is strictly speaking not the human virus he started with but a variant—a laboratory-adapted variant. Sometimes the difference may be very striking indeed. The stock influenza viruses of the laboratory are studied mainly by observing their capacity to produce pneumonia in mice or to agglutinate red blood cells in chick embryos. Influenza virus A as it comes from the human throat is quite incapable of doing either of these things. Similarly the virus used for vaccination against yellow fever, though a live, lineal descendant of a fatal virus taken from a patient who died, produces no illness at all, because it has been changed into a harmless strain by passage through chick embryos.

The capacity of viruses to change their character in nature or in the laboratory is obviously of the greatest practical importance. It is accomplished by the processes of mutation and selective survival. The human influenza virus becomes capable of growing freely in the chick embryo not because it has gradually learned how to do so but because random mutations have provided virus variants from which those most capable of surviving and multiplying in the chick embryo have been selected. Laboratory experiments have definitely proved that this is the case, not only for influenza viruses but also for bacteriophages (viruses that attack bacteria). There is much evidence, too, that influenza virus mutations occur in nature and play an important part in determining the timing and extent of epidemics of influenza. For some reason the influenza viruses appear to be especially mutable. This can be positively embarrassing at times. A standard influenza virus is sent to two laboratories which maintain it in slightly different fashions. At the end of 10 or 15 years the descendant viruses in the two laboratories may differ very considerably, and these differences can create confusion or even ill-feeling when investigators, thinking they are working with



COLONIES OF VIRUS grow as small white "plaques" on a membrane of the chick embryo. The virus is vaccinia, the close relative of the smallpox virus that infects cattle and is used to vaccinate humans against smallpox.



MOUSE LUNGS are a means of measuring the amount of influenza virus in a given extract. At left is a normal mouse lung; at right, an infected lung. Darker, or consolidated, areas are a measure of the amount of virus.

the same virus, obtain discrepant results.

Most present-day biologists would agree that the most fundamental aspects of living processes are all related in one way or another to the problems of reproduction and variation—the subject matter of genetics. If we are to get to grips with the real nature of viruses, it will be necessary to have a genetic approach here, too. The necessary beginning is to obtain a wide range of mutants with each variant as pure as possible, *i.e.*, at least 99.9 per cent of its population uniform. This is relatively easy to do in the case of influenza virus, which produces spontaneous mutations so readily that there is no difficulty in obtaining most of the mutants one desires. For other viruses the artificial acceleration of mutation by radiation or chemical treatment may become important, not only as an aid to research but also to produce variants that can be used for immunization against the diseases caused by these viruses.

The Virus in the Cell

Until recently it was a convenience to believe that viruses lived and reproduced very much like small bacteria; that is, that they multiplied by the same process of enlargement and division and differed from bacteria merely in the fact that they required a more complex nutrition, which only the interior of the living cell could provide. Today it seems that this is almost certainly incorrect. The virus actually multiplying in the cell is something quite different from the virus that passes as the infectious agent from cell to cell or from person to person. We do not yet understand the process that takes place inside the cell; when understanding comes, it may throw a flood of light on some of the most important aspects of fundamental biology.

This idea that a virus within the cell is distinct from the infectious particle whose picture is given by the electron microscope came first from studies of the viruses that attack bacteria—the bacterial viruses, or bacteriophages. Like the viruses that cause disease in man or animals, the bacterial viruses are incapable of multiplication except within the cells they infect. The virus particle first makes a chemical union with some component of the bacterium's surface and then by some process penetrates the cell wall and finds itself within the cell substance. After it has made this entry, the virus vanishes for a time; we can find no sign of its presence by any test. What happens can only be judged by indirect evidence. We observe, for instance, that when viruses are damaged beforehand by treatment with ultraviolet light, they can somehow combine their materials in the bacterium to produce whole offspring. Moreover, when two different viruses are made to infect the same bacterium, they yield a mixed inheritance, including forms that can only be interpreted as hybrids. From these evidences we conclude that the virus on entering the cell liberates or breaks up into a number of subunits, which are sufficiently analogous to the bearers of genetic characters in higher organisms to be called genes. Each gene multiplies more or less independently until a large "pool" of genes is created at the expense of the bacterial substance. Then from the pool groups of genes begin to aggregate in such a way that each group contains all the genetic components needed for the construction of the virus particle. Once formed, the group becomes a center of organization that draws to itself the material needed to complete the formation of a virus particle of the new generation. As new virus accumulates, the bacterium wastes and weakens until there is a sudden collapse of its structure, with liberation of 100 or more new virus particles.

The fact that this mechanism provides a means of combining the properties of two different viruses is a point of particular interest. The genes contributed to the pool by both parents are re-sorted and may appear in various combinations in the groups of offspring. Actually not only two but three or even more different viruses entering a bacterium may combine some of their hereditary characteristics in a single virus particle among their progeny! Hybridization is hardly an adequate term for such a process.

There are as yet no studies on animal viruses to match this work on the bacteriophages. Influenza virus, however, has been extensively studied along similar lines, and it is extremely likely that the eventual interpretation of its process of multiplication will be almost identical with that of the bacterial viruses. It has been found, for instance, that when an influenza virus is grown in one of the cavities of the chick embryo, the virus particles become attached to the cells within an hour; then they disappear until a fresh generation of descendant particles is liberated from the cells between five and eight hours after infection.

In the case of influenza virus, treatment of the particles with ultraviolet light can interfere with the multiplication of living virus in the embryo. It seems that this "killed" virus—killed at least in the sense that it never multiplies in susceptible cells—can often enter a cell and in some way block a component of the cell that is necessary for the reproduction of active virus. This interference effect also occurs when two living viruses infect a cell, if proper experimental methods are used. It plays an important part in the experiments which we shall now have to discuss. These provide more definite evidence as to how influenza viruses multiply.

In experimental biology one can often learn more about the working of an organism by observing its behavior in some alien environment than by watching it in its normal place in nature. We have obtained our most interesting results by injecting influenza virus into the mouse brain, which is even farther than the chick embryo from the virus' natural habitat—the human air passages.

Viruses in Foreign Cells

When an ordinary influenza virus is injected into a mouse's brain, even in rather large amount, the mouse may show some evidence of sickness for 24 hours but later recovers completely. The virus is not inert; some sort of abortive multiplication must take place, for the amount of virus often increases slightly in the first 10 or 12 hours and it does not disappear entirely until four or five days later. R. Walter Schlesinger of the New York Public Health Research Institute has obtained strong evidence that when virus enters "alien" cells, instead of multiplying in normal fashion it gives rise to something which may be called "partial virus." His finding was that the blood-agglutination test indicated a much larger amount of virus substance to be present in the cells than did the standard chick-embryo and mouse infection tests. This suggests that the virus offspring in the alien cells retain the ability to agglutinate blood but have weakened in their power to infect. The conception of "partial virus" is not easy to grasp, and many virologists are chary of offering any detailed interpretation of Schlesinger's facts. But his finding fits in rather neatly with the results of our mouse-brain experiments.

Although no ordinary influenza virus can infect the mouse brain, about 12 years ago a combination of accident and "training" in a laboratory in England did produce a strain of influenza virus that could multiply freely in a mouse's brain and kill the animal. This strain, which remains an influenza virus in every respect except its unusual ability to infect brain cells, we have named "neuro-flu" virus. It can be grown quite normally in chick-embryo cavities, giving highly infectious fluids for experimental use.

When highly diluted "neuro-flu" virus is inoculated into the brains of a group of mice, the animals appear quite normal as soon as they recover from the anesthetic. But after four or five days they begin to sicken, and a day later they die with signs of brain infection. Tests of the brain show that it contains very large amounts of fully active virus.

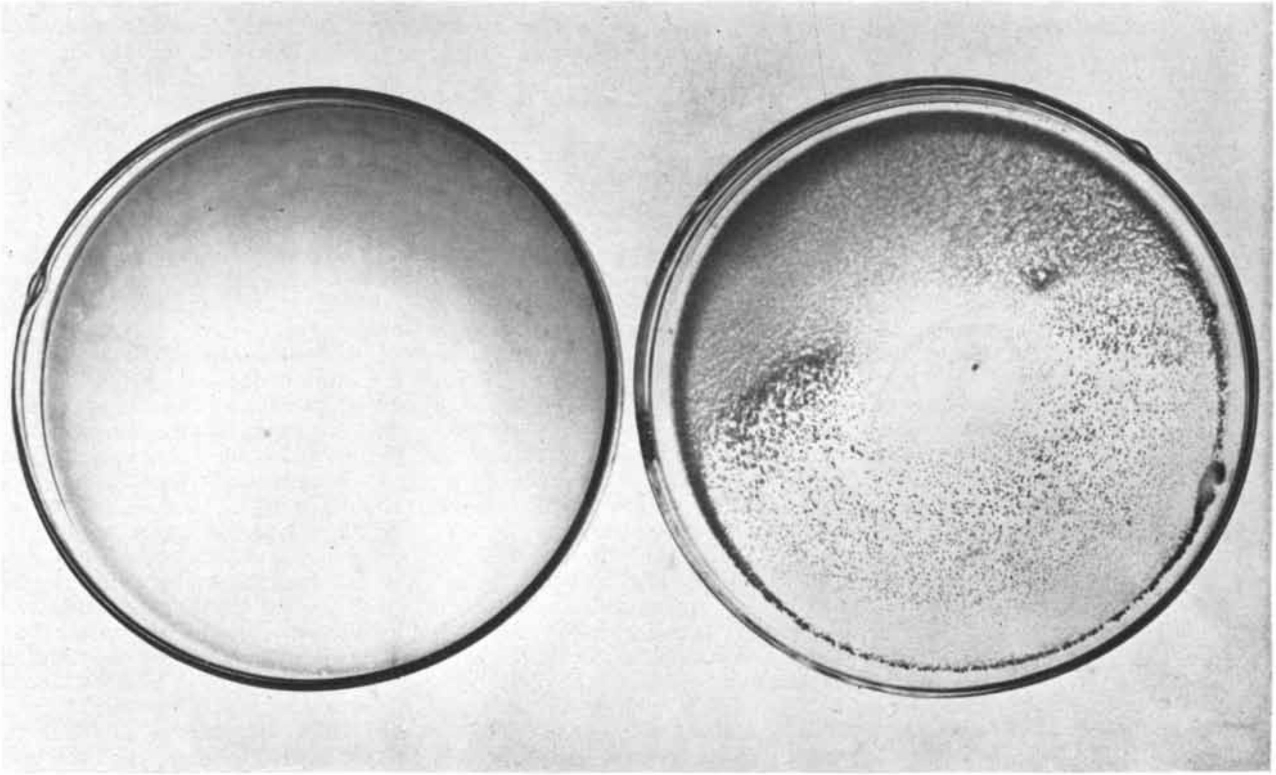
We found, curiously enough, that when a large amount of ordinary influenza virus is mixed with a little of this neuro-flu, the result of the injection is quite different. It might reasonably be expected that with the double infection the mice would probably die just a little sooner than if they had the neuro-flu alone. In fact they usually show no signs of illness whatever. The explanation is that there occurs a type of "interference," in a rather special technical sense of the word, which is well known to virologists. The effect depends on the relative amounts of the two viruses. A mixture of one part of neuro-flu to 10 or 100 parts of ordinary flu is harmless; when the mixture contains equal amounts of both viruses, there is little interference and the death of the animals is delayed only a short time.

An experiment in which mice received a mixture of the two viruses that produced partial interference, with some mice in a group dying and some surviving, yielded another very interesting result. Examination of the viruses in their brains showed that there were not two but three types: neuro-flu, ordinary flu and a third type which possessed several characters of the ordinary virus and the most obvious quality of the neuro-flu, namely its capacity to produce fatal brain infections. The most likely, though perhaps not the only, interpretation of these results is that the third type of virus is a "recombinant" in which the qualities of the other two have been combined.

So far there have been no accounts of any other experiments on this "hybridization" of viruses. For technical reasons it may be hard to find other situations in which the process can be shown. It is unjustifiable, therefore, to say that the conclusions derived from the neuro-flu experiments are applicable to other types of virus. Nor, to be quite honest, do I think that other virologists are yet as convinced as I am that the recombination experiments done in my laboratory in Melbourne have all the significance that I have given them. That is only likely to come when the experiments have been repeated and more deeply analyzed in other laboratories.

With these reservations, our interpretation of the experiments is that influenza viruses multiply in the same fashion as bacterial viruses. For most of the cycle inside the cell, virus as we normally know it is not present. The invading virus particle has given rise to genetic subunits, perhaps a dozen, perhaps a hundred, which for a time multiply virtually independently. We must assume that, as in the case of the bacterial viruses, toward the end of the cycle groups of "genes" come together from this pool of accumulated virus material to reconstruct the infective virus particles. Such a system could account for the various experimental findings: the "disappearance" of virus after the cell has been entered, the production of partial virus, the phenomenon of interference and the appearance of recombinant virus in mixed infections.

These may seem heretical concep-



CLUMPING OF BLOOD is another means of measuring the amount of influenza virus. At left is a dish containing chick red blood cells. At right is a dish of cells to which virus has been added; the cells have formed tiny clumps. The phenomenon was photographed in the laboratory of George K. Hirst, who first discovered it.

tions, and further studies may compel their modification, but there is no possible escape from the general conclusion that viruses are in no sense ultimate particles. They are complex organisms, with a genetic mechanism which has to be thought of as something other than the virus particle as a whole and which seems to be built up of units analogous to the genes of higher organisms.

Their Size and Chemistry

To the layman the most interesting thing about viruses is their smallness. There is a tendency to feel that until you can see something there is no way of studying it. This of course is a complete fallacy. With the electron microscope we can now produce very detailed pictures of influenza viruses and of the bacterial viruses, and every virologist has been excited and delighted by seeing them. We must know what viruses look like to satisfy our curiosity and to provide background for the refinements in the use of electron microscopy which in the future will make it a really valuable technique. But it is fair to say that what is revealed by these pictures has hardly helped at all in understanding how viruses produce the effects that make them so important. At the present time our pictures are only of the free virus particles; for technical reasons it is not yet possible to see what is happening while the virus is multiplying in the cell. Electron microscopists who are interested in viruses are seeking to devise ways in which clear pictures of what is happening in the early stages of cell infection can be obtained. This is obviously not going to be an easy task, but one can feel reasonably certain that it will be accomplished.

What electron microscopy has achieved so far is to show that viruses come in a considerable range of sizes. The smallest, those of poliomyelitis and foot and mouth disease of cattle, are approximately one-twentieth the diameter of the large ones, *e.g.*, those of psittacosis and smallpox. Nearly all appear roughly spherical in the electron microscope, but their true shapes may be distorted considerably by the drying in a vacuum which is an essential part of the preparation of a specimen for this instrument. There is one sharp exception to the rule of spherical shape. Certain types of the influenza and related viruses are extremely long and filamentous, and these are almost certainly an alternate form of the actual infectious virus. In the chick-embryo fluids containing these long forms, there are always large numbers of short and round forms as well. It has not yet been conclusively proved that the long forms will actually cause infection, but they certainly behave just like the small forms in the way they attach to the surface of a red blood cell.

The chemical structure of viruses is in somewhat the same shadowy realm as their physical appearance. With sufficient effort, instrumentation and ingenuity it is possible to obtain milligrams of "pure virus" from the fluids or tissues of infected animals. This can be analyzed by accurate micromethods for its elementary composition—so much carbon, hydrogen, nitrogen and phosphorus—and for the proportions of protein, carbohydrate, fatty materials and nucleic acids. With the new method of paper partition chromatography it is even possible to check the individual amino acids of the protein and the components of the nucleic acids. The results, however, tell us little more than that viruses are built of the same sort of material as other living organisms. Nucleoprotein, the most important component of the chromosomes in higher cells, is always present in viruses in moderately large amount; plant viruses may contain nothing but nucleoprotein.

Unfortunately a truly pure virus is a chemist's dream rather than a biological reality. If our views on virus multiplication are correct, one could never expect the virus particles made in the interior of a disintegrating cell to be free of adventitious fragments of substance from the cell. There is direct proof of this in the fact that influenza virus grown in mouse cells and thoroughly purified still shows by its reaction with an "anti-mouse" serum that there are some "mouse molecules" as well as virus substance on its surface. Similarly the same virus grown in a chick embryo can be shown to have some chick substance incorporated in it.

For these various reasons our information on the size and chemical nature of viruses is too meager to be in itself of any current help in understanding virus disease.

Immunity

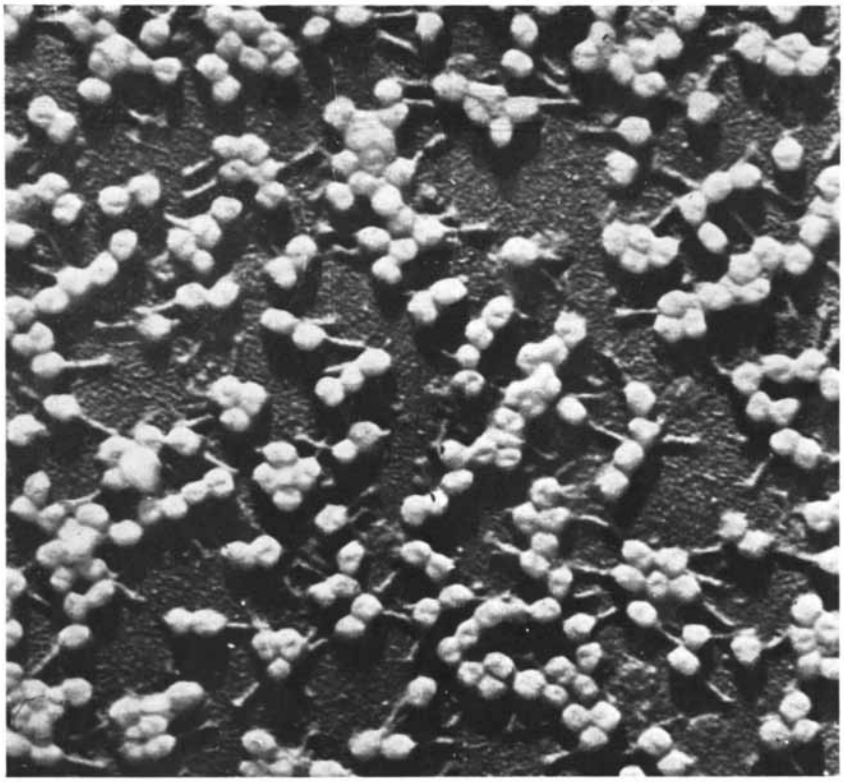
So far in this discussion of the virus and the cell, the host has played a purely passive role. The virus is the invader, and the effectiveness of its attack, it would seem, depends only on whether its genetic make-up is appropriate to the host cell concerned. Fortunately life is not like that. There is a rule about infectious disease to which I know of no exceptions: Whenever a parasite and its host species have lived together for many generations, they will have found a *modus vivendi* whereby the parasite species survives without producing more than minor damage to the host species. It would be of no advantage to the influenza virus to be so virulent that every human cell could be invaded and every human being killed in some ghastly pandemic. Having murdered its host, the virus itself would perish just as completely. The dramatic epidemic that kills a high proportion of those it strikes will always on investigation prove to be the result of some new development. In the old days of yellow fever in the West Indies the native population appeared unaffected by the disease, while European armies melted away in a few months under its onslaught. The Europeans were intruders into a virtually stabilized biological equilibrium.

The practical control of a virus disease nearly always depends essentially on obtaining an understanding of the means by which the balance between the virus and the host is maintained in nature and how it can be modified in either direction by biological accident or by human design. In the approach to such an understanding two important related concepts have emerged—"subclinical infection" and "immunization."

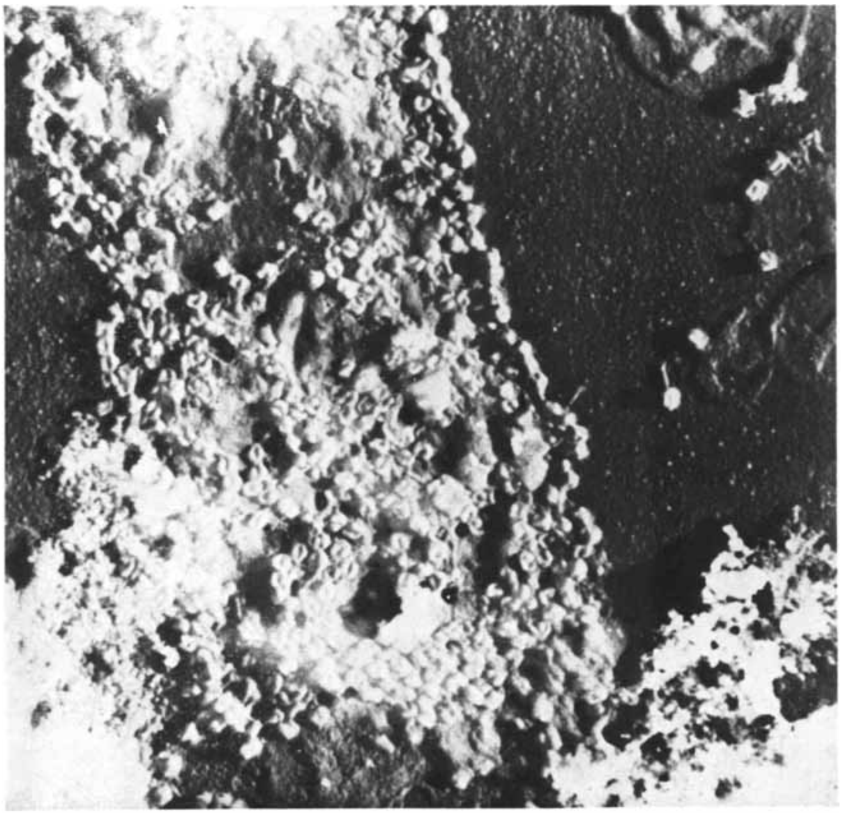
A subclinical infection is one in which the infected person gives no sign of any ill effect. In a population attacked by an infectious disease, subclinical infections often greatly outnumber those severe enough to produce unmistakable symptoms of the disease. For example, when a child comes down with a paralyzing attack of poliomyelitis, a careful examination of the rest of the family will commonly reveal that all the other children have the virus in their intestines over a period of a week or two, but they either show no symptoms at all or have only a mild, nondescript illness. Fortunately even a subclinical infection produces

CLUMP OF RED CELLS in the presence of influenza virus is shown by an electron micrograph. This micrograph, which enlarges cells and viruses 5,300 times, was made by F. Heinmets at the University of Pennsylvania.

INFLUENZA A AND B VIRUSES adhere to the dried "ghost" of a red cell to which they were adsorbed. This micrograph, which enlarges the viruses 9,000 times, was made by F. Heinmets at the University of Pennsylvania.



BACTERIAL VIRUSES which infect colon bacilli are revealed by an electron micrograph. This micrograph, which enlarges the viruses 40,000 times, was made by R. W. G. Wyckoff of the National Institutes of Health.



COLON BACILLUS infected by bacterial viruses is almost completely converted to virus particles. This micrograph, which enlarges the viruses 63,000 times, was made by R. W. G. Wyckoff of the National Institutes of Health.

heightened resistance or immunity to the virus for a period after the attack. This capacity of mild or subclinical infection to confer immunity is probably the greatest factor in maintaining a tolerable equilibrium between man and the common virus diseases. The trouble is that viruses are labile beings, liable to undergo mutation in various directions, and a virus that causes only mild infection may evolve into one far more deadly.

Malta and St. Helena

Perhaps the best available example to illustrate this point is the contrast between two epidemics of poliomyelitis that occurred during the last decade, one on the island of Malta, the other on St. Helena. Both were severe epidemics, but one attacked a much wider range of victims than the other. The Maltese epidemic (which began a few months after the siege of Malta had been lifted in 1943) was almost entirely restricted to the youngest children among the island's inhabitants; over 90 per cent of those paralyzed were under five years of age and more than half of these were under two years. On the other hand, the St. Helena epidemic not only involved the youngest children but also hit hard at the older age groups and even considerable numbers of adults.

We can assume that on both islands an unusually virulent type of virus was active and that every inhabitant was exposed to contact with infection. What was the reason for the difference in the results on the two islands? The clue lies in the past history of poliomyelitis in the two places. On Malta a few cases of infantile paralysis, almost wholly among very young children, had been reported each year for as long as accurate medical statistics had been kept. Evidently polio viruses of low virulence had been steadily disseminated among the population for many years. In such a community most of the babies would become infected quite early in life. Since the viruses were not very virulent, only a tiny proportion would be paralyzed. The others would develop a certain degree of immunity which later infections would strengthen. When in 1943 a more virulent polio virus appeared, the older children and adults, who had acquired such immunity, were little affected by the new virus. But among very young babies not previously exposed, the new virus caused a much higher proportion of paralysis than had the earlier mild forms. In other words, the fact that subclinical poliomyelitis had been prevalent on Malta for years, possibly for centuries, had ensured immunity against paralysis for all but the unlucky infants whose first contact with the virus was with an unduly virulent variety.

The poliomyelitis history of St. Helena was quite another story. On that island there had been no record of infantile paralysis for at least 20 years. It was a "virgin soil" for the virus. None of the adolescents or young adults had any immunity from previous exposure to polio. Hence the new invader struck with paralyzing effect in all these age groups.

The Host's Defenses

Immunity to virus disease was known long before any virus could be handled in the laboratory. In fact, it was from Jenner's early vaccination attempts against smallpox that the whole science of immunity sprang. But then immunology turned almost wholly to bacterial diseases. The toxin-antitoxin approach, which developed from the late 19th-century discovery of the cause and the means of prevention of diphtheria, for many years dominated the outlook of immunologists. In recent years the study of immunity in virus disease has been renewed, and it has profited from the concepts developed in the bacterial investigations.

One cannot claim that there is full agreement about the nature of immunity to viruses, but it is possible to offer a simplified account which most virologists would accept as at least the most convenient approach to understanding that is available at the present time. This interpretation is that all immunity to viruses is mediated through antibody, and that the effectiveness of the protection depends first on the amount and character of the antibody and second on the availability of the antibody to protect the particular cells that are exposed to infection. Antibodies can be described most simply as modified blood-protein molecules which are capable of attaching themselves firmly to the specific virus or other invading organism that provoked their production by the body. If a sufficient number of antibody molecules can attach themselves to a virus particle, they have a blanketing effect which effectively prevents the virus' attachment to the host cell and its multiplication within the cell.

Antibody appears in the blood a few days after infection and reaches a peak in two to three weeks. The body continues to produce antibody at a slowly diminishing level long after recovery—in some diseases, such as measles and yellow fever, for the whole of life. Immunity is long-lasting only against those diseases in which the virus must pass through the blood at some stage before it produces symptoms. The explanation, in general, is as follows: After any virus infection, the antibody produced in response to it is always concentrated most abundantly in the blood. In a disease such as measles, where the virus must pass through the blood, the large amounts of antibody there waylay any virus in a second invasion and render it inert before it has a chance to create any symptoms of illness. The virus of a disease such as influenza, which does not have to pass through the blood but spreads from cell to cell over the surface of the air passages in the respiratory system, has an easier time. The concentration of antibody here is always less than in the blood, and it soon declines to an amount insufficient for protection. Hence the immunity that follows an influenza infection is less complete and less lasting than that in a disease where the virus must run the gamut of the blood.

Artificial Immunization

To return to the problem of how a tolerable equilibrium between man and a common virus is maintained, the situation can be summarized as follows: The first contact with the virus normally takes place in childhood. How early it will occur depends on how prevalent is the virus and how effective are the social barriers against its spread, such as cleanliness and good housing. The standard virulence of the virus is low, and young children as a rule recover after a mild illness or no illness at all. This induces an immunity not only against virus of normal or low virulence but also against the occasional type that has undergone mutation to higher virulence. The process will never be completely effective. As long as the common virus diseases (measles, influenza, poliomyelitis) persist, there will be epidemics in which some patients will require all the help the physician can provide. But under present-day conditions the great majority of people pass through childhood and middle life with no more than trivial episodes of infectious disease. They have not escaped infection, but by the sequence of subclinical infection and immunization they have been kept from even knowing of its occurrence.

It is against virus diseases not commonly present in their own communities that people most need the protection of artificial immunization. Men having to work or fight in the tropics of Africa or South America must be immunized against yellow fever. Smallpox, still prevalent in many parts of the globe, may enter any country, so vaccination is a necessity for any traveler and desirable for all. In these two instances immunity is produced by procedures which very closely imitate the natural process of subclinical infection. The immunizing agent is a living virus, a variant of the virulent form which can be relied upon to produce no more than trivial symptoms. If its safety can be assured, this is the most effective type of immunization. But in many cases it is not possible to produce a variant that is both effective and safe. The only available method of immunization against such viruses is to inject relatively large amounts of killed virus. On the whole this is not a particularly satisfactory method, and the only human disease against which it has proved reasonably effective is influenza. Provided the proper type of virus is used in preparing the vaccine, and provided the immunizing dose is given not too soon before the epidemic, about 80 to 90 per cent protection can be expected.

The Hardest Question

From its very nature virus research, like bacteriology in general, has tended in the past to concentrate on medical and veterinary problems. It will probably always be carried on against a background of its significance for medicine. But if one looks around the medical scene in North America or Australia, the most important current change he sees is the rapidly diminishing importance of infectious disease. The fever hospitals are vanishing or being turned to other uses. With full use of the knowledge we already possess, the effective control of every important infectious disease, with the one outstanding exception of poliomyelitis, is possible.

Today the most intellectually exciting aspects of virology are not directly concerned with medicine. As I see it, the main interest of the virus to biology now is the possibility of using it as a probe in the study of the structure and functioning of the cell it infects. In many ways the cell is the center of life, the unit from which all but the very smallest organisms are built—ourselves included. All the biological sciences, with biochemistry and genetics in the lead, seem to be converging to attack the central problem of cellular structure and function. In this endeavor the detailed study of the interaction between the virus and the cell promises to be very fruitful.

The very smallness and simplicity of viruses have a special attraction to the biochemist bold enough to look for an answer to the hardest question he can ask: How is the specific pattern of living chemical structure reproduced within the cell? The answer to that will be more likely to come from the study of plant viruses than from any other source. For similar reasons geneticists are attracted to the possibilities arising from the investigations of the recombination of genes in bacterial viruses, now also becoming visible in some of the animal viruses as well.

Microbiology is today the queen of the biological sciences. It can provide biologists with work and pastime and reward for many generations to come.

F. M. Burnet is director of the Walter and Eliza Hall Institute of Medical Research at the Royal Melbourne Hospital in Melbourne, Australia.

MUSICAL TONES

The wave structure of music is made visible for the classroom

by Hugh Lineback

THE photographs on these two pages show oscilloscope recordings of musical notes and combinations of notes. They make visible the vibrations that the ear hears as sound, and they have proved to be very effective in teaching students the science of sound. The tones shown here were all made by a Hammond organ, which is especially suited to such a demonstration because the electrical signals that are converted to sound by the organ's loud-speaker can also be translated into patterns of light by a cathode-ray tube, so that the vibrations produced by the organ can be heard and seen at the same time. The visible wave patterns can be used to explain the three characteristics of a musical tone: pitch, loudness and quality.

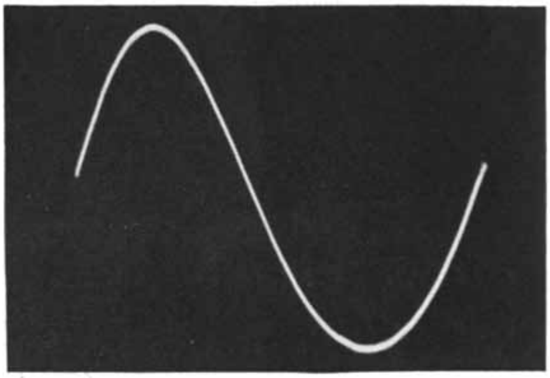
The pitch of a note is determined by the number of complete vibrations, or cycles, per second—what is called the frequency. The note A above Middle C on the piano, for example, is produced by a sound vibration with a frequency of 440 cycles per second. Taking this note as a reference, we call it the fundamental tone and designate it as A-440. By doubling the frequency we produce a note an octave higher, or A-880, and doubling it again we get the second octave, A-1760. A musical instrument produces these various notes simultaneously as harmonics, which are simply multiples of the fundamental frequency. In this case the first octave could just as well be called the second harmonic of A-440, the next octave the fourth harmonic and the next the eighth harmonic. Other harmonics fall in the intervals between octaves: thus the third harmonic of Middle A falls on the second E above it, the fifth harmonic on the third C Sharp, and so on.

The loudness of a tone is measured by the amplitude, that is, the height of the wave peaks. The larger the vibration, or amplitude, the louder is the sound.

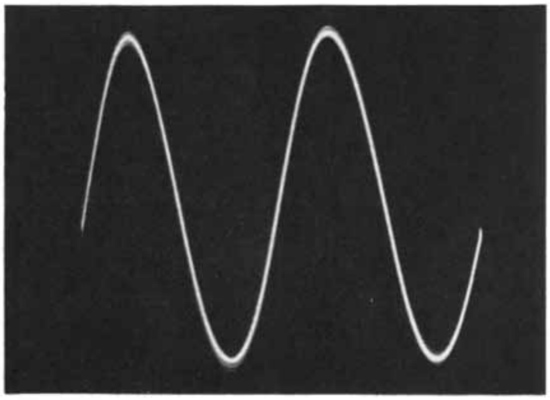
Even at the same pitch and loudness, one kind of instrument produces a markedly different tone from another. This third characteristic of a sound is known as its quality, or timbre. Timbre is determined by the blending of the fundamental and its harmonics in certain proportions. To obtain complex waves representing various instruments or tone qualities, the organ was set to produce combinations of harmonics of predetermined relative intensities, with the fundamental frequency at a certain strength, the second harmonic in a certain ratio to this, and so on.

These representations of harmonics make clear the qualities and limitations of various instruments. The fundamental tone alone would make rather dull listening. A predominance of high harmonics adds an effect of crispness, while the lower frequency components give power and dignity to music. Too much emphasis on the low harmonics may impart a muffled quality, and an absence of frequencies between the lower and upper harmonics contributes a weird and hollow effect.

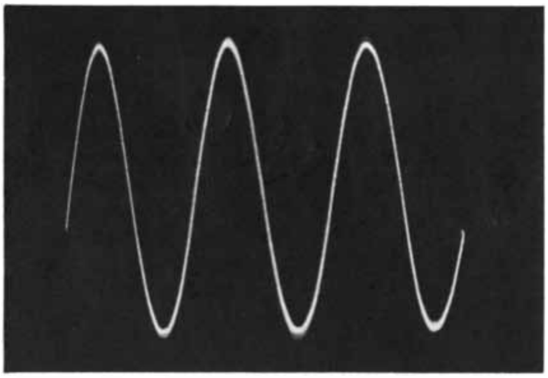
Hugh Lineback is assistant professor in the radio and electronics department of Oklahoma Agricultural and Mechanical College.



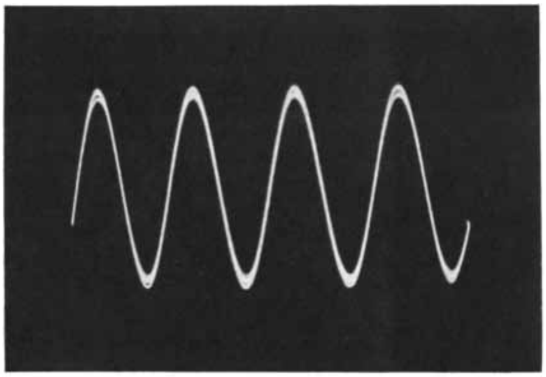
Fundamental



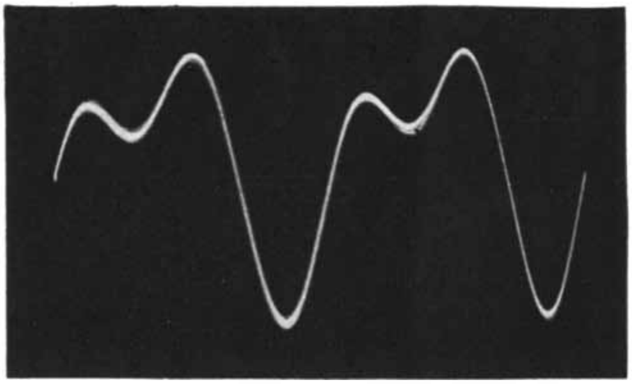
Second harmonic



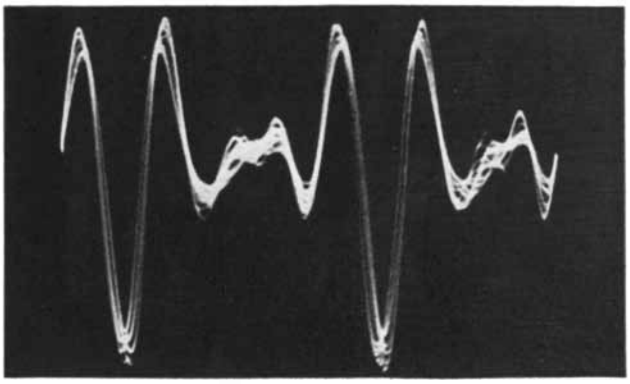
Third harmonic



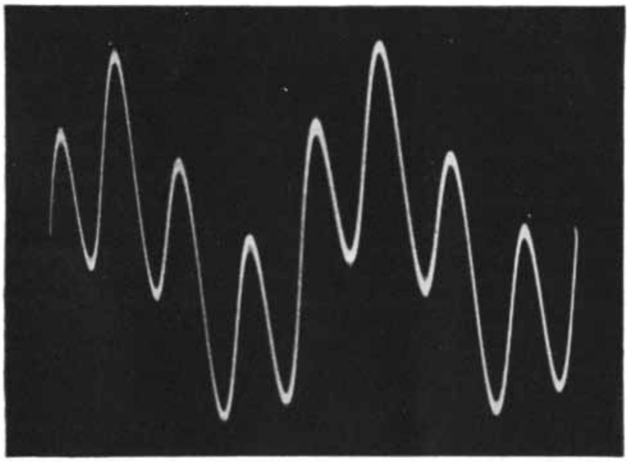
Fourth harmonic



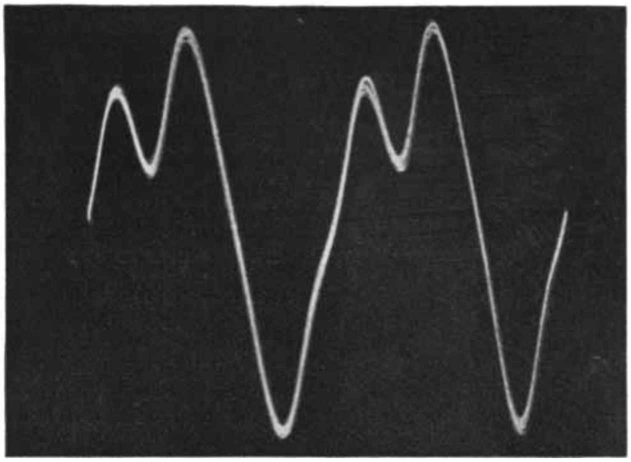
Combination of fundamental and second harmonic



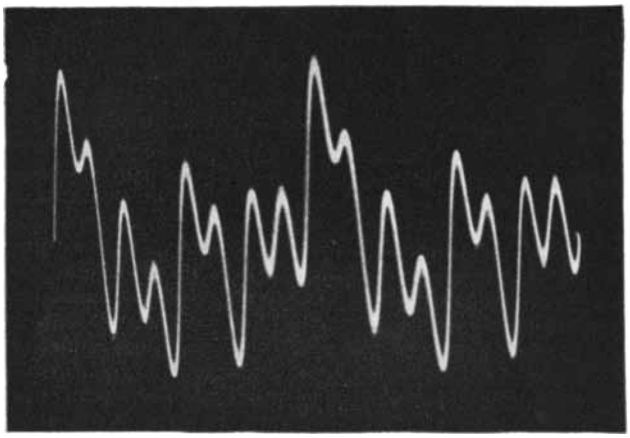
Tone of oboe



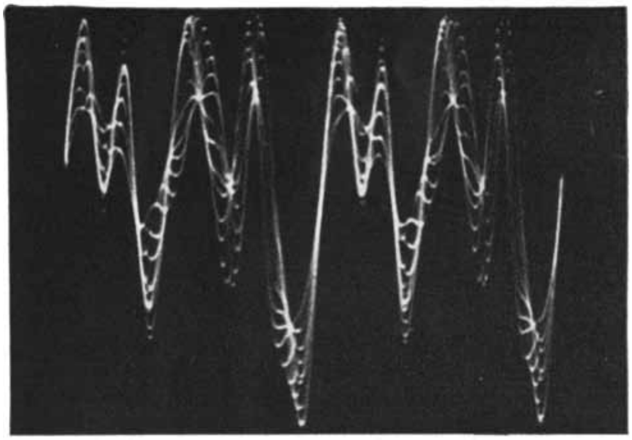
Combination of fundamental and fourth harmonic



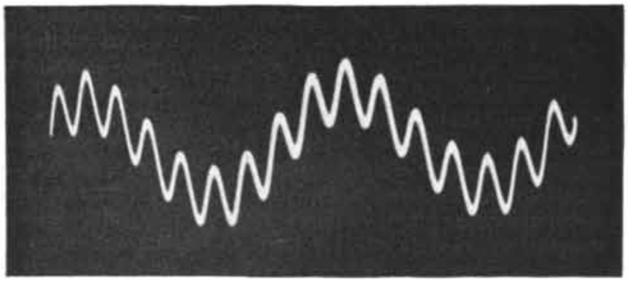
Tone of French horn



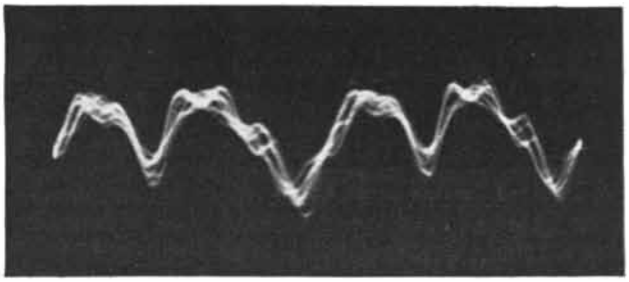
Combination of all even harmonics



Tone of trumpet



Combination of fundamental and eighth harmonic

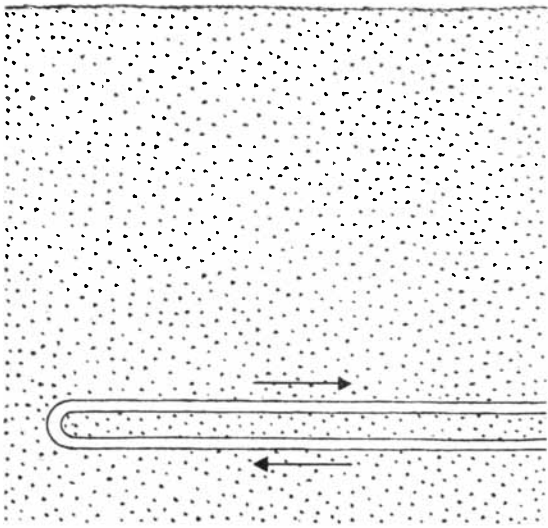


Tone of flute with strings

THE HEAT PUMP

Invented a century ago and widely applied in recent years, the device that utilizes the temperature of the ground or the air to heat and cool houses is still evolving

by John F. Sandfort



ONE KIND OF HEAT PUMP circulates a working fluid through pipe

IN recent years the heat pump has progressed from a theory to a practical reality which is receiving serious consideration by the heating industry. A great deal of engineering study is being given to the device by engineering societies, manufacturing firms and other organizations. Architects and home owners also are showing an increasing interest in this radically new type of heating system, which produces heat without the nuisances of combustion. Several heat-pump units are on the market. The number of installations in the U. S. already probably runs into the thousands. They range from small self-contained units in private homes to a large system recently installed for the heating and air-conditioning of the 12-story Equitable Building in Portland, Ore.

The concept of the heat pump itself is not new. As long ago as 1852 the great British physicist Lord Kelvin outlined the principle of the heat pump and proposed a design for a practical model. His calculations showed that such a system can deliver several times more heat energy than needs to be put into it in the form of work energy.

How is this possible? To understand the theory of the heat pump we must look into some of the principles of thermodynamics, which has to do with the interchange of heat and work.

A heat pump is a device for causing heat to flow from a low-temperature region to a region of higher temperature. It has long been established that such a process never occurs spontaneously in nature. The Second Law of Thermodynamics, one of the great scientific principles upon which our technology of heat engines rests, states that heat tends always to flow from a warmer body to a cooler. What the heat pump does is to apply work energy to reverse this flow.

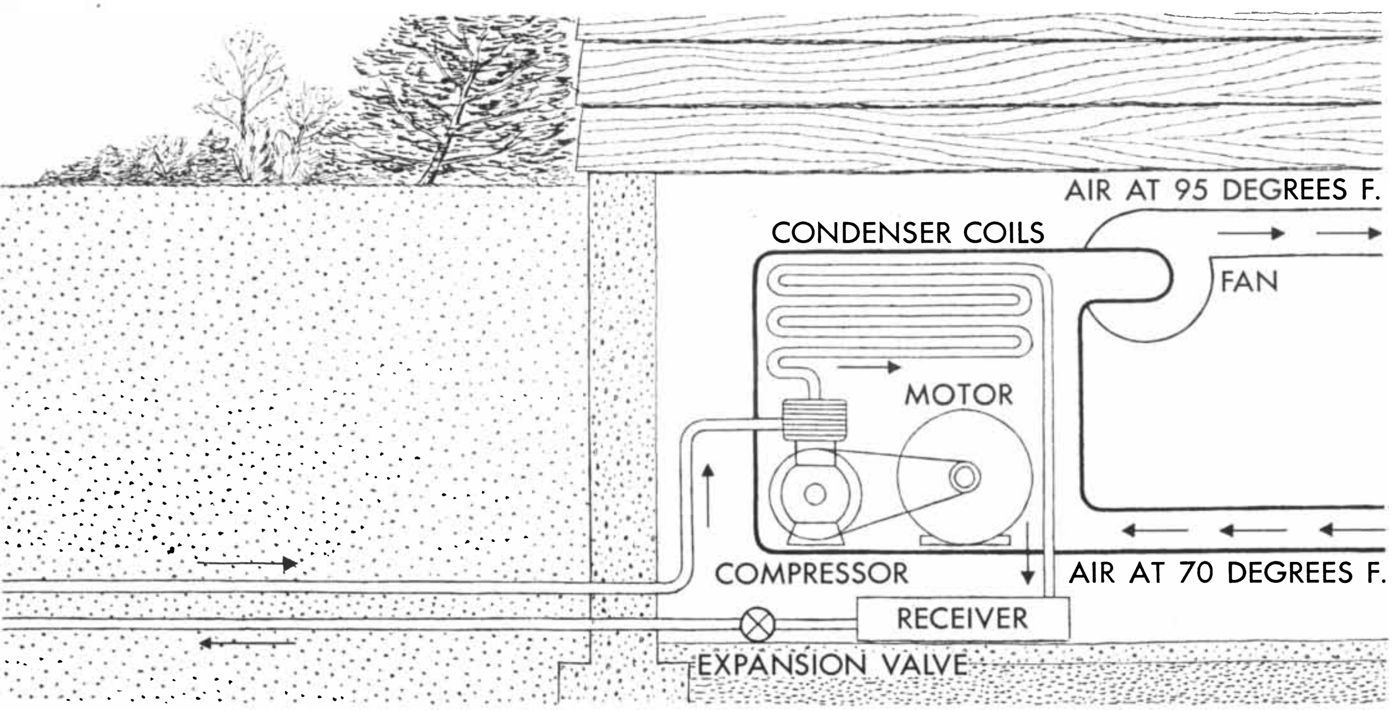
In 1824 Sadi Carnot, a young French army engineer and mathematician who had undertaken to explore the mysterious relationship between work and heat, published a historic treatise called "Reflections on the Motive Power of Heat." In it he showed, by logical reasoning from the Second Law of Thermodynamics, that if an appropriately designed system was placed between a higher-temperature heat source and a lower-temperature heat "sink," it would continuously produce work. Furthermore, he demonstrated that the efficiency of such a system, defined as the ratio of the work output to the heat input, would be a function only of the absolute temperatures of the source and the sink, and that its maximum conceivable efficiency could not exceed that of a *reversible* cycle operating between the assigned temperatures of the source and the sink. This is the essence of the classical Carnot principle. The system Carnot described was a heat engine.

Carnot went on to propound a theoretical heat-engine cycle which would be completely reversible when operating between two areas of different but constant temperatures. In its operation heat flowed reversibly into the engine from the high-temperature source; a portion of this energy was then converted to shaft work through appropriate frictionless processes, and the remainder was rejected reversibly by the engine to the lower-temperature sink. The performance of this engine was continuous, since the successive processes were cyclic in operation.

THIS was the famous Carnot cycle. Although the theoretical efficiency he postulated was unattainable in practice, his cycle has contributed much to the development and understanding of thermodynamics and heat-power engineering. Since it is a reversible cycle, its efficiency represents a theoretical maximum which gives us a standard against which the performance of actual cycles and engines can be measured. It can be shown that the theoretical thermal efficiency of the Carnot heat engine is equal to the temperature difference between the high- and low-temperature areas divided by the higher temperature, or $(T_1 - T_2)/T_1$.

Now it is quite obvious that by the simple process of reversing its operation the Carnot heat engine becomes a heat pump. Instead of using the energy of heat flowing from the warmer to the cooler area to do shaft work, we supply shaft work to drive heat from the cooler to the warmer area. Since the heat pump is fundamentally the same thing as the heat engine, the Carnot principle still applies. From it we can show that no heat pump can operate with less work input than a reversible heat pump having the same capacity and the same conditions of operation.

In the case of a heat engine the de-



laid in the earth. When the earth-warmed fluid is compressed, it can become hot enough to satisfactorily heat a house. In summer the process can be reversed to cool a house. In this diagram length of pipe has been shortened.

sired effect is a conversion of heat energy to work, and its efficiency is measured by the degree of perfection with which this is accomplished. In the case of the heat pump, however, the desired effect is not a conversion of energy from one form to another but rather a maximum transfer of heat to higher thermal potential with a minimum expenditure of work. The amount of heat being transferred is usually more than the shaft work consumed, so in this case the term "efficiency" has no meaning. Instead the standard is the "coefficient of performance," defined as the ratio of the desired effect to the work required to produce that effect. The heat pump actually has two applications: cooling and heating. In the first the desired effect is the removal of heat from a low-temperature body, and the system is called a refrigerator. In the second the desired effect is the supply of heat to a higher-temperature space or body, and this apparatus is the one known as the heat pump, although in reality both are heat pumps. The maximum coefficient of performance possible for any heat pump operating between fixed temperature limits is $T_2/(T_1-T_2)$ in the case of a refrigeration system and $T_1/(T_1-T_2)$ in the case of a heat pump.

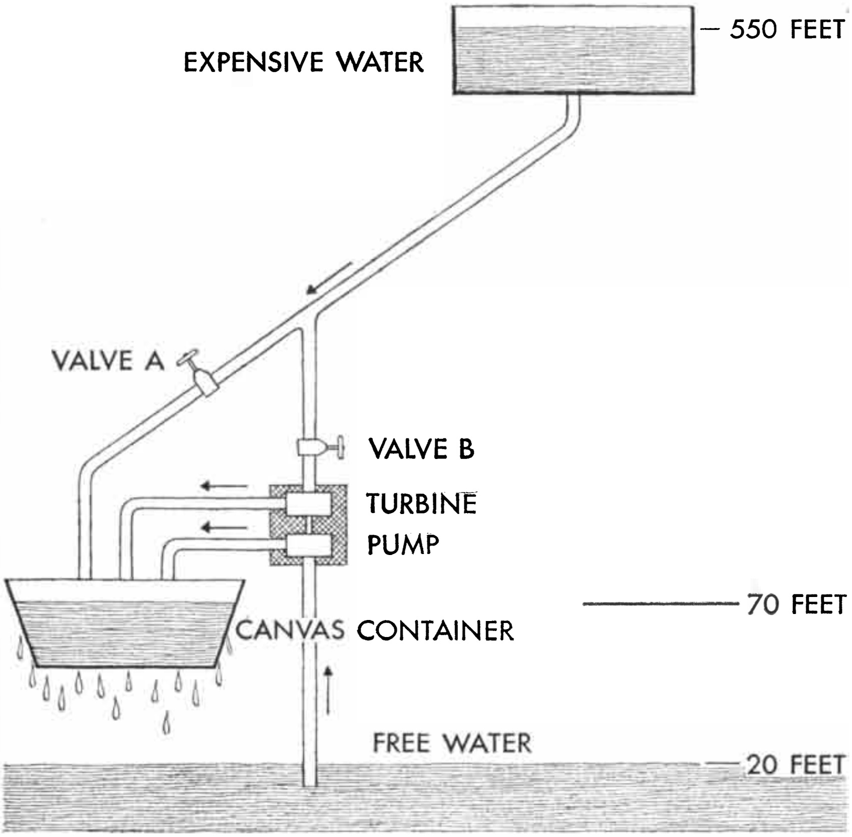
To illustrate what these performance figures mean, let us consider a Carnot heat engine operating between a high-temperature area of 70 degrees Fahrenheit and a low-temperature area of 20 degrees. (This is only a theoretical example; actual power plants operate on much greater temperature differences.) The theoretical maximum thermal efficiency of this Carnot engine would be 9.43 per cent. In other words, out of every 1,000 British Thermal Units per hour of heat input, 94.3 could be converted into work and 905.7 would flow as rejected heat to the low-temperature area. If this cycle were reversed and used as a refrigeration system, 905.7 B.T.U. per hour could be removed from the 20-degree region with an expenditure of only 94.3 B.T.U. per hour of work. In other words, its coefficient of performance would be 9.6. If it were used as a heat pump, the same expenditure of 94.3 B.T.U. per hour of work could supply 1,000 B.T.U. per hour to a 70-degree region (the air in a building, for instance). In this case the coefficient of performance would be 10.6.

So much for the theory. It is usually a big step from theoretical solutions to practical machines. To understand clearly the engineering problems involved in the heat pump, we must examine briefly the engineering development of the heat engine and of the reversed heat engine that has now come into almost universal use for refrigeration. In both these cases the translation from theory to practice required long, tedious work by many investigators and experimenters.

The modern heat engine is a "steady-flow" machine in which the working medium—a gas or vapor—continuously passes through different units of the apparatus, each designed to perform the functions of a particular process in the cycle. Most of the electric power generated in this country today, for example, comes from power plants operating on the so-called Rankine power cycle or variations of it. This cycle uses water as the working medium. Heat is added to the system by the burning of fuel, which changes the water to steam in high-pressure steam boilers. The steam is then passed through turbogenerators, where work, in the form of electricity, is taken from the system. After this the steam passes through condensers where heat is removed from the cycle and the steam condenses to water, which in turn is pumped back into the boiler, completing the cycle.

In the reversed heat engine, as used for refrigeration, the design of equipment is greatly influenced by the choice of refrigerant. The earliest designs, brought out during the last half of the 19th century, used air as the working medium. The usual arrangement was to pass cold air through a coil, where it absorbed heat from the surroundings and thus produced the desired refrigeration effect. The air was then compressed to a higher pressure and temperature and sent through a heat exchanger where its heat was removed by some natural coolant such as water or the ambient air. This high-pressure air was then sent through an expander engine. Its expansion helped drive the compressor. In addition, as the air expanded its temperature dropped to that in the cooling coil. The air then passed into the coil again and thus completed the cycle.

There were practical objections to



HYDRAULIC ANALOGY of the heat pump uses water instead of energy. To let the expensive water flow only through valve A would be a costly irreversible process. To let it flow also through valve B would be more efficient.

this cycle, the most important being the large piston displacement required to handle the large volume of air necessary to produce substantial cooling. Since manufacturing techniques were not yet sufficiently developed to permit the high rotative-compressor speeds of today, the necessary machinery was very ponderous. A vapor-compression cycle was therefore developed to overcome these objections. This cycle, which bears a close resemblance to a reversed Rankine power cycle, employs volatile liquids as the working medium. The compressor is retained, but the cooling coil becomes an evaporator and the expander engine of the air machine is replaced with a throttle or expansion valve. The vapor-compression cycle permitted an appreciable simplification of design. Furthermore, because of the high latent heat of vaporization of liquids, the cycle needs less circulating refrigerant, and this in turn allows smaller piston displacements and smaller compressors.

For a long time the most widely used working medium, or refrigerant, in this cycle was ammonia, which is relatively inexpensive and has favorable thermodynamic properties. But ammonia is inflammable under certain conditions and also is highly toxic to human beings. Ammonia has now been largely replaced as a refrigerant by the group of fluorine-hydrocarbon compounds known as Freons.

THE vast amount of research given to refrigeration systems will of course be helpful in the development of the third form of the heat engine—the heat pump for heating. Why has the use of the heat pump lagged so far behind the other two applications? Probably the answer is mainly a matter of economics. For power and refrigeration, in the form and quantity needed, the heat engine was the only available device. But for heating there was plenty of fuel to burn, and heat could be provided much more cheaply by simple fuel-combustion equipment than by a heat pump. But with the probability that our oil and gas reserves will diminish and with the growing realization that the heat pump can give clean, convenient, fully automatic heat, plus complete air-conditioning, this system has begun to attract many engineers and consumers.

Perhaps the best starting point for a description of the heat pump is the design offered by Lord Kelvin, which is still basically sound. He proposed a two-cylinder thermodynamic engine which could be used for both heating and cooling buildings. It would use air as the working medium. The machine was designed to take in one pound of outdoor air per second at 50 degrees F., expand it into a receiver, during which time it would absorb heat from the outside air, and then compress it adiabatically (without removal of heat) in the second cylinder, back to atmospheric pressure. The pressure in the receiver was such that the subsequent adiabatic compression would bring the air to 80 degrees, at which state it was to be introduced into the building. The engine was so arranged that the work from the expansion cylinder helped drive the compression cylinder.

Kelvin calculated that with this cycle he could operate his engine ideally with only 1/35 as much work energy as the equivalent heat energy required to heat the air directly. He proposed to drive his heat pump with a steam engine, the available prime mover of his day, and he estimated that with adequate allowances for practical cycle efficiencies he could still realize 3½ times as much heating effect as would be realized if the coal consumed in generating steam for the steam engine were to be burned for direct heating.

Kelvin's analysis showed the possibility of remarkable savings in fuel consumption over the best possible performance of conventional heating systems. There was some talk of using his engine to heat and cool British Government buildings in India, but nothing came of it and no model was ever actually built. The whole scheme was premature, and the heat-pump idea lay dormant for about 75 years.

In the early 1930s the idea was revived, and reports of experiments with heat pumps again began to be published. A few field installations, some of appreciable size, were built. These systems were simply adaptations of the refrigeration and air-conditioning equipment of the day. They utilized the simple vapor-compression cycle. The condenser was set to operate at higher pressures and temperatures and so placed as to heat air recirculated from the building. The evaporator was usually located where it could pick up heat from the outside air or well water.

Most of the modern heat-pump research activity has been directed toward the problem of finding suitable energy sources and developing more efficient means of recovering that energy. The problem appears simple enough, but it has proved to be more difficult than it seems. Use of the outdoor air as the heat source has some serious drawbacks: it is necessary to move large volumes of air, which means high fan costs, and the air must usually be cooled below its dew point, with the result that frost builds up on the evaporator. Furthermore, on the coldest days, when the heating demand is greatest, the coefficient of performance is smallest, because of the low temperature of the energy source.

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source, but the cost is usually prohibitive because of the large quantities needed. Well water, with its year-round uniform temperature, is an ideal source. But well water is not always available, nor is its supply always dependable. Also, any large increase in the use of ground water for heating would almost certainly bring legislation restricting its use; restrictions have already been imposed in many localities on the use of well water in air-conditioning systems.

The most promising source of heat-pump energy is the earth itself. The thermal storage capacity of the earth is tremendous. It has been estimated that a cylinder of earth 30 feet in diameter and 100 feet deep could supply the entire seasonal heating requirements of a small residence. The temperature of this earth would drop only about 10 degrees, even if no heat flowed in from its surroundings. The problem in getting heat from the earth is obviously not one of quantity but of accessibility. The heat conductivity of earth is generally low, and many difficulties have been encountered in attempting to use this source efficiently.

STUDIES are now being made of systems different from that employed in refrigeration and air-conditioning. The vapor-compression cycle, which absorbs and extracts heat at fixed temperatures, is not ideally the most efficient for heating. Experience has shown that the most practical design for such a system is to add heat to circulating air which is rising in temperature anywhere from 25 to 60 degrees, and on the evaporator side to extract heat from fluids dropping in temperature. When we employ the vapor-compression cycle to heat a 70-degree space with air circulating to it at 120 degrees, for example, we are forced to add all the heat at that top temperature. This causes an appreciable increase in power requirements, due to what is called thermal irreversibility in the system. Ideal cycles can be devised which will reduce or even entirely eliminate this irreversibility. One approach is multi-staging; that is, employing two or more condensers and evaporators at different pressures and temperatures. This transfer of heat at progressive stages of temperature would increase coefficients of performance and still permit retention of conventional refrigeration equipment, although at increased first cost.

A more radical approach is to return to some modified form of the Kelvin air cycle. Some heat-pump manufacturers are now investigating the possibilities of the air cycle. For the heat pump the air cycle has appreciable theoretical advantages over the vapor-compression cycle, and the objections that caused the air cycle to be abandoned in refrigeration do not apply with the same force to heat-pump equipment. Recent improvements

MISTAKES IN SCIENCE

How Many of These Common Scientific Fallacies Are You Guilty Of Believing?

P. W. Bridgman

Do you believe that the general theory of relativity has been "proved"—that the arguments upon which it is based are accepted in toto by all reputable physicists? Do you believe that it is possible to give an accurate portrayal of experience by means of mathematics? Do you acknowledge as "established fact" the dimensions of the universe given to us by cosmogonists? Do you accept uncritically *all* judgments of time, space, wave mechanics, matter, mathematics, logic, etc., made by modern physics? Let Nobel Prizewinner P. W. Bridgman point out the error in these beliefs in his concise, readable

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in air-compression equipment developed in other fields may help overcome the old objections.

Only the future will tell what final direction heat-pump development will take. One thing is certain: there is a serious gap at present between the operating coefficients of performance of actual heat-pump installations and the maximum theoretical possibilities. It is reasonable to expect that engineering ingenuity will close this gap appreciably.

Even on the basis of present technology and the limited experience so far, the heat pump has demonstrated its value. In areas where power is relatively cheap and oil or gas comparatively expensive, heating by means of the heat pump may already be economically competitive with heating by oil or gas. The heat pump eliminates the need for chimneys, ash-handling equipment or fuel-storage space. It can provide both winter heating and summer air-conditioning. And it lends itself readily to completely automatic control.

The leader in heat-pump use and development has been Switzerland. That country, very short in natural fuel supplies but rich in hydroelectric power, is a natural area for this development. It has the largest heat-pump installations in the world.

THE annual consumption of energy for heating buildings in the U. S. is enormous. At present we are obtaining this energy almost entirely by burning up our natural fuels, with a strong trend toward increased use of natural gas and oil. Many engineers feel that this will eventually prove to be an unwarranted exploitation of our high-grade energy reserves. They suggest that we should use oil and gas only for those needs for which they are most advantageous, such as powering transportation, and should rely on our more abundant coal for heating buildings. The heat pump, drawing its power from coal-burning or hydroelectric central stations, could be one of the answers to this problem.

Ultimately, of course, we shall run out of natural fuel reserves in the earth, including the sources of atomic energy, if and when they can be harnessed for the production of power. But even in this extremity the situation will be far from hopeless. The sun's radiation will continue indefinitely as a fountainhead of energy. Because of it our rivers will continue to supply water power to great hydroelectric stations, and the earth will continue to bear vegetation from which synthetic fuels can be compounded. Man's problem now and in the future is to find more efficient ways to tap this energy source directly.

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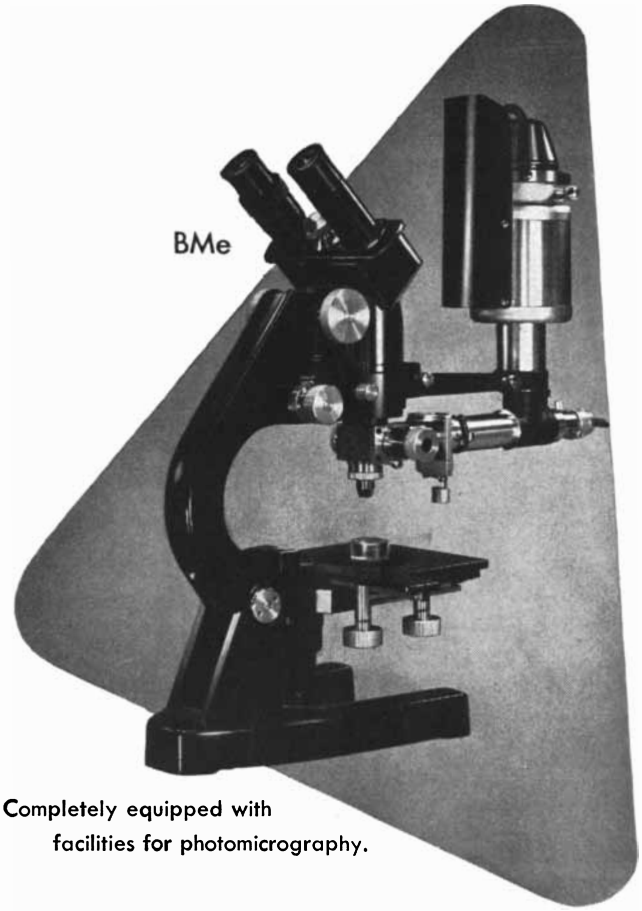
John F. Sandfort is associate professor of mechanical engineering at Iowa State College.



What People Dream About

In which 10,000 dreams are statistically investigated with respect to setting, cast of characters, plot, emotions and coloring

by Calvin S. Hall

MAN'S DREAMS have always interested and perplexed him. From ancient times and from every civilization and culture, we have evidence of man's concern about the meaning of dreams. They have been interpreted variously as divine messages, as the experiences of disembodied souls roaming heaven and earth during sleep, as visitations from the dead, as prophecies of the future, as the sleeping person's perceptions of external stimuli or bodily disturbances (what Thomas Hobbes called "the distemper of inward parts"), as fulfillments or attempted fulfillments of wishes (Freud), as attempts by the dreamer to discern his psychic development in order to plan for the future (Jung), as expressions of one's style of life (Adler), as attempted resolutions of conflicts (Stekel).

Probably all of these theories, however ancient their origin and however nebulous their validity, have their votaries today. Dream books based on the theory that dreams foretell the future are undoubtedly as widely consulted today as they were during the Renaissance, when the dream book compiled by the second-century soothsayer Artemidorus was republished in many languages and editions, and was plagiarized and elaborated by numerous opportunists, who in that day as in this knew a good thing when they saw it.

Even in modern times speculations about dreams have been long on theory and short on observation. What do people dream about? What is the content and character of their dreams? As far as I know, no one has made an extensive and systematic study of these questions. To be sure, psychoanalysts have given much careful analysis to the dreams of deranged and disturbed persons, but even for this unrepresentative segment of mankind there are no large-scale surveys of the content of their dreams.

The writer has undertaken to make such a survey, for the purpose of obtaining some empirical facts as a foundation for theorizing. He has collected more than 10,000 dreams thus far, not from mental patients but from essentially normal people. They were asked to record their recollection of each dream on a printed form which included questions requesting certain specific information, such as the setting of the dream, the age and sex of the characters appearing in it, the dreamer's emotions and whether the dream was in color. Obviously we cannot know how faithfully the subjects' recollections mirrored their actual dreams, so strictly speaking we should call our project a study of what people *say* they dream about. This has ever been the case and probably always will be, for no one has discovered a means of transcribing a dream while it is being dreamed.

We classified the dream material so that it could be studied statistically. From the many possible methods of classification we chose, as a beginning,

ACTIONS that are performed by the dreamer, which in the author's study come under the heading of plot, were divided into categories. The five categories shown from left on these pages were movement (34 per cent), verbal a simple breakdown into five fundamental categories: 1) the dream setting, 2) its cast of characters, 3) its plot, in terms of actions and interactions, 4) the dreamer's emotions, and 5) color.

WHAT are the most common settings in people's dreams? An analysis of 1,000 dreams reported by a group of educated adults provided 1,328 different settings. These could be classified into 10 general categories. The most frequent scene was a part of a dwelling or other building; this accounted for 24 per cent of all dreams. The other settings, in order of frequency, were: a conveyance of some kind, most commonly an automobile, 13 per cent; an entire building, 11 per cent; a place of recreation, 10 per cent; a street or road, 9 per cent; a rural or other outdoor area, 9 per cent; a store or shop, 4 per cent; a classroom, 4 per cent; an office or factory, 1 per cent; miscellaneous (including restaurants, bars, battlefields, hospitals, churches, and so on), 14 per cent. In dreams occurring in part of a dwelling the most popular room is the living room, with the bedroom, kitchen, stairway and basement following in order.

The outstanding feature of these dream settings is their commonplaceness. The typical dream occurs in prosaic surroundings—a living room, an automobile, a street, a classroom, a grocery store, a field. The dreamer may not always recognize the details of the place, but usually it is a type of scene with which he is familiar; seldom does he dream of a bizarre or exotic environment. Yet dream settings apparently are not entirely representative of waking life, as far as frequency is concerned. Considering the amount of time that people spend in places of work, such as offices, factories and classrooms, these places appear with disproportionately low frequency in dreams. On the other hand, conveyances and recreational places occupy a larger share in dreams than they do in waking life experiences. In other words, in our dreams we tend to show an aversion toward work, study and commercial transactions and an affinity for recreation, riding and residences.

FOR a study of characters appearing in dreams, we divided our subjects into two groups according to age, since it seemed likely that older people might differ from younger ones in the persons they dreamed about. The younger group was aged 18 to 28, the older 30 to 80. Let us consider the younger group first. They furnished a total of 1,819 dreams. In 15 per cent of these the only character was the dreamer. In the remaining 85 per cent, in which two or more characters appeared, the average number was two persons besides the dreamer.

Who are these characters? Of the persons other than the dreamer, 43 per cent appeared to be strangers, 37 per cent were identified as friends or acquaintances of the dreamer, 19 per cent were family members, relatives or in-laws, 1 per cent were famous or prominent public figures. The relatively infrequent appearance of prominent persons in dreams supports other evidence possessed by the writer that dreams rarely concern themselves with current events. Among the members of the family, the character that appears in dreams most often is mother (34 per cent); then come father (27 per cent), brother (14 per cent) and sister (12 per cent).

We also classified the characters in dreams by sex and age. It turns out that men dream about males twice as often as they do about females, whereas women dream almost equally about both sexes. In the dreams of both men and women 21 per cent of the characters are not identified as to sex.

The analysis showed, as is not surprising, that people dream most often about other people of their own age. In the sample of dreams from the subjects in the 18-to-28 age group, 42 per cent of the dream characters were the dreamers' peers in age, 20 per cent were older, 3 per cent were younger and 35 per cent were of unspecified age.

We found that in general there were no very pronounced differences between the characters in the dreams of the young and older groups. Older people dream more about family and relatives and less about friends and acquaintances, which is not very surprising, since the younger dreamers were for the most part unmarried. Older people also dream more about younger characters and less about older characters and peers than do younger dreamers. We may generalize our findings by saying that while children are dreaming about their parents, their parents are dreaming about them, and while husbands are dreaming about their wives, their wives are dreaming about them.

We come now to actions or behavior: What do people do in their dreams? We

(11), sedentary (7), visual (7) and antagonistic (3). The categories of appreciable size that are not illustrated were social (6 per cent), recreational (5), manual (4), mental (4), endeavor (4) and obtaining (3).

classified 2,668 actions in 1,000 dreams. By far the largest proportion (34 per cent) fall into the category of movement—walking, running, riding or some other gross change in bodily position. We found that, contrary to popular belief, falling or floating in dreams is not very common. After movement, the next most common activities were talking (11 per cent), sitting (7 per cent), watching (7 per cent), socializing (6 per cent), playing (5 per cent), manual work (4 per cent), thinking (4 per cent), striving (4 per cent), quarreling or fighting (3 per cent) and acquiring (3 per cent). From this it can be seen that passive or quiet activities occupy a large part of dreams, while manual activities are surprisingly infrequent. Such common waking occupations as typing, sewing, ironing and fixing things are not represented in these thousand dreams at all; cooking, cleaning house, making beds and washing dishes occur only once each. But strenuous recreational activities, such as swimming, diving, playing a game and dancing, are fairly frequent. In short, dreamers go places more than they do things; they play more than they work; their activities are more passive than active.

WHAT of the relations between the dreamer and the other characters in his dream? We classified the interactions in a sample of 1,320 dreams in various categories according to degrees of friendliness or hostility. In general, hostile acts (by or against the dreamer) outnumbered friendly ones 448 to 188. In the hostile sphere the acts of aggression ranged from murder (2 per cent) and physical attack (28 per cent) to denunciation (27 per cent) and mere feelings of hostility (8 per cent). The friendly acts ranged from an unexpressed feeling of friendliness to the giving of an expensive gift.

The emotions felt by dreamers during their dreams were recorded in five classes: 1) apprehension, including fear, anxiety and perplexity; 2) anger, including frustration; 3) sadness; 4) happiness, and 5) excitement, including surprise. Apprehension predominated, accounting for 40 per cent of all dream emotions; anger, happiness and excitement were tied with 18 per cent each, and sadness was the least frequent, 6 per cent. Thus 64 per cent of all dream emotions were negative or unpleasant (apprehension, anger, sadness) and only 18 per cent (happiness) were positively pleasant.

Yet paradoxically in the judgment of the dreamers themselves the dreams as a whole were rated pleasant much more often than unpleasant. They found 41 per cent of the dreams pleasant, 25 per cent unpleasant, 11 per cent mixed and 23 per cent without feeling tone. Older dreamers reported more unpleasant dreams than younger ones, but the difference was not great.

A question that has puzzled many students of dreams is why some of them are seen wholly or partly in natural colors ("technicolor"). I am afraid I have little to contribute to the solution of this puzzle beyond a few figures and a few negative conclusions. In a survey of over 3,000 dreams 29 per cent were colored or had some color in them and the rest were completely colorless. Women report color in dreams more often (31 per cent) than do men (24 per cent). There is a slight tendency for people over 50 to have fewer colored dreams than those under that age. Many people never experience color in dreams; on the other hand, a few have all their dreams in color.

What is the psychological significance of technicolored dreams? We have compared the dreams of people who dream entirely in color with those of people who never dream in color and have found no difference in any aspect of their dreams. We have compared the colored with the colorless dreams of the same person without discovering any way in which they differed. Nor can we find any single specific symbolic meaning in a particular color. We are forced to conclude on the basis of our present evidence that color in dreams is merely an embellishment, signifying nothing in itself.

WHAT do all these facts on the content of dreams mean? I shall present my general theory of dreams and show how some of the foregoing findings fit into this theory.

Dreaming is thinking that occurs during sleep. It is a peculiar form of thinking in which the conceptions or ideas are expressed not in the form of words or drawings, as in waking life, but in the form of images, usually visual images. In other words, the abstract and invisible ideas are converted into concrete and visible images. By an odd process which we do not understand, the sleeping person can see his own thoughts embodied in the form of pictures. When he communicates his dream to another person, he is communicating his thoughts, whether he knows it or not.

During sleep we think about our problems and predicaments, our fears and hopes. The dreamer thinks about himself: what kind of person he is and how well fitted he is to deal with his conflicts and anxieties. He thinks about other people who touch his life intimately. His conceptions are purely egocentric; there appears to be no place in dreams for impersonal, detached thoughts. Accordingly the interpretation of dreams—the translation of the dreamer's images into his ideas—gives us an inner view of him, as though we were inside looking out and seeing the world as he sees it. We see how he looks to himself, how others look to him, and how he conceives of life. This is the heart of the matter, and the reason why dreams are important data for the psychologist.

How a person sees himself is expressed in dreams by the parts the dreamer plays. He may play the part of a victim or an aggressor or both; he may conceive of himself as winning in spite of adverse circumstances, or losing because of these same adversities. He may assume the role of a saint or a sinner, a dependent person or an independent one, a miser or a philanthropist. As Emerson said, "A skillful man reads his dreams for his self-knowledge."

Although the characters in his dreams are many and varied, they probably all have one thing in common—they are all emotionally involved in the dreamer's life. If this is so, one may well ask, why do we dream so often about strangers? The answer is that they are not really strangers but personifications of our conceptions of people we know. A person who conceives of his father as stern and autocratic, for example, may in his dreams turn his father into an army officer or a policeman or a schoolteacher or some other symbol of strict discipline. Very likely he will also have other conceptions of his father, and for each conception he finds an appropriate older figure who personifies the particular father conception uppermost in his mind at the time of the dream. Many of these father figures will be strangers to the dreamer, although the qualities expressed will be familiar enough to him.

Similarly the dream setting may portray the ways in which the dreamer looks at the world. If he feels that the world is closing in on him, he dreams of cramped places; if the world appears bleak, the dream setting is bleak. Tumultuous and tempestuous scenery—raging seas, milling crowds, exploding bombs, thunderstorms—betokens an outlook of insecurity and chaos. In one series of dreams studied by the writer there was a plethora of dirty, dank and dismal settings—a visible projection of the dreamer's conception of a world decaying.

DREAMS are filled with the gratification or attempted gratification of impulses, particularly sexual and aggressive impulses. They tell us how the dreamer regards these impulses. If he thinks of sex or aggression as wicked, the expression of these impulses in his dreams will be followed by some form of punishment or misfortune. If he conceives of sex as a mechanical matter, he may have a dream like that of one young man who reported a nocturnal emission dream in which a lady plumber turned on a faucet for the dreamer. We study dreams, therefore, not to discover the wish motivating the dream, as Freud did, but rather to determine how the dreamer conceives of his wishes.

Dreams also provide a vista of the dreamer's conceptions of his conflicts. The dramatic quality of a dream—its plot, tensions and resolutions—is derived from an underlying conflict in whose grip the dreamer feels himself to be. In a series of dreams from the same individual we can see his conflict running like Ariadne's thread through the labyrinth of his dreams. The conflict may hang on with surprising tenacity over a period of years. Apparently the conflicts that motivate dreams are basic ones which rarely become resolved. We suspect that these internal wars have their origins early in life and are not easily, if ever, brought to a satisfactory conclusion.

In our studies of many dream series, a few conflicts stand out as being shared by many people. One such inner tug-of-war is that between the progressive pull of maturity, growth and independence and the regressive pull of infantile security, passivity and dependence. This conflict is particularly acute during adolescence and the late teens and early twenties, but in a large proportion of people it persists through later ages and returns to prominence in old age.

Another ubiquitous inner conflict is that between conceptions of good and evil—the moral conflict. The opposing forces are those of impulse and conscience. The dreamer impulsively kills a dream character and is then punished for his crime. Or he is driven to express sexuality for which he suffers some misfortune.

A third conflict arises out of the tug between the opposing tendencies toward integration and disintegration. By integration is meant all of the life-maintaining and love-encompassing aims of man; by disintegration, the forces of death, hate, fear and anxiety which produce disunity and dissolution. One pole affirms life and love, the other affirms death and hate. Anxiety dreams and nightmares express the conception of personal disintegration.

WE study dreams in order to enlarge our understanding of man. They yield information that is not readily obtained from other sources. This information consists of man's most personal and intimate conceptions, conceptions of which not even the person himself is aware. It is important to know these conceptions, for they are the foundation of man's conduct. How we view ourselves and the world around us determines in large measure how we will behave.

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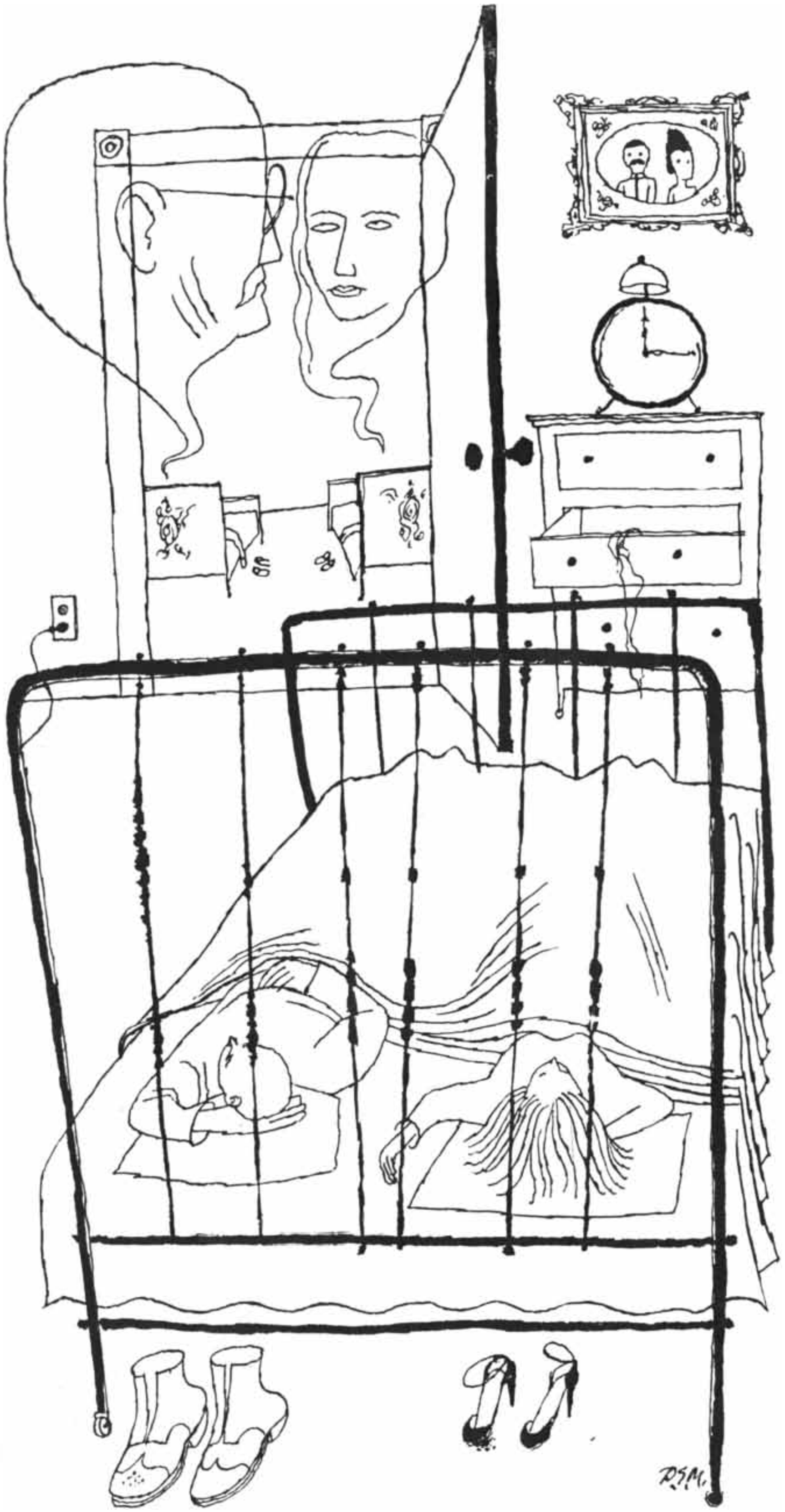
Calvin S. Hall is chairman of the division of psychology at Western Reserve University.



PARENTS AND CHILDREN revealed a significant dream pattern. The parents tended to dream about the children and the children tended to dream about the parents. The same appeared to be true of husbands and wives.

THE CANADIAN METEOR CRATER

An account of the discovery and exploration of the two-mile crater on the barrens near Hudson Bay. If it is conclusively shown to be meteoritic, it is the largest yet found on earth

by V. B. Meen

AERIAL PHOTOGRAPH on which the Chubb Crater was discovered was made by a Royal Canadian Air Force plane flying at 20,000 feet. The crater is the circular object at the left center; to its right is Museum Lake.

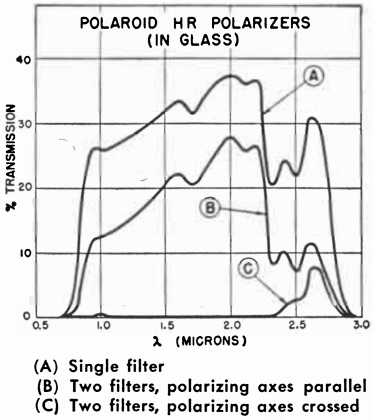
In February of last year Frederick W. Chubb, a prospector of Whitby, Ontario, was looking over some aerial maps and photographs of northern Canada with the idea of spotting likely locations to search for mineral deposits. The photographs, taken by the Royal Canadian Air Force, had only recently been made available to the public, and they provided the first aerial views of much of the uncharted northern wilderness. Chubb came upon one photograph with a most unusual feature. It showed a terrain laced with the long, irregular lakes that are typical of northern Canada. But in the center of the photograph was a lake that was perfectly circular! Moreover, it was surrounded by a rim which evidently stood several hundred feet high above the general terrain. Apparently it was a crater.

Here was something to quicken the blood of any prospector or geologist. Chubb thought it might be the crater of an extinct volcano. If so, it might contain diamond deposits; perhaps this was the source of the diamonds that have occasionally been found scattered in the glacial gravels and soils around the Great Lakes, apparently carried down from the north by the glaciers of the past.

Chubb brought the photograph to me at the Royal Ontario Museum of Geology and Mineralogy in Toronto. I could not agree that the crater was volcanic. What little information was available about the geology of this region of northern Canada indicated that its rocks were old and that glaciers had been active there long after the rock strata were formed. The moving ice would have ground off and filled in any volcano in the area. Considering everything, it seemed to me there could be only one possible explanation of the crater: it had been made by a meteorite. With its high rim and circular shape, it closely resembled the great crater near Canyon Diablo in Arizona, the largest meteoritic crater so far found on the earth. To a geologist the exciting fact was that the new crater appeared to be some 10,000 feet in diameter—twice as large as the one in Arizona.

Certainly we could obtain no proof on the origin of the crater sitting in an armchair. Though Chubb and I had different opinions, and different hopes, we were one in our desire and determination to get to the site as quickly as possible to determine the crater's origin.

On the aerial map the location of the crater-like lake was given as 61 degrees 17 minutes north latitude and 73 degrees 40 minutes west longitude. This point is in the extreme northwest of the province of Quebec, on a peninsula between Hudson Bay, Hudson Strait and Ungava Bay (*see map on the next page*). The only transportation to the location must be by air. For weeks and months we worked to obtain funds for the expedition. Since the project had commercial



CRATER IS LOCATED at the northernmost tip of the huge province of Quebec. The region is almost totally barren, with no trees and little soil.

as well as scientific possibilities, I could not approach scientific organizations for financing. Eventually the Globe and Mail Publishing Company of Toronto offered to provide the transportation, and six public-spirited citizens supplied the necessary funds for equipment and supplies, both as a service to science and on the understanding that they would share in any commercial benefits realized by Chubb.

WE left Toronto in a Grumman Mallard amphibian plane on July 17, 1950. There were six of us. Besides myself and Chubb, they were Robert Hermes of Buffalo, a naturalist and photographer; Kenneth W. MacTaggart, a staff writer of the *Globe and Mail*; and the plane's pilot, William Poag, and engineer, Andrew Gabura. To avoid having to land in the salt water of Hudson Bay, we flew a somewhat roundabout route: from Toronto east down the St. Lawrence River to Seven Islands, then north across Labrador and Quebec to Fort Chimo just south of Ungava Bay. Here we refueled for the last time and took off on the last lap of 300 miles to the crater.

Ten miles northwest of Chimo the country became completely barren. All signs of trees disappeared, and even soil appeared scarce. The glaciers had scoured the rocks clean.

Excitement was at fever pitch. None of us had been in this country before, and our only information regarding the crater was the map and the single photograph, taken from an elevation of 20,000 feet. Finally we spotted the crater site, some 15 miles away. From a distance it did not appear impressive—just a low, brown hill melting into the surroundings. As we approached and swooped down at 200 miles per hour, the hill opened up and we saw the lake inside. As we came in still closer, we could make out the remarkable rim, towering over the lake and surrounding countryside.

Motion picture and still cameras went into almost continuous action as we circled and then flew through the crater. We might have landed on the lake inside the crater but for the fact that it was three-quarters covered — in July — with floating ice!

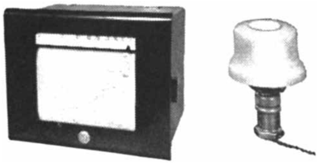
We made our landing instead on a moderately large lake two miles northwest of the crater. The lake edge was so full of boulders that we could not beach the plane. We assembled our sectional canoe and ferried ourselves and our gear ashore. There we found a narrow sand beach where we pitched camp. In all my years of field work I had never camped in so forbidding a spot. As far as the eye could see the ground was completely covered with boulders. This is the barrens of the arctic. No tree or shrub exists, and plant life of any kind is scarce. We saw no animals and few birds; even insects were relatively scarce.

Feeling very much like explorers, we promptly named the lake on which we had landed Museum Lake, and the crater, Chubb Crater. As soon as possible Chubb and I started off on our first trip to the crater. Walking over the boulder-covered ground was extremely difficult. The ground rose continuously from Museum Lake to the crater, and we had to climb over two ridges before we reached the steep slope of the rim itself. The slope had many patches of snow, with stratification indicating that the snow here never melts entirely, although during part of the short summer the sun is up 20 or more hours a day.

WE started up the 25-degree slope of the rim. The rim seemed to be composed of a jumbled heap of fragments of granite. At length, after a climb of nearly 300 feet, we set foot on the top and looked down into the crater. We were so awed by what we saw that I don't believe we spoke or even shook hands. Hundreds of feet beneath us lay a perfectly circular lake, cupped in a crater whose walls rose steeply in a slope of 45 degrees. No sound broke the stillness except the continuous grinding of the ice on the water far below and the wind blowing across the crater rim. From where we stood it was more than two miles (11,000 feet) across to the opposite side of the rim—almost the breadth of Manhattan Island at 42nd Street! We were looking down into what may well be the greatest crater of its kind anywhere in the world.

No sign of vulcanism appeared anywhere. Chubb's dreams of an extinct volcano and a fortune in diamonds vanished. Almost certainly the crater had been blasted by a giant meteor. But how to prove it?

The crater looks somewhat like a tilted cup, with one side considerably higher than the other. Using an aneroid barom-



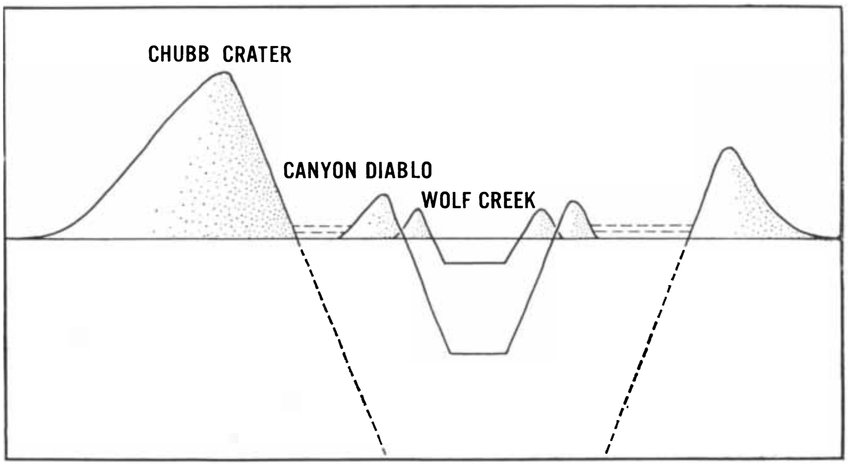
AUTHOR SURVEYS the interior of the crater. The highest point on the rim, 500 feet above the surface of the water in the crater, is at upper left.

eter I determined that the elevation of the rim top on the southwest was 300 feet (above Museum Lake) and at the highest point on the northeast, 550 feet. The rim is also wider on the northeast. Some of the proved meteoritic craters in the earth, notably the one in Arizona, have the same characteristics. So this was one fact strongly suggesting a meteoritic origin: the crater had just the appearance of a hole blown in the earth by an explosive missile striking at an angle from the southwest.

When I looked more closely at the broken rock that made up the rim, I found further evidence of a missile-caused explosion. The rim had a joint pattern radiating from the center, as if the original granite bedrock had been cracked and tilted by a gigantic blast. The top of the rim, the outer slopes and the surrounding plain were littered with rock fragments, which evidently lay just where they had originally fallen when they were blasted into the air. These granite fragments cover the ground to such a depth and so completely that for a distance of nearly two miles beyond the rim we found almost no other rock. We did come upon a few weathered fragments of diabase and peridotite rocks mixed with the granite on the rim; probably these were from a small body or bodies of such rock in the area blasted by the explosion.

The two ridges that we had crossed on the trip from Museum Lake to the crater also were composed of jointed granite bedrock. Our observations from the rim and aerial photographs indicated that the ridges were concentric ripples that extended all around the crater, surrounding the major ripple of the rim itself. Apparently they are compression ridges formed in the granite by the blast.

Chubb Crater also shows the marks of a splash effect, such as a drop of ink produces when it lands on a sheet of paper. Great trenches or rifts, some of them 200 feet deep, cut through the crater's rim in many places. The deepest are in the northeast part of the rim. Ridges of fragments continue outward into the plain beyond the ends of the rifts, thus accentuating the appearance of a splash effect.



SIZE OF THE CRATER is compared with that of Canyon Diablo Crater in Arizona and Wolf Creek Crater in Australia. Vertical scale is exaggerated.

Let me gather together the evidence concerning the origin of this gigantic hole. Positively it is not of volcanic or glacial origin. By negative evidence, at least, it must be of meteoritic origin. Certainly it is the result of a tremendous explosion which blasted a hole over two miles in diameter, raised a rim averaging 400 feet in height, pushed up ripples of solid granite around the rim, jointed the granite into a pattern characteristic of explosions and blew great quantities of the rim out into the surrounding area as ridges or splash marks. It is very similar in appearance to proved meteorite craters—but very much bigger than any previously found on the earth.

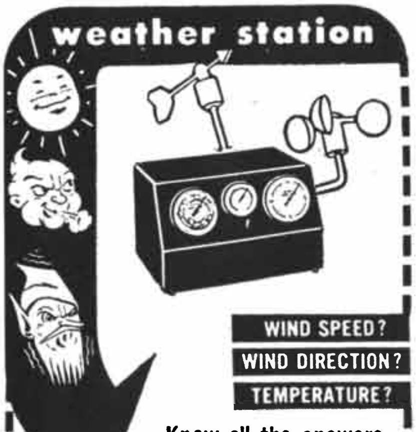
The one piece of evidence necessary to clinch the argument is a fragment of the meteorite itself. That we have not got. All the examination I have described was carried out in three days in three trips from our camp to the crater rim, including one trip around the top of the rim itself. We found no fragments that could be identified as of meteoritic origin. Actually if any such fragments survived the colossal explosion and the terrific heat generated by it, they should be scattered far beyond the rim. We were not able to examine much of this area because of the shortness of our visit. There is also the possibility that the meteorite was not metallic but was an aerolite or stony meteorite. If this was the case, the fragments would be difficult to distinguish on the boulder-strewn plain.

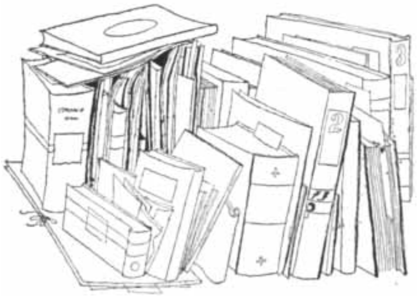
At the present time I am planning a second expedition. If sufficiently financed, we hope to be able to determine the depth of the crater lake and therefore the total depth of the crater, search the surrounding territory with mine detectors and magnets for meteorite fragments, make a magnetometer survey of the northeast part of the rim to determine if a mass of meteorite is buried beneath it and make a topographic survey of the immediate area to determine more accurately the elevations of the main features and their respective positions.

It is an ambitious program, but one well warranted by the scientific importance of this great crater. If Chubb Crater is meteoritic, it is the first such crater found on earth which is larger than the smallest noted on the moon. This should be very useful to the astronomers in their studies of the moon's craters. If we succeed in finding fragments of the meteorite itself, we shall have another sample from space of the shattered planet from which meteorites are believed to come, and this may shed further light on the probable composition of the interior of our own Mother Earth.

* * *

V. B. Meen is director of the Royal Ontario Museum of Geology and Mineralogy.





BOOKS

A study of the divorce of philosophy and science and their potential reconciliation

by Ernest Nagel

The Rise of Scientific Philosophy, by Hans Reichenbach. University of California Press ($3.75).

THE widespread conception of philosophy and science as radically independent fields of inquiry is of relatively recent origin. Less than two centuries ago it was usually assumed that at least part of philosophy's task was to analyze the structure and assumptions of the sciences, and thereby to make explicit the nature of knowledge and of the pervasive features of the universe. The later divorce between philosophy and science was due to a number of factors, but only one can be mentioned here. Under the influence of a powerful tradition it was supposed, even by some of the great masters of science, that the proper objects of knowledge must be truths which are capable of being established with complete certainty. It gradually became apparent, however, that knowledge obtained by scientific methods does not conform to these specifications. It was not easy for most men to emancipate themselves from the older tradition; many were persuaded that what could not be achieved by science could be attained through philosophy. In short, the view became fashionable, especially in Germany, that philosophy had a privileged access to ultimate truth, and that it could achieve a more profound understanding of things by turning its back on science. Philosophy was thus reputed to be the exclusive quest for the eternal and the certain. Indeed, many philosophers acquired a studied contempt for painstaking logical analysis, and produced speculative systems of the world that possessed imaginative and emotional appeal but found little support in empirical inquiry. And philosophy frequently served as an obscurantist defense for the intellectual and social *status quo*.

It is against this background that we must view *The Rise of Scientific Philosophy*. The book is divided into two parts; the first is a critique of the assumption, central to rationalist philosophy, that there are so-called "synthetic apriori" truths—that is, true propositions about the world which can be established by reason alone. The second and larger part of the book claims to show that with the help of modern tools of logical analysis, and when due heed is given to the findings and procedures of the empirical sciences, a number of outstanding issues in the theory of knowledge and the philosophy of nature can be definitively resolved. Its author, a professor of philosophy at the University of California who is well-known for many valuable contributions to the philosophy of science, has therefore written a vigorous plea for an end to the unfortunate divorce of philosophy and science.

Dr. Reichenbach's indictment of speculative philosophy as a way of achieving knowledge is severe, though often heavy-handed and not always judicious. The history of thought is not his forte, and he is not uniformly accurate in describing ideas men held in the past. He exhibits no sense of the cultural significance of traditional philosophy, nor of its leavening influence on the sciences. Nor does he always make it sufficiently clear that many defects of earlier philosophic systems were the reflections of mistaken views entertained by the sciences of their day. His attention is focused primarily on the supposed psychological causes that generate the pseudo-explanations of speculative philosophy, and for this reason also his critique lacks historical depth. Nevertheless he does point out the logical blunders underlying such explanations, and shows beyond doubt that philosophies of the synthetic apriori are a lost cause.

But the chief interest and real substance of the book is in its second part, where the reader is introduced to some of the achievements of what is called "scientific philosophy." It is perhaps unnecessary to say that scientific philosophy is not Dr. Reichenbach's individual creation, though the solutions he proposes to many problems are distinctively his own, and though much of the present book is simply a convenient summary of his previously published analyses. Scientific philosophy is an intellectual movement that is rooted in soil made fertile by logical and mathematical developments which began about a century ago; it counts among its contributors such eminent names as Mach, Poincaré and Russell. But it is not easy to characterize that philosophy in general terms. It is not committed to a fixed set of doctrines, nor even to a rigid technique of analysis. It has frequently revised its earlier tenets, and though Dr. Reichenbach sometimes gives the contrary impression, there is no complete agreement among those identified with it on many special issues. What can perhaps be safely said is that scientific philosophy finds no comprehensive plan controlling the operations of nature; that it attacks problems in a piecemeal fashion and eschews all attempts at a wholesale solution of nature's secrets; and that its standards of cogent reasoning and competent evidence are those which obtain in the empirical sciences. Its aim is to analyze and thereby to understand more clearly, rather than to moralize or to edify. It is not a discipline which can be sharply demarcated from science. The problems to which it addresses itself are problems germane to every science that has become conscious and critical of its methods and assumptions.

Modern science aims at generality, and at the same time it seeks to provide dependable guides for the intellectual and practical mastery of specific events. But the actual evidence for its laws and theories is never logically complete, and there is no logical guaranty that the guides to action which science provides will continue to function successfully in the future. Thus the procedure of science supplies support neither for a radical and sterile skepticism, nor for claims to final truth. A theory of knowledge adequate to the character of modern science must make explicit the remarkable fusion of deductive method and controlled observation by which science achieves dependable conclusions, and it must also deal seriously with the self-corrective procedure by which these logically uncertain conclusions become warranted. A good fraction of the present book is devoted to themes pertinent to such a theory of knowledge, and it is for this reason that much of the discussion is centered on the notion of probability. For the main thesis that emerges from Dr. Reichenbach's analysis is that all knowledge is only probable. He regards probability not merely as a concept basic to modern developments in natural science; he also uses it as a key notion in analyzing a variety of issues connected with the nature and grounds of inductive inference and the organization and interpretation of sensory experience.

Misconceptions of space and time have been serious obstacles to the recognition of the probability aspect of scientific knowledge. Indeed, rationalistic philosophies have drawn much of their sustenance from the alleged apriori nature of our knowledge of space and time. Dr. Reichenbach therefore devotes two chapters to the status of geometry and chronometry, in which the belief that they are systems of apriori truth is shown to rest on a series of confusions. Geometry (and similarly chronometry) is a body of apriori truth only as a branch of deductive mathematics, its asserted statements being then simply theorems of pure logic possessing no empirical content. On the other hand, geometry as a branch of physics is a set of contingent statements, and can be asserted only on the basis of experimental evidence. Moreover, the statements of deductive geometry do not refer to anything in particular, and expressions like "line" and "congruent" must first be interpreted in terms of physical configurations and processes before a geometric statement can be assumed to have factual content. Such interpretations are a species of definition; they are neither true nor false, but are decisions as to how language is to be used. Failure to recognize the need for such definitions in this and other branches of inquiry is still a potent source of belief in the synthetic apriori, and Dr. Reichenbach's discussion of this and related issues is authoritative and illuminating.

Dr. Reichenbach is an advocate of the statistical theory of probability, according to which probability is the limit of a relative frequency in an infinite series of items. Something like this interpretation is now widely accepted as the correct one for many uses of the word "probable," and his critique of the older Laplacian account of probability is excellent. However, he believes that there is no legitimate sense of the word other than the statistical one. He therefore maintains that even questions concerning the weight of the available evidence for a given hypothesis (for example, the probability of the gene theory of heredity relative to the known experimental data) must be reduced to the evaluation of a statistical probability. He argues that the traditional philosophic problem as to the reality of an external world can be resolved in terms of the frequency theory; for unlike many contemporary philosophers who also think they are employing a responsible method in their philosophizing, Dr. Reichenbach regards this question to be a genuine one. And he claims that the long-standing debate as to whether the inductive method of science can be "justified" can finally be given a positive answer on the basis of his analysis of probability. These issues and the proposed resolutions are too complex for adequate comment in this review. It must suffice to say that Dr. Reichenbach is far from being convincing in his claims concerning the universal scope and solvent power of the statistical notion of probability. These claims have been advanced by him in previous publications at greater length, and supported by an armory of detailed technical arguments; but thus far, at any rate, most contemporary students of the subject have not been able to endorse them fully. Dr. Reichenbach is somewhat less than just to those contemporary logicians who differ from him on the unique validity of the statistical theory of probability when he declares that in this respect they are "to be classified as rationalists." If a *sine qua non* for being a "scientific philosopher" is acceptance of the various analyses he advances as "established" conclusions, then it is likely that he is the sole bearer of the title.

Dr. Reichenbach is not concerned exclusively with issues in the theory of knowledge, and he has interesting chapters on the laws of nature, the ultimate constituents of the physical world and the mechanism of evolution. Partly on the basis of considerations drawn from quantum theory, he argues for the view current among physical scientists that the laws of nature formulate merely statistical regularities and express only relations of "probability implication." Indeed, he maintains that the notion of "strict causality" not only must be abandoned for subatomic processes but even for macroscopic events it is at best only an "idealization" or "simplification" of what actually occurs. Moreover, since the "unobservable" constituents of subatomic physics allegedly possess "causally anomalous" properties, he believes that the notion of "corporeal substance" is not adequate for describing physical reality in this sector of inquiry. On the other hand, he claims that the familiar but non-causal wave-particle interpretation of this reality can be avoided by adopting a new three-valued logic, which admits "indeterminacy" in addition to truth and falsity as a possible value for a statement. Dr. Reichenbach's examination of these and other matters is stimulating and generally highly readable. Nevertheless, some of his analyses are open to legitimate doubt, and raise questions he does not even try to settle. Is the notion of strict causality any more an "idealization" than his notion of probability implication? And is it quite accurate and clarifying to assert that all laws of nature formulate only probability implications? He himself appears to admit that for many macroscopic laws such a reading is practically irrelevant; and even for the behavior of atoms the "indeterminism" which quantum theory assumes falls far below the threshold of possible experimental detection. Dr. Reichenbach also ignores the interpretation of the principle of causality as a regulative principle of inquiry—although when it is so construed its career is by no means ended, and it is at the bottom of Einstein's reservations about current quantum mechanics. He rightly censures speculative philosophy for its indulgence in "pictorial thinking," but his own account of the allegedly acausal character of subatomic processes is in effect based on a pictorial interpretation of the mathematical formalism of quantum theory. His attempt to apply a three-valued logic to the analysis of that theory is undoubtedly interesting. At the same time, the present evidence seems to bear out Max Born's doubt as to whether natural philosophy stands to gain anything from the adoption of such a logical scheme. It is also somewhat perplexing to find Dr. Reichenbach declaring, on the one hand, that the ordinary two-valued logic of truth and falsehood is the product of the adaptation of human beings to the relatively simple environment into which they are born, and on the other hand that logic "does not express any properties of the physical world."

The substance of the final two chapters of *The Rise of Scientific Philosophy* is devoted to the nature of ethics, and to the refutation of the claim that ethics is a science. Dr. Reichenbach maintains that in the end ethical statements are imperatives which express "volitional aims," and therefore cannot be validated as true or false. On the other hand, he recognizes that questions concerning the relation of means to ends, or of subordinate aims to ultimate goals, do involve issues of fact and logic. Thus he believes that to the extent men agree in their ultimate aims, ethical disputes can be resolved by rational argument. But despite the fact that he rejects the view that ethics is a science, he himself suggests that there may be only a verbal difference between himself and contemporary pragmatists who maintain the possibility of a scientific ethics. Perhaps this is so, for these latter do not deny that interests and volitions are necessary conditions for the occurrence of values. Nevertheless, they also affirm that the mere occurrence of a preference or an act of will does not constitute a value judgment, and that experience and reflection are required for discovering what is valuable. Now Dr. Reichenbach admits that our actions are "trials" to find out what we want, so that "we learn through error, and often we know only after our action is done whether we wanted to do it." But surely we could not fall into error unless issues of truth and falsity were relevant; the difference in principle between the logic by which questions of "fact" are settled, and the logic by which moral problems are resolved, is therefore not obvious. If proposed ends of conduct, like the means suggested for achieving them, must be evaluated in the light of their consequences, is there a clear warrant for Dr. Reichenbach's recommendation that attempts at validating primary goals by cognitive means should be "denounced as unscientific"?

Dr. Reichenbach is more confident than the actual facts seem to justify that all the analyses he presents in this book have the status of conclusions as precise and dependable as those which science at its best achieves. He has nevertheless written a provocative book, one which makes clear the fascinating materials that the sciences supply for responsible philosophic analysis, and one which therefore deserves to be read widely.

* * *

Ernest Nagel is professor of philosophy at Columbia University.

Childhood and Society, by Erik H. Erikson. W. W. Norton & Co., Inc. ($4.00). A review of the psychoanalytic theory of child development, a survey of child-training procedures in two primitive societies, and a discussion of the problem of personal identity in certain modern nations lead to the fundamental thesis developed by Dr. Erikson in this interesting but poorly integrated book: That infantile anxiety, arising from the prolonged dependence of the human organism on others, remains with man throughout his life and is accompanied by an ". . . unconscious determination never to meet his childhood anxiety face to face again. . . ." This fear impairs man's judgment and his reason and gives urgency to the need for definition of his identity, a definition denied in the complex and changing circumstances of modern life. To remedy this condition, the author recommends a wide employment of group discussion and of group instruction by experts, especially for parents, so that the basic anxieties and the superstitions surrounding them may be ameliorated.

Public Opinion, 1935-1946. Under the editorial direction of Hadley Cantril; prepared by Mildred Strunk. Princeton University Press ($25.00). A prodigious omnium-gatherum of mass opinions on matters ranging from abortion and the mistreatment of animals through Catholicism and vegetable gardening, accumulated by various polling organizations in 16 countries from 1935 to 1946. Among the major underlying assumptions justifying the polling procedure, as well as the appearance of this tome, are: first, that public opinion on most of the issues in question constitutes valuable data for the social scientist; second, that polling is a reliable method for eliciting such opinion. As to both assumptions there is a sharp divergence of views among psychologists and others of related professional interests, a divergence which this compendium is scarcely likely to resolve.

Science and Common Sense, by James B. Conant. Yale University Press ($4.00). Dr. Conant's earlier book, *On Understanding Science*, has now been considerably enlarged with emphasis on the general reader's, as distinguished from the specialist's, interest in the history of science and the scientific

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method. Dr. Conant interprets the rise of science in the 17th century as the result of the "union of three streams of thought and action. . . . (1) speculative thinking, (2) deductive reasoning, (3) cut-and-try or empirical experimentation." He illustrates his ideas by a number of case histories which describe the background of some major advances in science, advances to which chance, common sense, curiosity, intuition, reasoning and formal method each contributed its share. Almost everything Conant has to say in this study, including his comments on the social relations of science, is balanced and honestly thought out. Yet at best his presentation ventures nothing rash and achieves nothing striking; it is neither profoundly original nor banal; it instructs without bringing the reader in contact with the difficult, elusive, inner aspects of the growth of scientific ideas.

NEUROSIS AND HUMAN GROWTH, by Karen Horney. W. W. Norton & Co., Inc. ($4.50). In this book Karen Horney broadens and deepens her basic concepts. Neurosis is seen as a desperate detour away from the normal human goal of self-realization. The dynamics of neurotic functioning, the living with people, with the world and with the self are clearly pictured. The author demonstrates how neurotic patterns are used, and in fact how they are needed to maintain some kind of self-unity; she also indicates the price that is paid for a life with this pseudo-self in inner and outer contradiction. She finally views the role of therapy and therapist in the light of her formulations. An unacademic, unpretentious account.

THE SCHOLAR ADVENTURERS, by Richard D. Altick. The Macmillan Company ($5.00). Although it is too long and costs too much, Dr. Altick's book contains a number of highly entertaining essays on literary swindlers, feats of literary detection, the uncovering of famous manuscripts, and other interesting trivia of bibliomania. Perfect for the tired reader.

SPACE-TIME STRUCTURE, by Erwin Schrödinger. Cambridge University Press ($2.75). The 1933 Nobel prize winner in physics investigates the geometry of the space-time continuum in three stages: 1) when only general invariance (underlying the General Theory of Relativity) is imposed; 2) "when in addition an affine connection is imposed"; 3) "when this is specialized to carry a metric." One chapter treats of attempts to generalize Einstein's theory of the gravitational field "so as to account in the same natural way for the electromagnetic field as well."

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SEX IN PSYCHOANALYSIS, by S. Ferenczi. Robert Brunner ($3.50). A reprint of a selection of important papers by a noted Hungarian pioneer of psychoanalysis, a disciple and associate of Freud. The collection and translation are by Ernest Jones.

WAVE MECHANICS, by J. Frenkel. Dover Publications, Inc. ($5.00). Another of the excellent Dover reprints making available at moderate prices outstanding works in the mathematical and physical sciences.

THE BIOCHEMISTRY OF THE NUCLEIC ACIDS, by J. N. Davidson. John Wiley & Sons, Inc. ($1.75). One of the series of useful Methuen Monographs consisting of brief surveys of various scientific subjects by leading experts. The author of this monograph is professor of physiological chemistry at Glasgow University.

THE BREAKING OF THE CIRCLE, by Marjorie Hope Nicolson. Northwestern University Press ($3.00). The theme of this book, based on the Norman Wait Harris lectures delivered by Miss Nicolson at Northwestern University in 1949, is the relationships among science, philosophy and poetry in the 17th century. Learned and rarefied.

SIR THOMAS BROWNE, by Jeremiah S. Finch. Henry Schuman, Inc. ($3.50). Finch, assistant dean of the college and lecturer in English at Princeton, presents a readable life of this kind, tolerant, humane man who was both a skilled physician and one of the greatest writers of English prose.

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THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

MASTERS and students in the Oundle School, the first of England's ancient "public" schools to make engineering and science its chief educational tools, built the telescope shown in the drawing on the opposite page. H. C. Palmer, assistant master in the school's department of mathematics and science, has supplied the facts concerning it.

"The preliminary drawings, all patterns and castings and machining were done cooperatively by masters, boys and instructors. The body of the telescope is of duralumin and cast aluminum. The balance weight at the short end is of cast iron. The trunnions forming the declination axis are part of a single casting in the form of a square box. The design had to be simple because all the patterns had to be made by schoolboys. The driving wheel is bronze, 12 inches in diameter, and has 360 teeth which were hobbed by a home-made tool on a milling machine. The three-inch polar axis that carries the fork runs in ball bearings. Four hand screws on this axis permit unlocking it from the driving worm wheel, so that the telescope can be rotated at will.

"The drive is taken from an old spring-driven phonograph motor modified in two important ways. The governor weights have been loaded to slow down the motor, so that the single-spring barrel rotates about once a minute; and the spring barrel has been fitted with a shaft which emerges from the frame of the motor and revolves at the same rate. The torque transmitted by this shaft when the spring is fully wound exceeds one pound-foot. The motor will continue to drive for about 15 minutes, and since the foundations are rigid it is in order to wind the motor during a run. The only service demanded of the gears in the motor is to drive the governor. The governor brake is controlled by a screw of fine thread.

"The motor is connected to the worm drive by a 1-to-4 bevel gear as shown in the insert drawing, making the gear ratio 1-to-1,440 and so giving ample torque to drive a heavy telescope. A spring-loaded clutch in line with the worm makes it possible to turn the latter either way without interrupting the motor; the resistance of the clutch is overcome by means of the capstan on the end of the shaft."

L. C. MARTIN'S *Introduction to Applied Optics*, a standard reference and textbook which went out of print during the war, has now been revised, enlarged into two volumes and given the new title of *Technical Optics*. The author is professor of technical optics at the Imperial College of Science and Technology in London, and the book represents the substance of a lecture course given to graduate students at the College. It is not elementary, but many advanced amateur telescope makers add such major works on optics to their libraries. Volume 1, containing 343 pages, deals with geometrical optics, paraxial theory of optical systems, light as wave motion, images and their defects, physiological and physical optics, radiation, optical glass and lens defects. It includes a chapter on spectacles, which most members of the optical fraternity wear without the understanding conveyed in this far from elementary discussion. Volume 2, containing 344 pages, deals with the telescope, microscope, binoculars, photographic lenses, photometry, testing optical instruments, aspheric surfaces. The volumes may be obtained, separately if desired, from the Pitman Publishing Corporation, New York.

DIFFRACTION, sometimes defined as the bending of light around obstacles into the shadow, is a process that goes on continuously in all wave fronts. The waves try to spread out sidewise as they advance. When a part of the wave is cut off by an obstacle, there is a special phenomenon, correctly called not "diffraction," but a "diffraction effect," which is what is usually meant in optics by the term diffraction. The misleading definition first stated sometimes creates the idea that the diffracted wave spreads only into the shadow behind the obstacle; actually it also spreads into the illuminated region.

Diffraction is a cause of imperfect imagery in optical instruments, but it has never been abolished. Edwin Emil Webb of New York now proposes a trick to defeat it in a reflecting telescope. "Why," he asks, "can't diffraction due to secondary mirrors be totally eliminated by a circular blackened area in the center of the main mirror, the radius of the dark spot being slightly greater than the radius of the secondary, so that the diffracted light would fall upon a nonreflecting area and not be returned to the eyepiece?"

"To prevent the spot itself from giving rise to diffraction," he continues, "its own edge would have to taper in intensity from full black to full reflectivity as its radius increased from the radius of the secondary to that radius plus, say, 1/8-inch. Optically, such a spot *would have no edge* and could not give rise to diffraction, though it could, being larger, absorb all the diffraction caused by the secondary.

"Such a spot would be difficult to produce. It could not be painted or airbrushed on, since these processes deposit particles greater in diameter than a wavelength of light, and each particle would then create its own diffraction effect. A molecular process such as tarnishing or anodizing would perhaps be required. Similarly, a narrow nonreflecting ring around the outer edge of the main mirror, tapering inward toward the center, could annul outer-edge diffraction. And finally, an appropriate pattern of tapered black lines could annul spider diffraction.

"The result, I think, is a diffractionless reflector!"

One optician to whom this proposal was shown commented, "This subject is dear to me. Webb's idea has some merit and some questionable points." Another said, "I've been thinking about the idea off and on for months since Webb's proposal was shown to me. In my opinion it would work well. Say the spacing of the subwavelength particles went from . . . . to . . . . , and then to solid packing at the black portion. As the spaces approached particle size, diffractionless partial reflection should occur. Such partial reflection does take place in fluids when the particle size is less than 1/100-wavelength. How the transition could be attained in practice I don't know. Probably not in 1/4-inch or so."

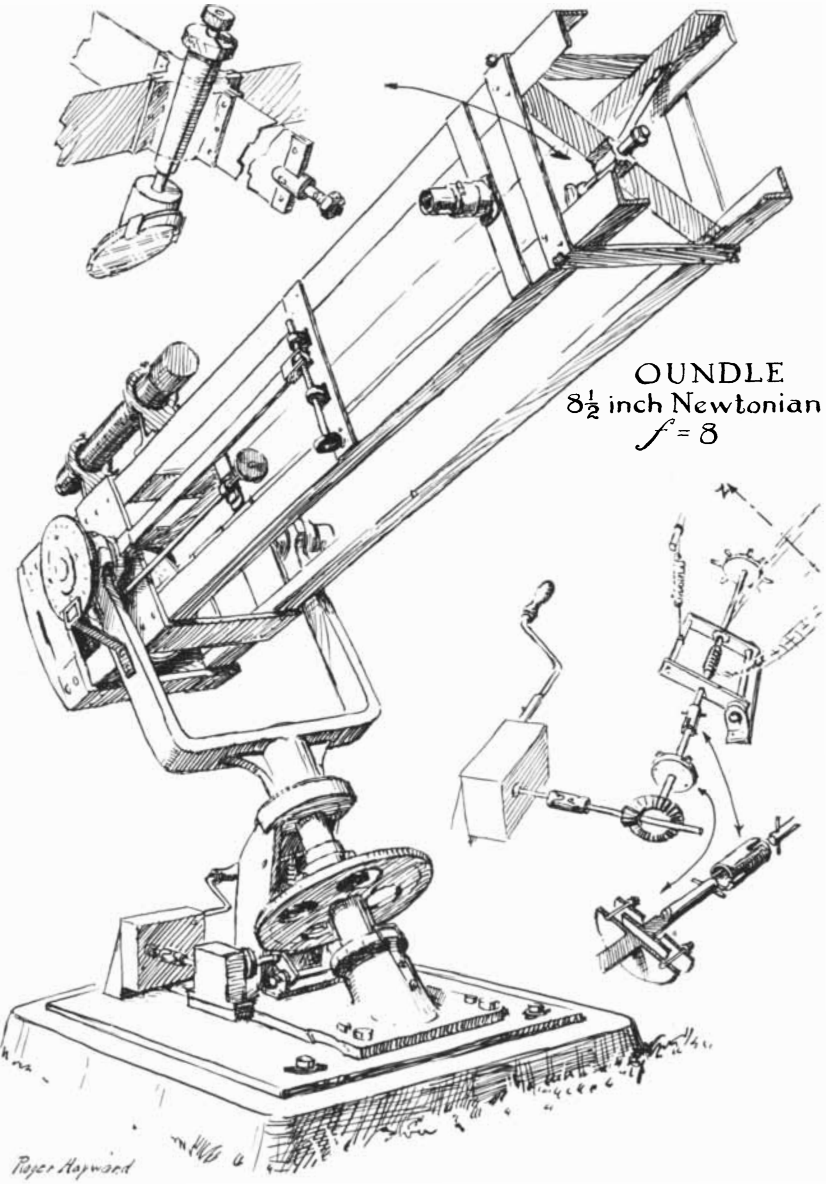
So here, the gift of Webb, is a route to a fortune for some developer—or anyway some fun.

IN January this department gave an account of a proposed method to reduce the weight and cost of mountings for very large telescopes to a small fraction of the customary amounts. If the large primary mirror and the heavy mechanism that supports and moves it are removed from a conventional mounting, the only essential parts that remain are the plateholder and a simple mechanism for moving it, or the correcting plate and plateholder of a Schmidt telescope. Mounted as a pivoted single unit, these need not weigh or cost a tenth as much as the original instrument. The primary mirror is attached to the earth without mechanism and derives its necessary motion from the earth. Such a telescope could photograph only one relatively narrow band around the heavens but a chain of them would together cover the sky.

Concerning this proposal Lyle T. Johnson, a physicist and amateur astronomer of La Plata, Md., states, "Your article was extremely interesting to me. Väisälä's proposal for a large telescope is the same as one I sent you in 1947, except that he uses a large number of spherical mirrors while I proposed a large single mirror. Russell W. Porter liked the idea when you forwarded it to him, but others at Palomar were against it, mainly on the ground that there would be flexure of the large correcting plate. But this could be reduced by using a spider to give it support at the center."

"Later on," Johnson continues, "I figured out ways by which the correcting plate of the monster telescope could be dispensed with by putting the correction on a secondary mirror. [Three methods are shown in the upper drawings on the next page.] The first is an adaptation of my modified Gregorian [described in this department in September, 1949]. The second is a Cassegrainian or Gregorian with a flat near the primary. The third has a perforated flat at the primary focus and a Gregorian secondary."

Johnson's present proposal is to combine his three unconventional telescopes with the fixed primary-mirror principle. He continues, "All the optical elements except the primary are attached to the mobile tube, which has a declination and a polar axis intersecting at the center of curvature. Elimination of the large correcting plate removes a limit on the aperture and permits use of the huge mirror's full aperture. The aperture



A telescope made in an English public school

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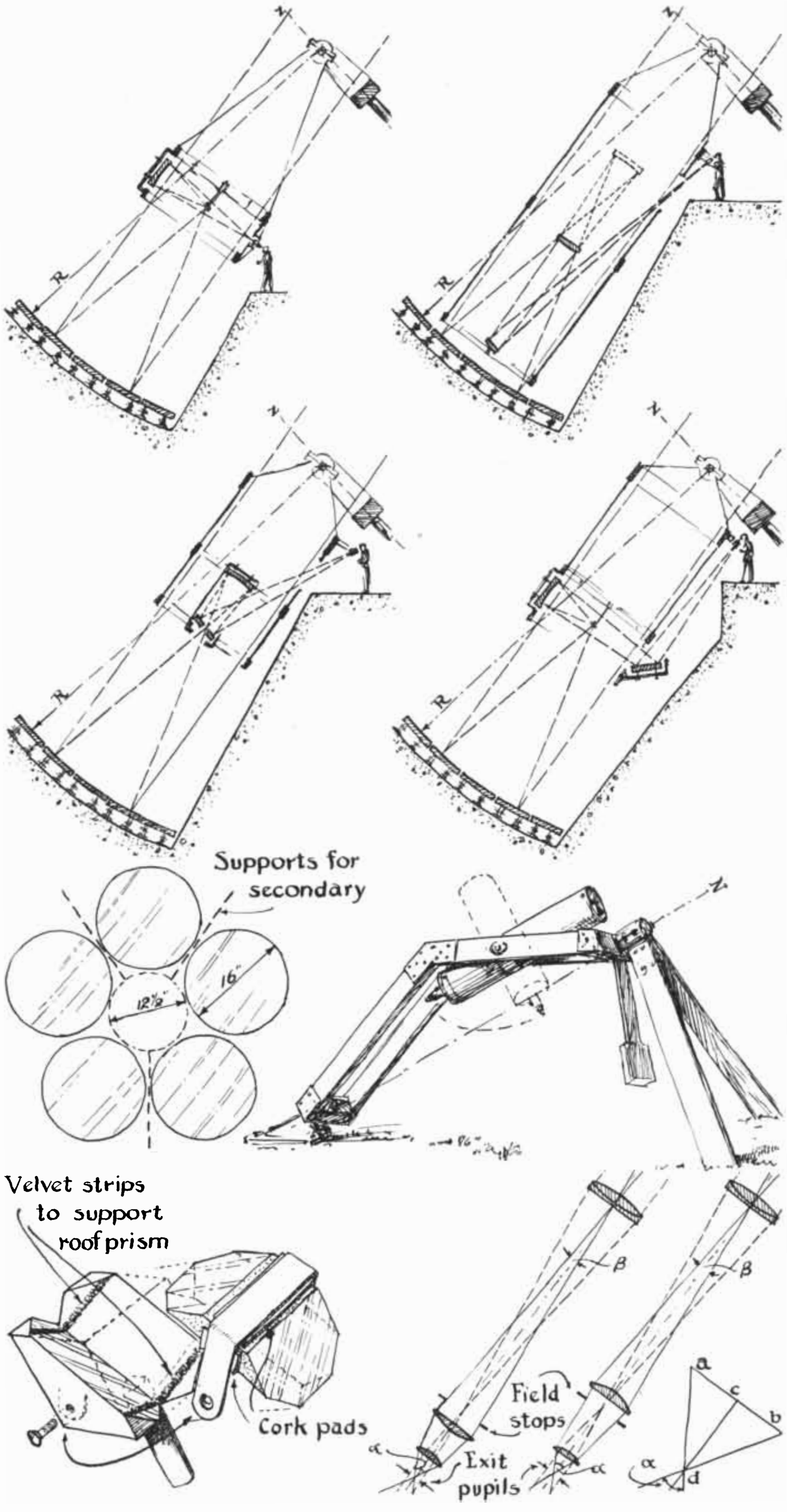

Johnsonian telescopes with fixed primary mirrors

would decrease as the telescope was moved."

Those who have admired Russell Porter's interpretive drawings in *Amateur Telescope Making* and in this department may find interest in an extended category of coincidences between Porter and Roger Hayward, the present illustrator of this department. Both men grew up and learned to use machine tools in New England; graduated from the Massachusetts Institute of Technology as architects, Porter in 1896, Hayward in 1922; designed public libraries;

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painted water colors; moved to Pasadena, Calif., where they became acquainted and friends; built telescopes, spectroscopes, grinding machines and prisms; made large models of the moon; ran toolmakers' lathes; did wartime work in optics, and illustrated technical books. Hayward puts into his drawings the same kind of interpretation of mechanics and optics that Porter did.

After illustrating this month's discussion Hayward wrote, "Johnson's fixed-primary telescopes are very interesting. I could not forbear adding a fourth which is a modification of the first. Its advantage lies in the fact that the image is brought back to a point near the trunnion, which is desirable from an engineering point of view. It also uses the tiny flat of Johnson's first scheme, cutting down diffraction. If the instrument is built so that the observing platform is near the ground, the dome and superstructure would be relatively small. I have indicated, by the scale of the observers in the diagrams, instruments with a primary-mirror array 28 feet wide, a radius of curvature of 56 feet and an effective aperture of about 14 feet. The focal ratio at the prime focus would be 2. If the primary-mirror array were arranged to be rolled north and south on suitably curved rails, the instrument could cover most of the visible heavens except the polar region.

"The principal defect in this scheme is that the Cassegrainian or Gregorian instruments are by nature long-focus affairs, which means that exposures must also be long, yet the length of exposure with this instrument is limited by the east-west diameter of the primary-mirror array. If the mirrors had the east-west diameter that is shown they would permit exposures of an hour. This is very short, especially for spectrographic work where limiting exposures are about 100 times as long as for direct photography."

Continuing on another subject, Johnson writes: "Väisälä's trial telescope with seven 12½-inch mirrors in a cloverleaf pattern and 33½-inch diameter, described in the January issue, has interesting possibilities for the person who wants to build a fairly large telescope. If five 16-inch mirrors are grouped as shown in the drawing, the clear space between them, about 12½ inches in diameter, might be used as the central 'perforation' of the primary. Thus this secondary would obstruct practically none of the light going to the 16-inch mirrors. The large mirrors are spherical and the correction is on the secondary."

A VARIANT of the double yoke mounting with an offset declination axis to permit access to the pole of the heavens, described in this department in the February issue, is proposed by Frank McCown of Holtville, Calif., and is shown in one of the drawings. The purpose of the dog-leg yoke is to keep the eyepiece clear of the A-frame.

The drawing in the lower left-hand corner shows how A. G. Chartier of East Hartford, Conn., mounted an Amici roof prism as an image erector, in the usual place of the diagonal mirror. He seated the prism in a right-angle groove in a cube of brass.

IF the diameters, focal lengths, and spacing of the two lenses in a Ramsden or a Huyghens eyepiece are given, what is the apparent angular field of the eyepiece? No answer to this problem has been found in the reference books on optics, but one is now supplied by Lieut. Col. Alan E. Gee of the Frankford Arsenal, who is privately an amateur telescope maker.

"The kind of answer depends upon how fussy you want to be. To determine it exactly a designer must ray-trace to find the angle of the limiting principal ray. In practice, there are several ways of arriving at an excellent approximation. In the drawing the Greek letter alpha is the apparent field in each case. The sloping dashes show the location and proper size of the eyepiece field stops, if any. Obviously, it would be simple to determine alpha by starting at the objective and using $1/f=1/u+1/v$ to determine the intersections with the axis, and then using trigonometry to find the final angle. The clear aperture of the field lens will be the limiting field stop in the absence of metal diaphragms.

"Even that method is needlessly precise. A satisfactory and much simpler method is to measure the clear aperture of the field stop (if any) or the field lens and figure thus: $\overline{ab}$ = diameter of stop or field lens, $\overline{cd}$ = e.f.l. of eyepiece, alpha = apparent field. Solve for alpha by trigonometry, or scale off and measure with a protractor.

"Properly, if this method is used with the Huyghens eyepiece and $\overline{ab}$ is the *stop* (not the field lens) diameter, then $\overline{cd}$ should be the f.l. of the eye lens only. In practice the difference is negligible.

"Note that these methods indicate that the diameter of the field lens is the controlling factor for the apparent field. This presupposes that the eye lens is large enough. I have never seen an eyepiece where this was not the case. Anyway, the drawing shows how to determine the minimum size of the eye lens necessary to pass the field that is passed by the field lens. Both eyepiece lenses should be a little larger than the drawing indicates, so that no vignetting of the objective aperture occurs at the edge of the field.

"Obviously the larger you make the field lens (keeping the same focal length) the larger the apparent field. Unfortunately both the Ramsden and the Huyghens eyepieces go to pot very badly at fields wider than 40 degrees."

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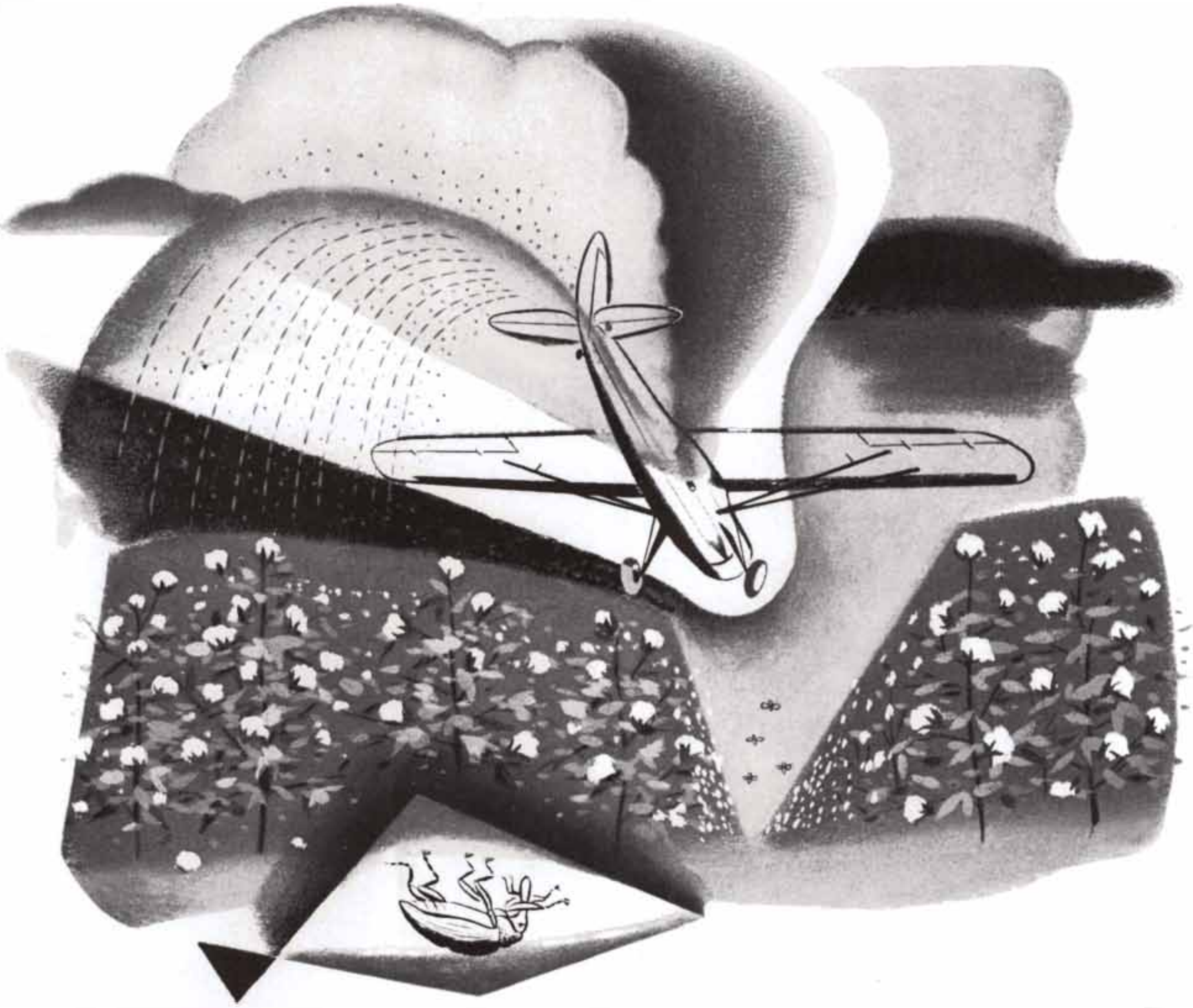

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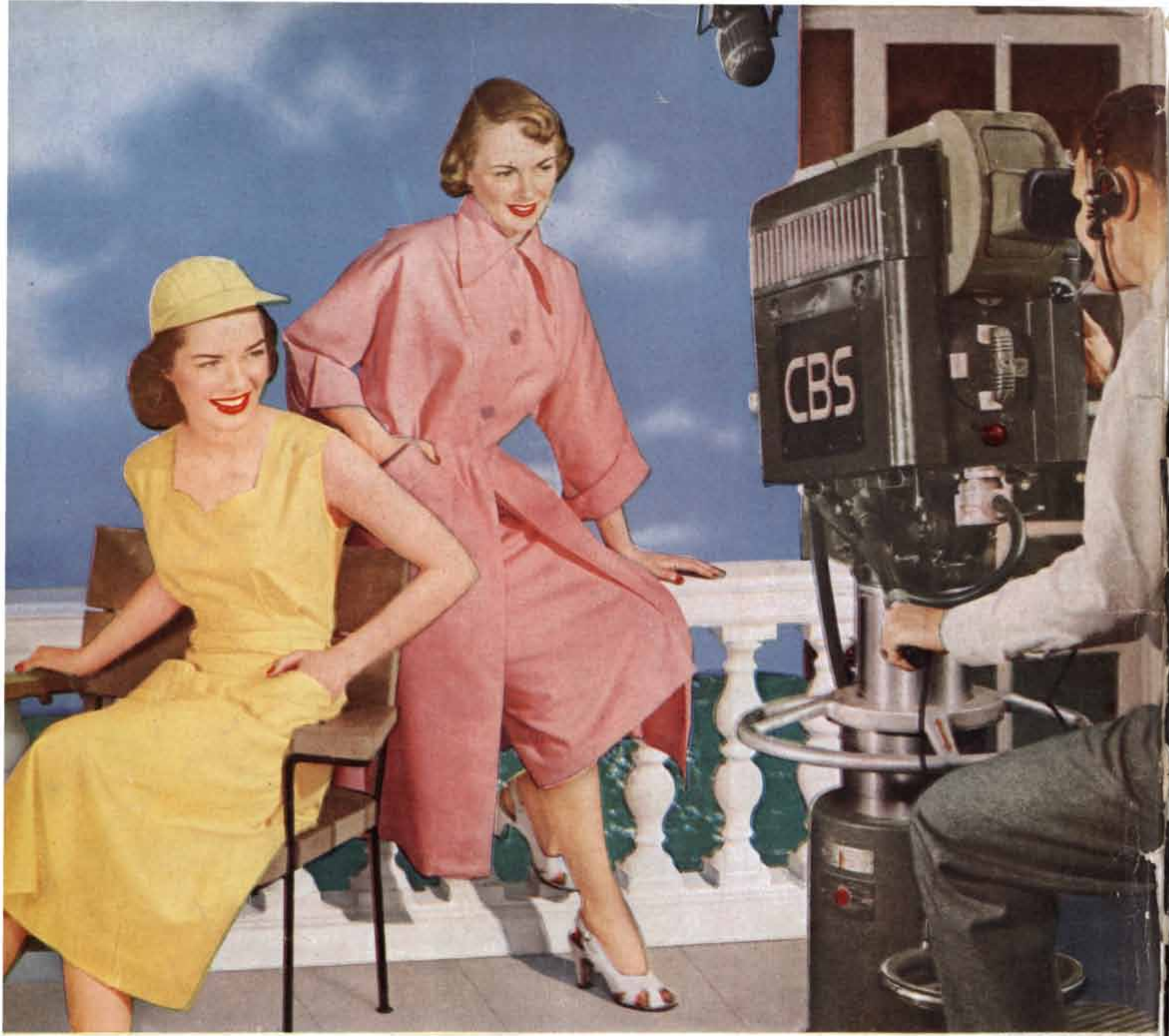

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