SCIENTIFIC AMERICAN

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FIFTY CENTS

June 1951

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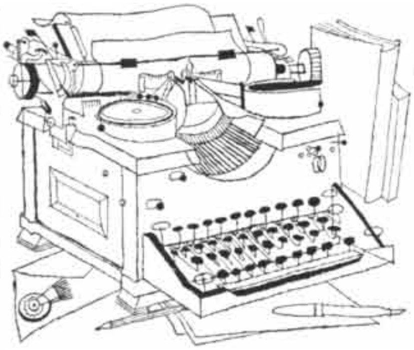

LETTERS

Sirs:

The article on chromatography by William H. Stein and Stanford Moore in your March issue gives an excellent review of the many important advances which have been made in this field in recent years, but we should like to comment on a point of historical interest. The authors state, in common with many others, that the discovery of column-chromatography was made in 1906 by the Russian botanist M. S. Tswett; in fact, however, a survey which we have recently made of the early literature in this field leaves no doubt that the credit for the discovery should rightly go to the American petroleum chemist D. T. Day, who gave a full account of his chromatographic experiments in 1900 at the First International Petroleum Congress held in Paris. At this congress Day's work was singled out for special mention by the president, B. Dvorkovitz, who said that like all discoveries "it looks simple—in fact is simple—but it required much previous thought, patience, and perseverance."

Day succeeded in fractionating crude petroleum by passing it through columns of fuller's earth, an extension of the method of adsorptive filtration which had first been technologically utilized some 10 years previously by the German chemists C. Engler and M. Boehm. The importance of Day's method was at once realized by Engler, who, with E. Albrecht, introduced several further refinements, and published details in 1901. Russian petroleum chemists, too, such as W. E. Herr and E. Phyälä, were also quick to see the importance of Day's discovery and applied it to their own research. It is clear, therefore, that petroleum chemists, first in the U. S. and soon afterwards in Europe, were using chromatography several years prior to 1906.

For the origin of methods of paper capillary analysis, fundamentally related to modern methods of chromatography on paper, one must go back very much further. The discovery of this method of analysis is generally but erroneously attributed to Schoenbein (1861) and his pupil Goppelsroeder, but as early as 1850 the German scientist F. F. Runge described the use of blotting paper for the analysis of mixtures of dyes. Runge was led to this discovery from "spot-tests" which he invented and which were subsequently applied by Schoenbein; for example, he used paper impregnated with starch and potassium iodide for testing bleaching solution. The American chemist J. U. Lloyd also, in 1885, submitted a report on filter-paper separation to the 32nd Meeting of the American Pharmaceutical Association at Milwaukee. Crude spot-tests have, however, been used in the dyeing industry from ancient times—Pliny, for example, describes, as Yagoda pointed out, a test paper for detecting ferrous sulphate—so that the ultimate roots of chromatography are clearly very remote.

HERBERT WEIL

London, England

TREVOR I. WILLIAMS

Oxford, England

Sirs:

We are much interested in the comments of Herbert Weil and Trevor I. Williams concerning the origins of chromatography. In preparing our article, we did not undertake an exhaustive search of the literature, but rather adopted what appeared to be the prevailing view and ascribed to Tswett the discovery of the method. Drs. Weil and Williams feel, on the basis of their very extensive survey, that this credit should fall to Day, and we are happy that his

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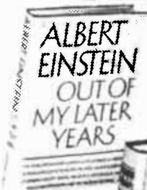

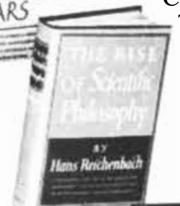

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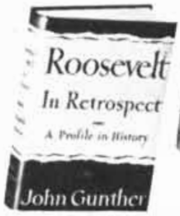

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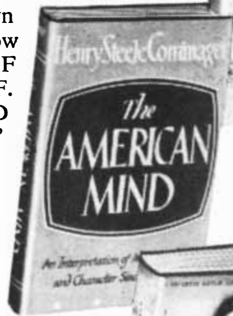

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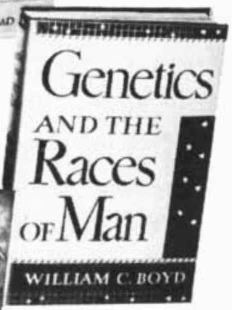

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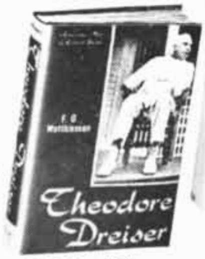

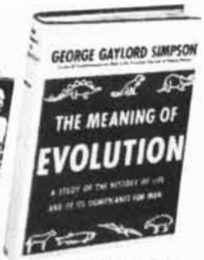

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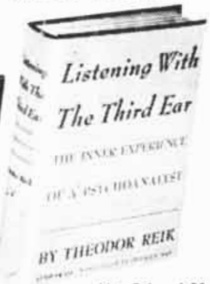

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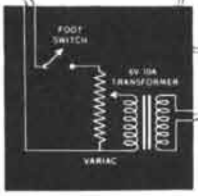

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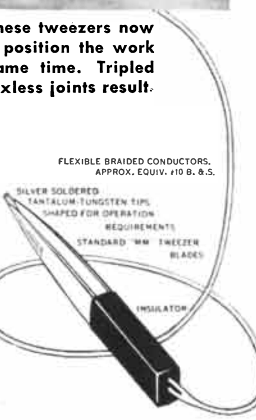

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name has been brought to the attention of the readers of *Scientific American*. It should be pointed out, however, that Laszlo Zechmeister, one of the pioneers in the modern development of chromatography, recognizes the contributions of Day but feels that "Tswett is the true inventor of chromatography in all its important aspects. [*Nature, 167*, 405 (1951)]." Whoever is ultimately designated the "father" of the method, it is clear that both Day and Tswett were men of great vision and experimental skill.

WILLIAM H. STEIN

STANFORD MOORE

Rockefeller Institute for Medical Research
New York, N. Y.

Sirs:

In your March issue you published a letter from Lieutenant M. S. Jones, Jr., U. S. N., concerning the item "Hazards of the Stratosphere" which appeared in your December, 1950, issue. Since I am the author of the original article on which this item was based, I should like the privilege of answering Mr. Jones.

The data of Millikan and the fact that maximum ionization occurs at 80,000 feet are reviewed at considerable length in my original article. I have based the calculation for the maximum dosage on the conservative value of 360 ions per cubic centimeter per second per atmosphere reported by Millikan (R. A. Millikan, *Reviews of Modern Physics, 21*, 1-13, 1949). It is perfectly correct that the ionization drops beyond this peak, and the pertinent data can be read from the graphs in my article. However, it has to be kept in mind that these extreme altitudes are the region of the transition effects of the primary radiation. Therefore, the actual ionization dosage depends greatly on the kind of absorber because the equilibrium between primaries and secondaries, which at lower altitude has already been established by absorption in the atmosphere, must be built up in the absorber itself.

Jones' reference to "the accepted American tolerance-dose of 0.3 roentgen per week" is both incomplete and misleading. The correct formulation reads: The accepted American tolerance-dose is 0.3 roentgen equivalent physical per week for X and gamma rays and *is 0.03 roentgen equivalent physical per week for alpha radiation from internal sources.*

This brings up the main issue which Jones failed to mention, namely, that the biological effects of the heavy component of cosmic radiation must be compared to alpha irradiation of living

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tissue from internal sources. The reasons for this have been discussed in detail in my original article. I have also pointed out that a considerable fraction of the component shows values for the specific ionization which are much higher than the ones for alpha particles.

The dosages administered to the patient during X-ray fluoroscopy exceed by far the official tolerance-dose. All experts agree that it is the roentgenologist's responsibility to weigh the good for the patient from fluoroscopy against the genetic damage. The appraisal of exposures for pilots and passengers of future strato-air traffic on the basis of these values is unthinkable and I for one stand in protest.

Analogies based on the comparison of the total energy of cosmic radiation and of starlight should be made with care. I don't consider it wise to deal with problems of radiation hazards in terms of administered energy units. For example, the energy administered to a human being in a total body irradiation of 350 roentgens which produces a death rate of 50 per cent is less than the heat energy incorporated in one swallow of hot tea.

I appreciate very much any forthright discussion and criticism of my contribution to this highly controversial problem and it was a chief purpose of my article to initiate such discussions. However, they should be undertaken with a full and discriminate use of the basic facts of radiation biophysics and should be centered upon the actual problem, namely, whether and to what extent the biological effects of this entirely new type of radiation, which produces columns of extremely dense ionization of many inches' length in living tissue, can be dealt with by a schematic extrapolation based on the common types of radiation.

Moreover, it has to be realized that in the field of the low-dosage long-term radiation damage our concepts have changed considerably in recent years. The general reduction of the tolerance dose from 100 milliroentgen per day to half this value and the special reduction to one-tenth for alpha radiation are indicative of a more and more cautious attitude being inspired by the results of animal experimentation and unfortunate injuries among investigators. H. J. Muller, Nobel prizewinner for his work in radiation genetics, says in *American Scientist* (July, 1950) with regard to the long-term damage: "It is to be expected that such damage would be insidious but far-reaching, and that some of it would be produced even by very low-level exposures if these were often repeated or long continued."

H. J. SCHAEFER, PH. D.

Naval School of Aviation Medicine
Pensacola, Fla.

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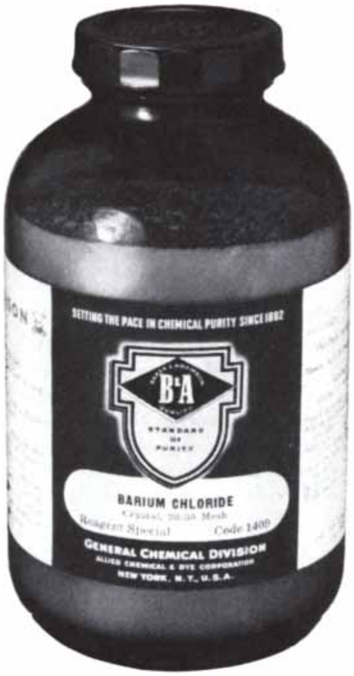

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SETTING THE PACE IN CHEMICAL PURITY SINCE 1882

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50 AND 100 YEARS AGO

JUNE 1901. "John D. Rockefeller has given $200,000 to found 'The Rockefeller Institution for Medical Research.' The gift is not intended for an endowment fund, but is for immediate expenditure. Facilities for original investigation are to be provided, especially in such problems in medicine and hygiene as have a practical bearing on the prevention and treatment of disease. The first work of those connected with the institution will be that of co-operating with the New York Board of Health in studying its work and the problems confronting it, and particularly that of milk supply. Researches of a more ambitious nature will be begun in the fall under the guidance of experienced investigators."

"From Paris to Bordeaux by road is a distance of 348 miles, and this year has witnessed a feat which is not only the most sensational in the annals of automobilism, but one of the most remarkable speed performances of any kind whatsoever, whether by road, rail or sea; for the same distance was covered in 8 hours 44 minutes and 44 seconds, at an average speed of about 40 miles an hour. The most remarkable feature of the whole performance is the nerve and skill possessed by the chauffeur Fournier, for at the terrific pace achieved, it is evident that the slightest error in judgment could easily have precipitated disaster."

"Undoubtedly one of the most wonderful discoveries of modern chemistry has to do with the soil. It has been ascertained that the most barren land can be made rich simply by adding to it certain mineral elements which cost but little. On this basis it is estimated that the United States will be able eventually to maintain 500,000,000 people—more than one-third of the present population of the world. It is merely a question of supplying the requisite quantities of nitrogen, phosphoric acid and potash. The last two are readily obtainable at small expense, whereas the first may be supplied either by furnishing to the soil condensed nitrogen in the shape of slaughter waste or nitrate of soda or by planting clover, beans or peas."

"A special meeting of the Manchester Literary and Philosophical Society was held on Monday, April 22, when Dr. Elie Metchnikoff, of the Pasteur Institute, Paris, delivered the Wilde Lecture. Before the lecture the president of the society (Prof. Lamb) presented the Wilde Medal for 1901 to Dr. Metchnikoff."

"A company has been formed to manufacture the new storage battery invented by Thomas A. Edison, which will be known as the Edison Storage Battery Company. The new company will proceed at once to enlarge the factory of Mr. Edison at Glen Ridge."

"Science and art are becoming more and more the mere hand-maidens of industrialism. Our greatest scientific men are devoting their energies, not to pure science, not to their noble profession in its abstract or elementary form, but to those applications of it which result in some new economy of the world's work and in the formation of more immense stock companies, with bonds and common and preferred shares, dividends, and all the paraphernalia of modern financial operations on a big scale. The men who love science for science's sake are giving way to the Edisons, Teslas, Triplers, Pupins, Marconis, those wizards who by day and by night seek to wrest from nature some new and commercially profitable service to mankind. The number of patents taken out at Washington steadily increases, notwithstanding the predictions made not long ago that American inventiveness had reached its high tide. This is the age of materialism and of Mammon, sure enough."

JUNE 1851. "Professor Agassiz has determined that the common porpoise of our waters, which has generally been regarded as identical with the *Phocoena communis* of Europe, is a distinct species, and hitherto undescribed. Professor Agassiz proposes as a name for this new species that of *Phocoena americana.*"

"A case of Colt's pistols at the great British exhibition attracted the attention of army officers. They say, 'these are just the kind of arms for the war in Kaffirland,' and they recommend their introduction into the British army. Colt, the inventor, manufactures his pistols at Hartford, Conn., and employs 300 men now, but will soon employ 200 more."

"The census of the United States, for 1850, is enough to astonish all the world but ourselves. The increase of our wealth and population are evidences of our great prosperity. How striking the contrast between our country and the civilized countries of Europe. Our superiority in every respect has been strikingly manifested. We have beheld Europe convulsed from center to circumference. Every nation in Europe but Russia and England have had the knife of civil war bared in the savage contest of father against son and brother against brother; Ireland has lost two millions by the famine and the pestilence, and what country in the old world has escaped some scourge or reverse of fortune? Not one. It would seem as if those things which injured and retarded the progress of other nations, tended always to advance and prosper ours. In the year 1800 the population of the United States was 5,300,000; it is now 23,500,000. The number of the States then comprising the Union was sixteen; it is now thirty-one. Our territory then was 1,000,000 square miles; it is now 3,200,000. All our present domain west of the Mississippi then belonged to France and Spain, and was an unbroken wilderness. Illinois, Indiana, Michigan, and half of our western States were yet but hunting grounds where Indians roamed unmolested. At that period the total value of all kinds of manufactures and products of industry in the United States hardly exceeded a hundred millions of dollars; the total value now will be about six hundred millions."

"A patent has been granted to Nelson Goodyear, of New York, N. Y., for an improvement in the manufacture of India rubber."

"A new clipper-ship, the 'Flying Cloud,' built by Donald McKay, of Boston, for Grinnel, Minturn & Co., of New York, for the California trade, has been the subject of much comment and observation since she has been in our city. She was built we believe without any restriction by the owners—the naval architect had it all his own way—and we have been informed that she is warranted to be the fastest sailer afloat. Take her all in all, she is the finest ship that we ever saw."

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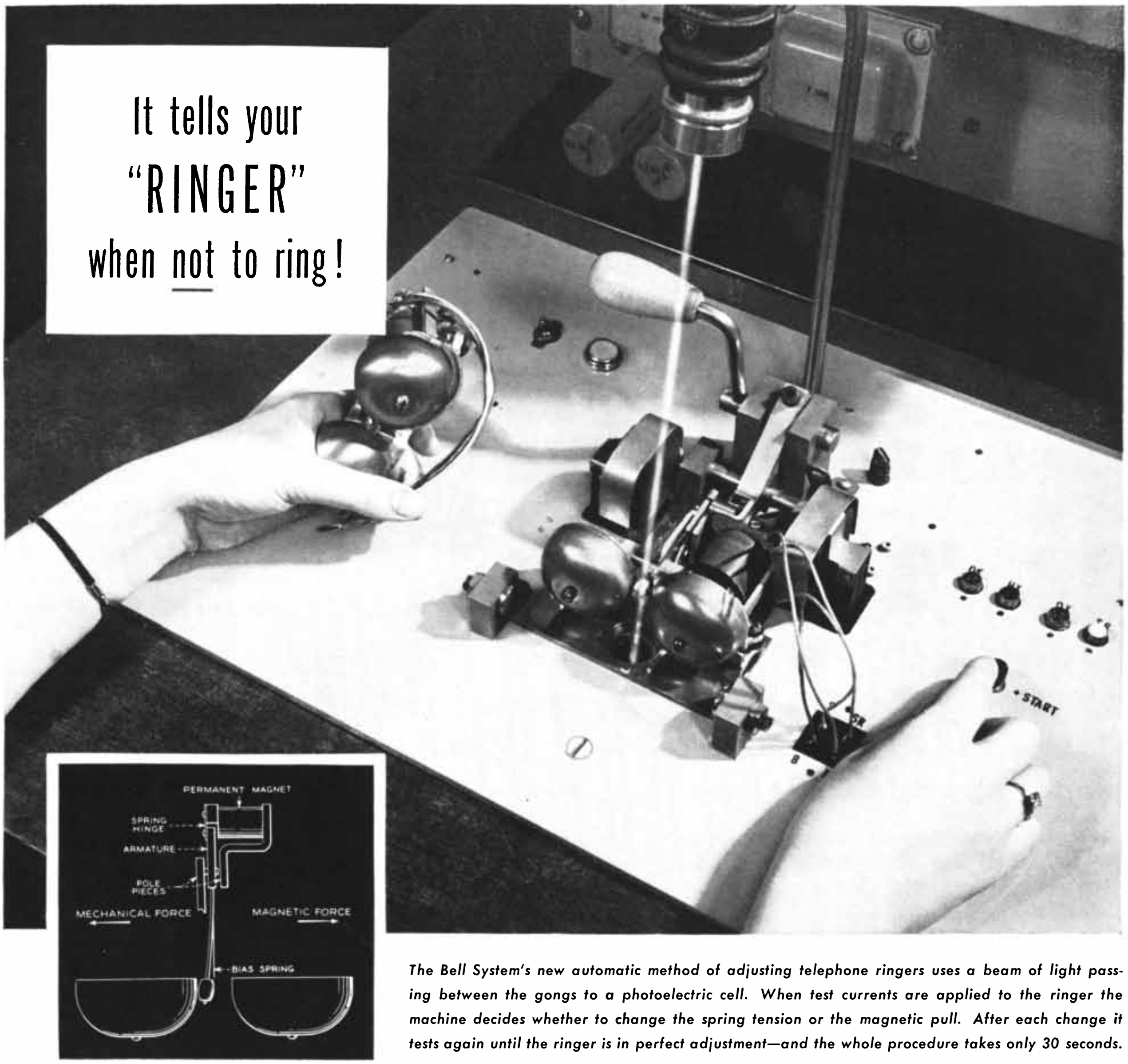
It tells your "RINGER" when not to ring!



The Bell System's new automatic method of adjusting telephone ringers uses a beam of light passing between the gongs to a photoelectric cell. When test currents are applied to the ringer the machine decides whether to change the spring tension or the magnetic pull. After each change it tests again until the ringer is in perfect adjustment—and the whole procedure takes only 30 seconds.

To YOU, it's your familiar telephone bell. To telephone engineers, it's a "ringer." And it has two jobs to do. It must ring, of course, when someone calls you. And it must overlook the numerous electrical impulses which do not concern it, such as those sent out by your dial.

Ability to respond to some impulses, to ignore others, requires exact adjustment between the pull of a magnet and the tension of a spring. If they are out of balance your telephone might tinkle when it oughtn't, or keep silent when it should ring.

In the past, adjustment was made by hand, little by little until the proper setting was reached. It took time. But now Bell Laboratories engineers have developed a machine which adjusts new ringers perfectly, before they leave the Western Electric Company plants where they are made. And the operation takes just 30 seconds.

This is another example of how the Laboratories work constantly to improve every phase of telephony — keeping the costs low while the quality of service grows higher and higher.

BELL TELEPHONE LABORATORIES

WORKING CONTINUALLY TO KEEP YOUR TELEPHONE SERVICE ONE OF TODAY'S GREATEST VALUES

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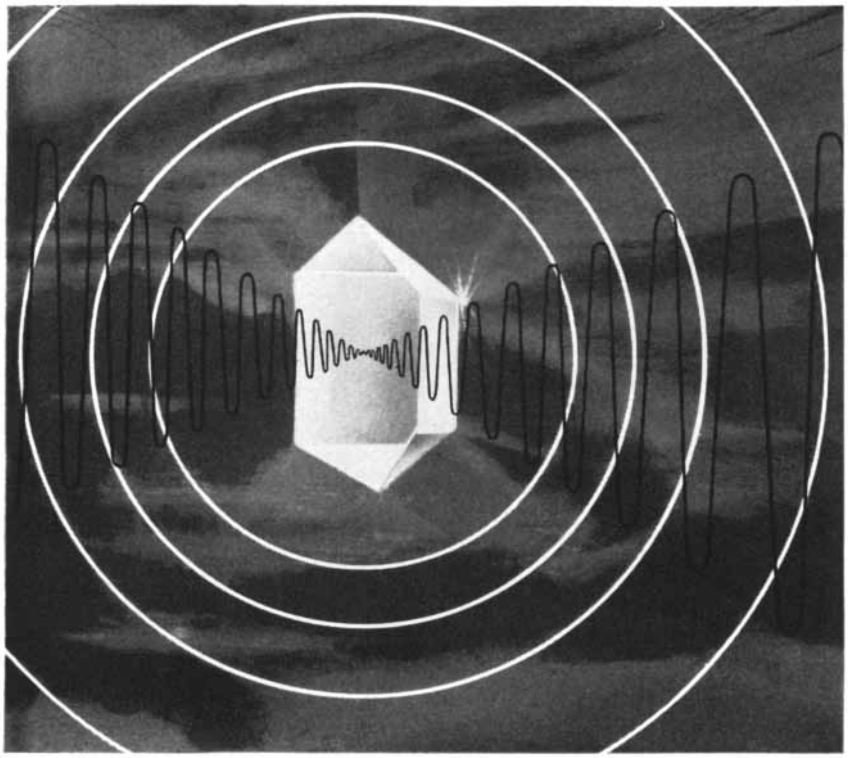

PIEZOELECTRICITY

IN ITS MANY PHASES FOR MODERN PRODUCTS

• It started more than 25 years ago—the study by Brush of piezoelectricity and its usefulness in solving new problems in acoustics and related fields.

The production and practical application of piezoelectric crystals and ceramics are Brush specialties. The Company is the largest producer in the world of artificially-grown crystals, and its production facilities are backed by a large and specialized research staff.

Brush Rochelle salt crystals are used almost universally in phonograph pickups and hearing-aid microphones. Brush ammonium dihydrogen phosphate (ADP) crystals are used in large quantities in equipment for the Armed Forces. Brush "piezoelectric" ceramics are now used in the construction of practical high-power focused ultrasonic generators and are meeting new piezoelectric needs. Other piezoelectric materials introduced by Brush include lithium sulphate and dipotassium tartrate (DKT), now available for special applications.

For more information about this Company's activities, write to the Crystal Division for the booklet, "This is Brush".

Manufacturers of

ACOUSTICAL EQUIPMENT   MAGNETIC RECORDING DEVICES
RESEARCH AND INDUSTRIAL INSTRUMENTS
PIEZOELECTRIC CRYSTALS   ULTRASONIC EQUIPMENT

OUR BUSINESS IS THE FUTURE
THE BRUSH DEVELOPMENT CO.
3405 PERKINS AVENUE • CLEVELAND 14, OHIO

THE COVER

The painting on the cover shows a bee visiting a flower in the jungles of Burma. The flower is an orchid of the genus Cymbidium; the bee, a species found in Burma. The various features of the orchid, like those of many other flowers, have been shaped by evolution to attract one kind of insect and anoint it with pollen. The features of other flowers have been adapted to pollination by the agencies of birds, bats and the wind (*see page 52*).

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
16-17	Sara Love, from Study No. 1, prepared by the National Association of Educational Broadcasters for the Joint Committee on Educational Television
18	Humphreys Gold Corporation
21	Bureau of Mines, U. S. Department of the Interior
22	Harvard College Observatory
24-25	John A. Pierce, Harvard University
26	Irving Geis (*top*), courtesy Fletcher G. Watson, Harvard University (*bottom*)
27	Peter M. Millman, Dominion Observatory
28	Harvard College Observatory
42	International Health Division Laboratories, The Rockefeller Foundation
44-46	David E. Scherman
47-49	International Health Division Laboratories, The Rockefeller Foundation
50	David E. Scherman
51	Courtesy Jesse W. Beams, University of Virginia
53-55	Grambs Miller
58-59	Burndy Library, Inc.
61	Irving Geis
62	Peter Rieser, Fordham University (*top*); Floyd Wiercinski, Hahnemann Medical College (*middle*); courtesy L. V. Heilbrunn, University of Pennsylvania (*bottom*)
65-66	Eric Mose
77-78	Roger Hayward

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TENNESSEE PRODUCTS & CHEMICAL Corporation

NASHVILLE, TENNESSEE

PRODUCERS OF FUELS • METALLURGICAL PRODUCTS • BUILDING PRODUCTS • COAL CHEMICALS • WOOD CHEMICALS • FINE CHEMICALS • SPECIALIZED COMPOUNDS

EVERYWHERE YOU LOOK *Muriatic Acid*

Just another thing we take for granted! But Muriatic Acid (HCl) has plenty to do with how well you live.

Eliminate the work Muriatic Acid does from the scene above and the whole picture changes. It's used in chrome tanning for the leather in shoes, for the manufacture of dyes that give us brilliant colors, for bleaching cloth, processing of photographic film, to put shining chromium on automobile bumpers and trim by electroplating, for steel pickling, even to make the engravings for the page you're reading. Plenty of other uses such as an analytical reagent, for intermediates and a long, long list of major processing jobs put Muriatic Acid high on the list of low cost chemicals upon which industry has come to depend.

Industry has learned that a dependable source of Muriatic Acid is Tennessee Products & Chemical Corporation . . . an industry producing for all industry.

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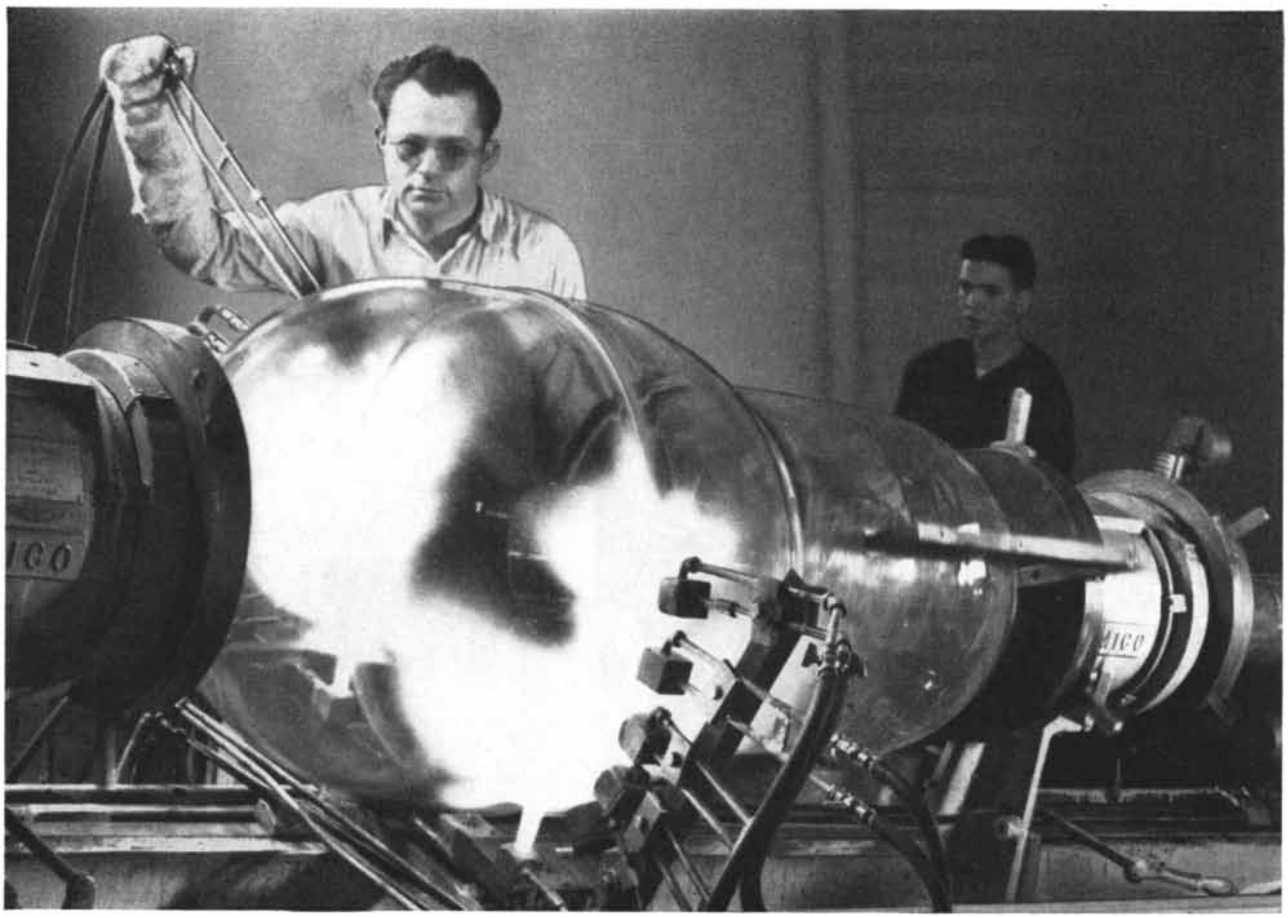

Do you have material problems?

GLASS BY CORNING HAS SOLVED MANY

In this time of critical shortages, almost every company faces a material problem of one kind or another. Changes in design and materials are inevitable. If you face such a problem even as large as the piece of processing equipment shown above . . . consider glass by Corning.

First, glass is available . . . and at reasonable cost. Second, glass is versatile. New methods of manufacturing and new compositions make it a practical material for many uses not generally associated with glass. Third, Corning is starting a second century of service to industry through research in glass. All this "know-how" is yours to use.

Tell us what you think you are going to need. What physical factors must we meet? What design problems are involved? How about assembly, volume, delivery? One thing is sure—if it's possible to meet your needs with glass, you can depend on Corning to do so. Why not write to-day . . . or if you prefer, use the coupon.

1851
100 YEARS OF MAKING GLASS
BETTER AND MORE USEFUL
1951

Corning means research in Glass

Corning Glass Works
15 Crystal St., Corning, N. Y.
Please send me your "Designers Bulletin IZ-1."

NAME__________ TITLE__________
COMPANY__________
ADDRESS__________
CITY__________ ZONE____ STATE__________

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

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Established 1845

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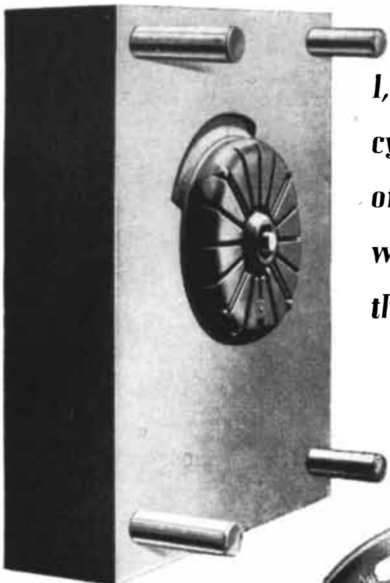
What's New at CRUCIBLE

about Die Casting Die Steel

Mt. Vernon Die Casting Corporation, Mt. Vernon, N. Y. —big name die casting company, prides itself on dies that retain their accuracy for longer periods; yield clean, flawless castings around-the-clock; quickly write off initial costs and reduce ultimate costs appreciably.



1,250,000 casting cycles—and no signs of heat checking or wash on the face of the NU-DIE V die!

Aluminum base motor housing

Mt. Vernon and Crucible have worked for many years as a team in the interests of better castings. Therefore, when Mt. Vernon was called on to produce aluminum base motor housings, they came to Crucible for the die casting die steel.

For this job, Crucible and Mt. Vernon selected NU-DIE V—a steel designed for aluminum—magnesium—and long run zinc base dies. Experience has shown that greater resistance to heat checking and washing is obtained when using NU-DIE V.

Mt. Vernon went to work preparing the blocks of NU-DIE V for the intricate job of duplicating the casting shown in the illustration. Since about 80% of the cost of a die is represented by the labor, it is important that the requirements for a successful die be met to the fullest degree.

An outstanding aluminum die casting die is the successful combination of four factors:

1. Proper steel composition to meet the ultimate service requirements.
2. Proper die design.
3. Proper response of the steel to heat treatment.
4. Proper control of casting pressures and temperatures.

It is a credit to the characteristics of NU-DIE V, and the skill of Mt. Vernon die designers and production personnel that this die casting die has gone 1,250,000 casting cycles without a sign of heat checking or wash on the face of the NU-DIE V die.

Write for your Tool Steel Selector today!

Crucible metallurgists can help you in the application of NU-DIE V and other tool and die steels. And, if you haven't the new, three-color, 9″ diameter, Crucible Tool Steel Selector, write for yours today! It uses the only logical method of tool steel selection—begin with the application to pick the right steel. Address: Dept. SA, Crucible Steel Company of America, 405 Lexington Ave., New York 17, N. Y.

3-color, 9″ diameter

CRUCIBLE first name in special purpose steels

51 *years of Fine steelmaking*

Spaulding Works, Harrison, N. J. • Midland Works, Midland, Pa. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa.
National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

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SCIENTIFIC AMERICAN

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AN ANALYSIS OF TELEVISION PROGRAMS

What is the total picture they present and how much of it may be considered educational? U. S. educators have collected some data on the question to support their plea for educational TV channels

by Dallas W. Smythe

THE power of television to capture men's attention and sway their minds, which was so dramatically demonstrated by the Kefauver hearings, is inevitably a matter of major concern to educators. U. S. educators recognized the great potential of this new medium last year by forming the Joint Committee on Educational Television to seek the reservation of some TV channels for education. The Committee obtained wide popular support, manifested in thousands of contributions from individual citizens. In preparation for public hearings before the Federal Communications Commission on the allocation of channels the Committee decided to make a survey of the programs on TV. The purpose was to ascertain what kinds of material commercial television was presenting to its huge U. S. audience and how much of it was educational.

We chose for study the output of New York City's seven stations, because these programs as a group represent the widest variety of offerings and the best in commercial TV. The survey consisted in a complete inventory of every program produced by the seven stations during one full week, from the morning of January 4 to the night of January 10-11, 1951. A staff of 21 monitors with experienced supervisors was stationed at television sets in a suite in the Waldorf-Astoria Hotel to view the programs. Using seven TV receivers, with an eighth as a spare, they made a careful record of the type, content and duration of each program and of all advertisements, or "commercials."

By preliminary analysis and from experience as the viewing progressed we worked out a scheme of classification for the programs. They fell into 17 classes, some of which were further divided into subclasses. For example, the drama class included domestic serials ("soap operas"), crime melodramas, Westerns, comedies, romantic stories, musical comedies, classical plays and so on. Programs classed as information included science demonstrations or discussions, travelogues and miscellaneous documentary or instructional material for a general audience.

The results of the study are shown in the table on the next page. Readers will find that this table repays close study; here we shall mention only a few of the most significant findings.

OF the total of 564 hours of TV programs broadcast by the seven New York stations during the week, one-fourth (a little over 143 hours) were given to drama. Crime plays, the largest single TV offering in terms of time, accounted for 57 hours, or 10 per cent of all programs, and Westerns accounted for another 8 per cent. After drama as a general classification came variety or vaudeville-type programs (14 per cent), children's programs of various kinds (13 per cent), sports (10 per cent), homemaking (10 per cent), quiz, stunts and contest programs (7 per cent), personalities, *e.g.*, interviews with celebrities (5 per cent) and news (5 per cent), one third of which was accounted for by a single daytime program that showed news bulletins on a ticker tape.

There were considerable differences between stations, as the table on the following pages shows, but the question of the over-all offering to the public on seven scarce channels is pertinent to the issue of channel allocations for education.

In timing commercials we encountered the problem that much of the advertising on television is not strictly timable. For example, in some programs visual advertising material is obtrusively present on the screen throughout the program, and in others advertising is so closely intermixed with contests, news, stunts and so on that it is impracticable to determine where the advertising stops and the program begins. We classified these few programs as "untimable" advertisements.

The timable commercials, not including the stations' advertising of their own programs, occupied about 56 hours, or 10 per cent of the total TV broadcast time during the week. Untimable advertisements amounted to another 22 hours. Thus altogether advertising accounted for 14 per cent of all the program time. The heaviest concentration of advertising was in the "housewives' hours" during weekdays. One station, WABD, devoted 52 per cent of its air time during these hours to advertising, and WNBT was a close second with 44 per cent. During the week as a whole WNBT carried 14 hours and 43 minutes of timable commercials—almost twice as much as any other station.

NOW what of the programs themselves—how educational were they? We chose a broad and flexible definition for an "educational" program: it should have some rational plan and continuity, with regularity in the presentation of the material and progression in its content. Basic principles should be emphasized and the viewer should be car-

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ried by gradual stages to a deeper understanding of the subject. If a program met these specifications, it was considered educational whether or not it was presented in cooperation with an educational institution and regardless of whether it was in the format of a lecture, drama, discussion or any other means of expression.

We must note at once that there was no formal education of any kind on commercial television—no extension courses, no vocational courses, no special educational programs for particular groups. Of all the programs viewed during the survey only one, the Johns Hopkins Science Review, was produced under the auspices of an educational institution. The science information programs during the week amounted to less than one per cent of the total broadcast time; besides the Hopkins program there was a film on psychology and a Hayden Planetarium program. Informational programs in general occupied about 18 hours, or three per cent of the week's broadcasts. They included the science programs; a few travelogues, intended more for entertainment than to provide a real understanding of foreign lands; seven film shorts on wildlife, of which the favorite subject was fish; four films on the customs of other peoples; one on rivers and water supply and one on "spelunking." There were two zoo programs, some institutional advertising films about industry and four miscellaneous films. Only one genuinely instructional program was observed: a teaching demonstration of art techniques by Jon Gnagy.

Another one per cent of the total broadcast time was devoted to children's information and instruction programs. They included a travelogue on Alaska and films on Eskimo dogs, salt mining, fish, baby animals, how a pump and pulley work, how to change a tire. There were also a 15-minute violin class, a 30-minute United Nations Stamp Club and some Western lore in a chuck-wagon program.

In the light of our criteria we concluded that all but a few of these programs could not be considered "educational" except in a most superficial sense. They were for the most part a hodgepodge of isolated, shallow bits of information, presented without plan, without regularity and frequently without advance notice to the public of what was to appear. Honorable exceptions were the Johns Hopkins and the Jon Gnagy programs and possibly the violin class.

Where else might we look for programs of educational value? We turned to current events programs. They included a broadcast of the President's address opening Congress, daily news programs, several discussions of current affairs and some public institutional programs. All these performed a necessary public service. The amount and time-of-broadcast of such programs, however, was woefully inadequate; the inadequacy was especially marked in coverage of local public events and issues. We observed, moreover, that little effort was made to provide systematic background information to aid the public in understanding and evaluating the material presented.

WHEN one comes to the "entertainment" programs, it is much more difficult to apply standards of judgment. A few programs, such as a romantic-historical play on Andrew Jackson performed in the Pulitzer Prize Playhouse, could be placed on the credit side of the account as education. (We did not class this play as "domestic drama," as Robert Saudek of the American Broadcasting Company is said to have charged.) But most of the entertainment programs did not rise above the rut of two-dimensional formula productions. The profusion of Western and crime pictures, with their trite, polarized plots, and of quiz, stunt and contest programs, mostly at a very immature level, far overbalanced the few entertainment programs with educational value. A depressingly large proportion of the "entertainment" offered on TV was uninspiring, monotonous and ultimately derogatory of human dignity.

Conspicuous among television's omissions was its failure to make available any significant portion of the enduring art and literature which are part of our cultural tradition. There were only 77 minutes of programs of serious music during the week. The field of fine arts was represented by a single film program on Italian religious art. The only presentations of classical drama were a modern-dress version of *Macbeth* and a play by Henry James.

Spokesmen for the television industry argued at the FCC hearings that we failed to give adequate recognition to educational or classical material that was interspersed in entertainment programs, such as variety shows. They contended that our classification of each program on the basis of its dominant content was unfair; we should have broken down a variety show into so many minutes of popular music, comedy, serious music, ballet, and so on. Our answer was that it was unrealistic to attempt to atomize each program. If variety shows were broken down, we should also have to break down the more serious programs; it seemed no more appropriate to credit a snippet of opera in a variety show as serious music than to classify a songless scene in an opera as comedy drama.

The inevitable general conclusion from this survey was that from an educational standpoint the performance of commercial television was far from satisfactory. Although it presented some entertainment programs of high quality, it was not meeting any substantial part of its responsibilities and opportunities as an educational medium. We concluded that the survey had clearly demonstrated the necessity for independent educational television stations, which could serve not only as channels for education but also as yardsticks for judging the performance of commercial broadcasting.

After its hearings the FCC tentatively

PROGRAM CLASS
1. NEWS
2. WEATHER
3. PUBLIC ISSUES
(a) Opinion
(b) Discussion and debate
4. PUBLIC EVENTS
5. INSTITUTIONAL
(a) Exposition
(b) Dramatization
6. INFORMATION
(a) Science
(b) Travelogue
(c) Other
7. RELIGION
8. DRAMA
(a) Domestic
(b) Crime
(c) Western
(d) Comedy
(e) Romance
(f) Musical
(g) Classics
(h) Other
9. DANCE
10. MUSIC
(a) Serious
(b) Light
(c) Popular
11. FINE ARTS
12. VARIETY
(a) Vaudeville
(b) Informal
13. PERSONALITIES
14. QUIZ, STUNTS, CONTESTS
(a) Experts, guests
(b) Studio audience
(c) Telephone
(d) Amateur shows
(e) Other
15. SPORTS
(a) News, interviews
(b) Spectator events
(c) Participant sports
16. HOMEMAKING
(a) Cooking
(b) Decorating, etc.
(c) Shopping
(d) Personal care
(e) Personal relations
(f) Housewife's variety
(g) Other
17. CHILDREN'S PROGRAMS
(a) Puppets and marionettes
(b) Cartoons
(c) Quiz, stunts, amateur
(d) Thrillers
(e) Westerns
(f) Drama
(g) Stories (narrated)
(h) Children's variety (incl. circus)
(i) Teen-age variety
(j) Information and instruction
(k) Pre-school entertainment
(l) Other
TOTAL

PRINCIPAL RESULTS of the study are tabulated. The classes of pro-

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allocated about 10 per cent of the unassigned TV channels for use by educational institutions. It said, however, that it would review this reservation "from time to time." Because supervisory bodies in our educational system necessarily move slowly, this uncertain reservation is unsatisfactory to educators. The FCC will hold further hearings on the tentative proposals this summer. At that time the commercial television industry will, it appears, urge the FCC to withdraw its reservation of channels for education. On the other hand, U. S. Senator William Benton has asked Congress to act to ensure "development of the educational and public service potentialities of television." How the issue is decided will depend on the actions of the American people in the next few months. The New York State Board of Regents presented the issue in concrete terms last month by filing with the FCC a plan for a network of 11 educational TV stations in the state. The state would appropriate $3,500,000 for building the stations and educational institutions or communities would operate them.

Dallas W. Smythe, research professor in the Institute of Communications Research at the University of Illinois, directed the study discussed in this article. His associate was Donald Horton of the University of Chicago.

WCBS-TV		WNBT		WABD		WJZ-TV		WOR-TV		WPIX		WATV		TOTAL	
utes	Per cent	Minutes	Per cent	Minutes	Per cent	Minutes	Per cent	Minutes	Per cent	Minutes	Per cent	Minutes	Per cent	Minutes	Per cent
23	5	179	4	60	2	35	1	825	15	427	8	111	2	1,860	5
		25	1	1	*			25	*	95	2	1	*	147	*
60	2	150	3	60	2	30	1	38	1	45	1	86	1	469	1
30	1	90	2					38	1			59	1	217	1
30	1	60	1	60	2	30	1			45	1	27	*	252	1
50	1	50	1	35	1	50	1	50	1	51	1	35	1	321	1
		60	1	30	1			161	3	45	1	90	1	386	1
		9	*	30	1			30	1	15	*	75	1	159	*
		51	1					131	2	30	1	15	*	227	1
		120	2	75	2	165	4	414	8	33		283	5	1,090	3
				30	1	15	*	40	1					85	*
						10	*	116	2	20	*	223	4	369	1
		120	2	45	1	140	3	258	5	13	*	60	1	636	2
30	1			75	2	120	3			15	*			240	1
85	14	600	12	803	21	482	11	1,506	26	1,509	30	3,004	58	8,589	25
135	3	60	1			90	2	15	*	30	1			330	1
305	6	150	3	302	8	177	4	631	11	777	15	1,090	21	3,432	10
60	1	30	1	139	4			195	3	295	6	1,141	22	1,860	6
35	1	150	3			95	2	150	3	162	3	522	10	1,114	3
60	1	150	3	179	5	90	2	382	7	95	2	251	5	1,207	4
30	1	60	1											90	*
60	1			30	1									90	*
				153	4	30	1	133	2	150	3			466	1
								24	*			12	*	36	*
85	6	291	6	165	4	292	7	55	1			134	3	1,222	4
		30	1			7	*	40	1					77	*
285	6	261	5	165	4	285	7	15	*			134	3	1,145	3
								30	1					30	*
52	32	1,613	34	300	8	930	22	150	3	53	1			4,598	14
60	7	420	9	270	7	180	4			30	1			1,260	4
92	25	1,193	25	30	1	750	18	150	3	23	*			3,338	10
01	6	155	3	133	3	558	13	285	5					1,432	5
70	5	390	8	478	12	419	9	335	7	148	3	265	5	2,305	7
90	2	150	3			60	1	30	1	32	1			362	1
60	1	120	2	328	8	60	1			30	*			598	2
60	1	30	1	150	4	209	5	150	3	86	2	265	5	950	3
60	1	90	2			60	1	155	3					365	1
						30	1							30	*
68	4	90	2	420	11	364	9	720	13	1,241	23	403	8	3,406	10
		60	1					40	1	128	2			228	1
68	4	30	1	405	11	364	9	670	12	1,113	21	360	7	3,110	9
				15	*			10	*			43	1	68	*
39	8	411	8	625	16	127	3	597	10	910	17	338	6	3,447	10
209	4	122	2	159	4	82	2	240	4			169	3	981	3
15	*			15	*	30	1							60	*
		289	6	451	12			210	4	12	*	139	3	1,101	3
								120	2					120	*
								27	*			30	*	57	*
										898	17			898	3
215	4					15	*							230	1
16	16	704	15	600	16	702	16	300	6	720	13	517	10	4,259	13
133	3	179	4			14	*	75	1					401	1
		105	2			90	2			3	*	301	6	499	2
						30	1			60	1			90	*
		20	1	150	4	134	3			30	1	149	3	483	1
255	5	165	3			105	2			292	5			817	2
		30	1							75	1	38	1	143	*
				151	4	30	1	30	1					211	1
150	3	115	2	149	4	90	2	150	3	260	5	29	*	943	3
						165	3							165	*
178	4	90	2			15	*	45	1					328	1
				150	4									150	*
						29	1							29	*
79	100	4,838	100	3,860	100	4,274	100	5,515	100	5,292	100	5,279	100	33.837	100

grams are in the column at left. The stations whose programs were observed are at top. The totals for each class of program are at right; for each station, at bottom. Percentages smaller than one are indicated by asterisk.

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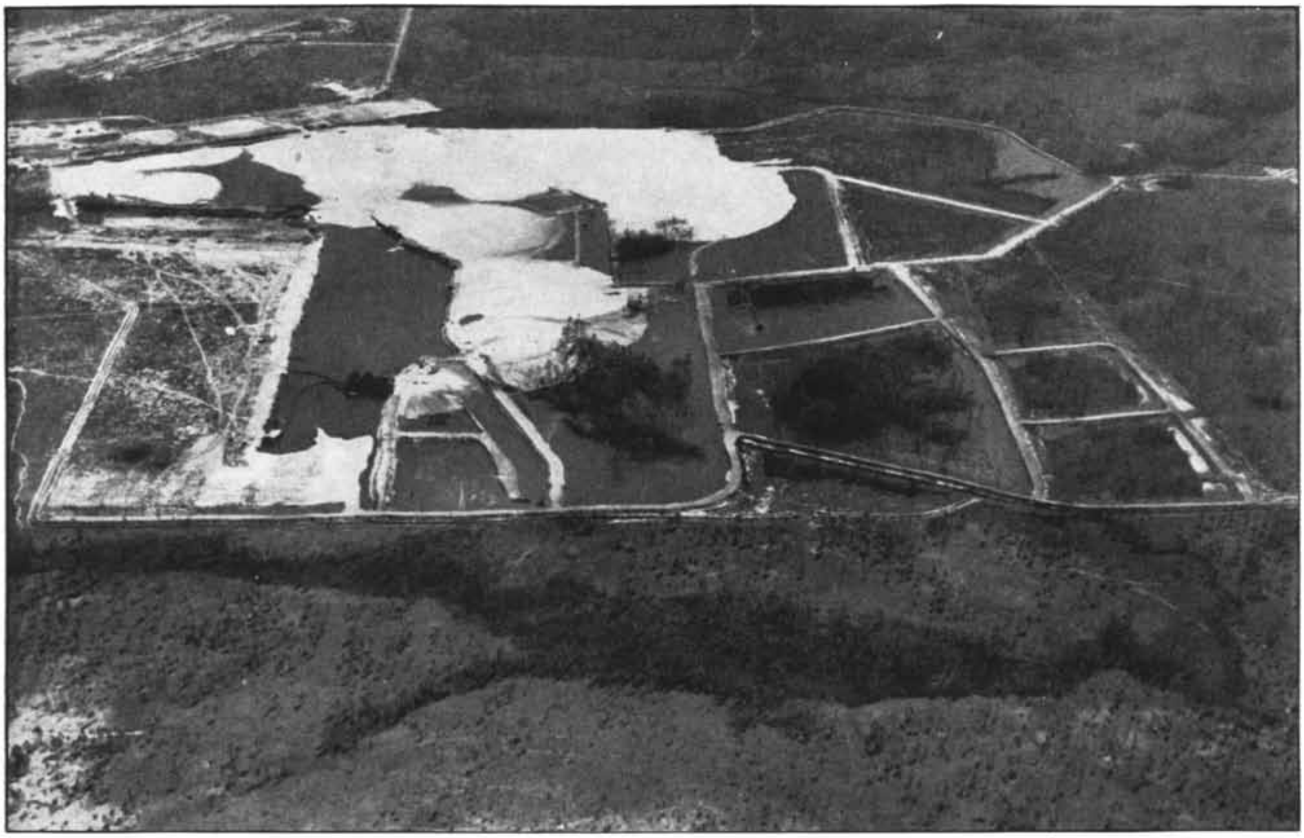

ZIRCON SAND, the principal source of zirconium, is a by-product of ilmenite in this dredging operation at Trail Ridge, Fla. Ilmenite is a mineral containing iron and titanium; it is mined here to obtain the latter metal.

ILMENITE is concentrated at the Trail Ridge plant, the tailings of which are treated for the recovery of zircon sand. The plant is operated by the Humphreys Gold Corporation for E. I. du Pont de Nemours & Co., Inc.

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ZIRCONIUM

Extraordinarily resistant to heat, corrosion and hard radiation, yet malleable and ductile, the metal meets some of the stern engineering requirements of nuclear reactors and jet engines

by Stephen M. Shelton

ZIRCONIUM has recently come to the attention of metallurgists and engineers as a structural metal having tremendous potentialities. It has been referred to as the "Cinderella" metal. Because it is highly resistant to heat and radiations, it is a promising structural material for nuclear reactors and may play an important part in harnessing atomic power. It is also of great interest to engineers seeking a metal that can withstand the terrifically high temperatures in the combustion chambers of jet engines and super-rockets. In addition, zirconium is remarkably resistant to corrosion—even more resistant than tantalum, which has heretofore been considered the most impervious metal. Zirconium metal has other valuable properties as well. Science and industry are beginning to realize that the new wonder metal is almost certain to play a major role in this country's rapidly moving technological development.

Zirconium used to be considered in the class of "rare" elements, but actually it is fairly abundant in the earth's crust—more abundant than nickel, copper, lead, zinc or some other familiar metals. Its chief mineral, called zircon, occurs in sands. The largest present sources are beach sands in Australia, India and Brazil, but there are commercial quantities in this country also, in the beach sands of Florida and Oregon and the vast placer sands of Idaho. The main supply problem with regard to zirconium is not the mineral but production of the refined metal, which presents some technical difficulties. These are being solved, however, and substantial production of purified zirconium metal is now under way in the U. S.

This element with the new-found qualities and the strange name, which comes originally from a Persian word meaning gold-colored, is not precisely a new discovery. The mineral zircon (zirconium silicate) was known to students of gems as long ago as the early part of the Christian era. They called it hyacinth, from the Greek word for a flower or a gem. The particular mineral to which they gave this name was a reddish-orange variety of zircon found in the gem-bearing gravels of Ceylon. The element zirconium itself was discovered in 1789 by the German chemist Martin Heinrich Klaproth, who is now famous also as the discoverer of uranium, titanium and cerium. He identified zirconium while analyzing a precious stone from Ceylon. In 1824 the Swedish chemist Jöns Jakob Berzelius succeeded in extracting from zircon some zirconium metal, though in an impure state.

In the next 100 years many attempts were made to isolate the pure metal, but apparently without success. Zirconium is a very reactive metal and readily forms stable compounds with many elements. Efforts to reduce the mineral with carbon, boron, aluminum, iron and other agents produced only an impure form of the metal.

Impure zirconium is hard and brittle and therefore worthless as a structural material, but it does have some uses. In 1930 it came into vogue as an ingredient in a smokeless flashlight powder for photographers. Finely divided zirconium metal, mixed with magnesium and barium nitrate, provided a brilliant flash without smoke, because the zirconium ash was so heavy that it was not dispersed into the air. Instead of smudging the furniture and lace curtains with a film of magnesia powder, photographers could restrict the damage to a small deposit of zirconia ash on the rug. The popularity of smokeless powder for a time created a real market for zirconium metal. When photoflash bulbs were introduced, the bottom promptly fell out of this market. Other employments were found, however, for zirconium powder; its relatively low ignition point, its rapid burning and its high heat of combustion make it useful in ammunition priming compounds, electric blasting caps, Very signals, airplane landing flares, movie flares and commercial fireworks.

BUT it is the pure metal that has excited the great present interest in zirconium. The metal was first isolated in pure form in 1925 by the Dutch investigators A. E. Van Arkel and J. H. DeBoer, working at the University of Leyden. They succeeded by a physical method where chemical reduction methods had failed. In a Pyrex glass bulb containing a tungsten filament stretched between two tungsten electrodes they placed some crude zirconium metal and iodine. Then they evacuated the bulb with a vacuum pump and heated it in a furnace. As the bulb was heated, the iodine combined with the crude zirconium to form zirconium tetraiodide, which vaporized. This gaseous compound was then decomposed by the glowing tungsten filament, heated to a temperature of nearly 1,500 degrees Centigrade. Pure zirconium metal was deposited on the filament and the liberated iodine reacted with more of the crude zirconium in the bulb to form additional iodide. In a few hours the filament, accumulating deposits of zirconium, grew to rods several millimeters in diameter.

The metal thus purified proved to have a number of previously unsuspected properties. It was not brittle, like the impure earlier samples of zirconium, but very malleable and ductile; it could be cold-rolled, swaged or forged without requiring intermediate annealing. It resembled stainless steel in appearance, and could be polished to a mirrorlike finish. In contrast to powdered zirconium, the solid metal was extremely resistant to heat; a thin 1/16-inch sheet

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can be heated to redness in an open flame without igniting, and even in an atmosphere of oxygen it will not burn below 900 degrees C. Ductile zirconium also showed remarkable resistance to attack by air, sea water, alkalies and acids (except wet chlorine and hydrofluoric acid).

Despite the spectacular properties of this wonder metal, it was slow in becoming available for wide use. For a number of years the only commercial production was by the Van Arkel process, which was taken out of the laboratory and modified for practical factory operation by the Philips Lamp Company in Eindhoven, the Netherlands. But even with improved techniques and factory-scale production, ductile zirconium metal produced by this process still costs about $125 a pound.

In the past few years the growing realization of the metal's potentialities has spurred the metallurgical industry of the U. S. into action. At least three different processes for producing ductile zirconium, in addition to the Van Arkel method, are being developed at the present time. Of these the furthest advanced is one conceived by the renowned metallurgist William J. Kroll, who left his native Luxembourg just before the Nazi invasion in 1940 and later joined the staff at the Bureau of Mines Electro-development Laboratory in Albany, Ore., where he has supervised the development of his process.

THE Kroll method, a magnesium reduction process, is carried on amidst a maze of complicated machinery and control instruments. The first step is reaction of the reddish-brown zircon sand concentrate with graphite in an electric-arc furnace. This drives off the silicon and produces zirconium carbide, which in turn is heated in another furnace and treated with chlorine gas to form zirconium tetrachloride. This product, after a treatment to remove impurities (mainly chlorides of iron), is then subjected to a reduction process which is the essential step of the method. The zirconium tetrachloride is heated in a helium atmosphere in the presence of molten magnesium metal so that the chloride reacts with the magnesium. The result is a spongy mixture of pure zirconium and magnesium chloride. By distillation under vacuum the magnesium chloride and any excess magnesium metal are removed, leaving the purified zirconium sponge. The zirconium can then be melted into metal ingots.

Zirconium is extremely difficult to handle in the molten condition, because it reduces or dissolves all of the known refractories. Consequently the melting and casting of the metal present problems. If the molten metal is not protected from air or other active gases, the cast metal produced is too hard and brittle. The entire melting and casting operation therefore must be carried out in a high vacuum or in an atmosphere of inert gas. Two types of electric furnace have been used successfully for this operation: an arc furnace and a graphite-resistor furnace.

The Kroll process yields a very pure finished metal, containing less than .02 per cent carbon, .06 per cent iron, .07 per cent oxygen, .01 per cent nitrogen, .02 to .05 per cent aluminum and about .5 to 1.5 per cent hafnium. Incidentally, zirconium's association with the rare element hafnium is one of the intriguing aspects of its development. Hafnium, which occurs in varying amounts in all zirconium ores, is high on the list of "little-known metals" that the metallurgical industry is eager to investigate.

After preliminary laboratory experiments, Kroll and his co-workers put into operation in 1947 a pilot plant with a capacity of 60 pounds of zirconium sponge per batch. Later a larger pilot plant was built. It was so successful that in August, 1950, the Bureau of Mines completed and began to operate at Albany a full-size Kroll-process plant—the first major zirconium plant in the world. The experience in this plant indicates that zirconium ingots can be produced commercially by the Kroll method for less than $20 a pound.

The two other developments known to be under way in the U. S. are by the Westinghouse Electric Corporation, which is trying out a process that reduces zirconium oxide with metallic calcium, and by the Titanium Alloy Manufacturing Division of the National Lead Company, which reduces zirconium tetrachloride with metallic sodium.

The cold malleability of zirconium metal is influenced to a marked degree by the amounts of oxygen, nitrogen and hydrogen that are present as impurities. Hydrogen is easy to control, because in each of the processes for producing ductile zirconium there is a vacuum step in which the hydrogen is pumped off. The presence of oxygen or nitrogen, however, is quite different. Once these gases are present there is no known method of removing them completely.

The metal is very reactive with air at elevated temperatures; this complicates initial working of the ingots. It is soft enough to be rolled, forged or swaged into almost any form if it can be protected so that it does not react with the air and become hard and brittle. The standard procedure at the Bureau's laboratory has been to sheathe the ingot in mild steel tubing with welded plugs at each end. The sheathed ingot can be heated to temperatures as high as 700 degrees C. and can be forged and rolled to a sheet less than half an inch thick. The sheath is then removed, and the worked metal, still ductile, can be cold-worked further to finished thickness. Sheet formed in this manner has an oxide layer on the surface, but this can be removed by a combination of sandblasting and a pickling operation with hydrofluoric acid and lead nitrate.

Ductile zirconium is amenable to drop-forging and pressing. Well-filled commercial shapes have been made, using dies designed for steel hand-tools. The metal can also be swaged into rod or drawn into wire.

SINCE ductile zirconium is only now beginning to become available in quantity and at something approaching reasonable cost, its possible uses are still largely unexplored. The metal is receiving considerable attention, as is already well known, from scientists and engineers who are designing reactors for harnessing atomic power. Its outstanding ability to resist attack by alkalies and acids also suggests that it will have an important future in the chemical industry, as a material for tank linings, pipes, valves, immersion heaters and the like. The metal's resistance to hydrochloric acid makes it invaluable in industries that use this acid, notably those that produce magnesium, pulp paper, salt and bleaches. Not only does zirconium equal or surpass tantalum in resistance to chemical attack, but it has the additional advantages of being lighter in weight, more plentiful and cheaper to produce.

There is a good possibility that zirconium will replace the more expensive tantalum in surgical equipment. It is well-suited for surgical instruments because of its high tensile strength and resistance to attack or discoloration by iodine, mercury salts or high-temperature sterilization. The metal has special value for suture wire, bone screws and cranial plates. Tissue grows directly to the metal without any signs of decay or deterioration; body fluids will not corrode it. One medical use to which zirconium has already been put is in the construction of a false eyeball. The rear half of the eyeball is made of zirconium, with hooks that attach to eye muscles. This device can be moved by the muscles and is indistinguishable from a normal eye. At the University of Pennsylvania investigators have been experimenting with zirconium to find out whether it can solve a problem created by the removal of a diseased lung. In such cases other organs frequently move into the space left by the removed lung and cause trouble. The experimenters formed finely rolled zirconium sheets into artificial lung spacers and spliced them into laboratory dogs. After three years the dogs are still frisking around in perfect health.

Zirconium has recently been put to use as the light source in a new lamp which has a brilliance nearly rivaling that of the sun. This high-power, high-intensity

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electric arc lamp heats a film of molten zirconium to a temperature near 6,500 degrees Fahrenheit. The light source is only a fifth of an inch in diameter. It operates in the open air, not in a glass bulb. In a 1,000-watt lamp, operating at 55 volts and 18 amperes alternating current, the light has 20 times the brightness of the ordinary tungsten filament and one-eighth the brightness of direct sunlight. Possible applications for the lamp are in motion-picture projection, television, lithography and photocopying.

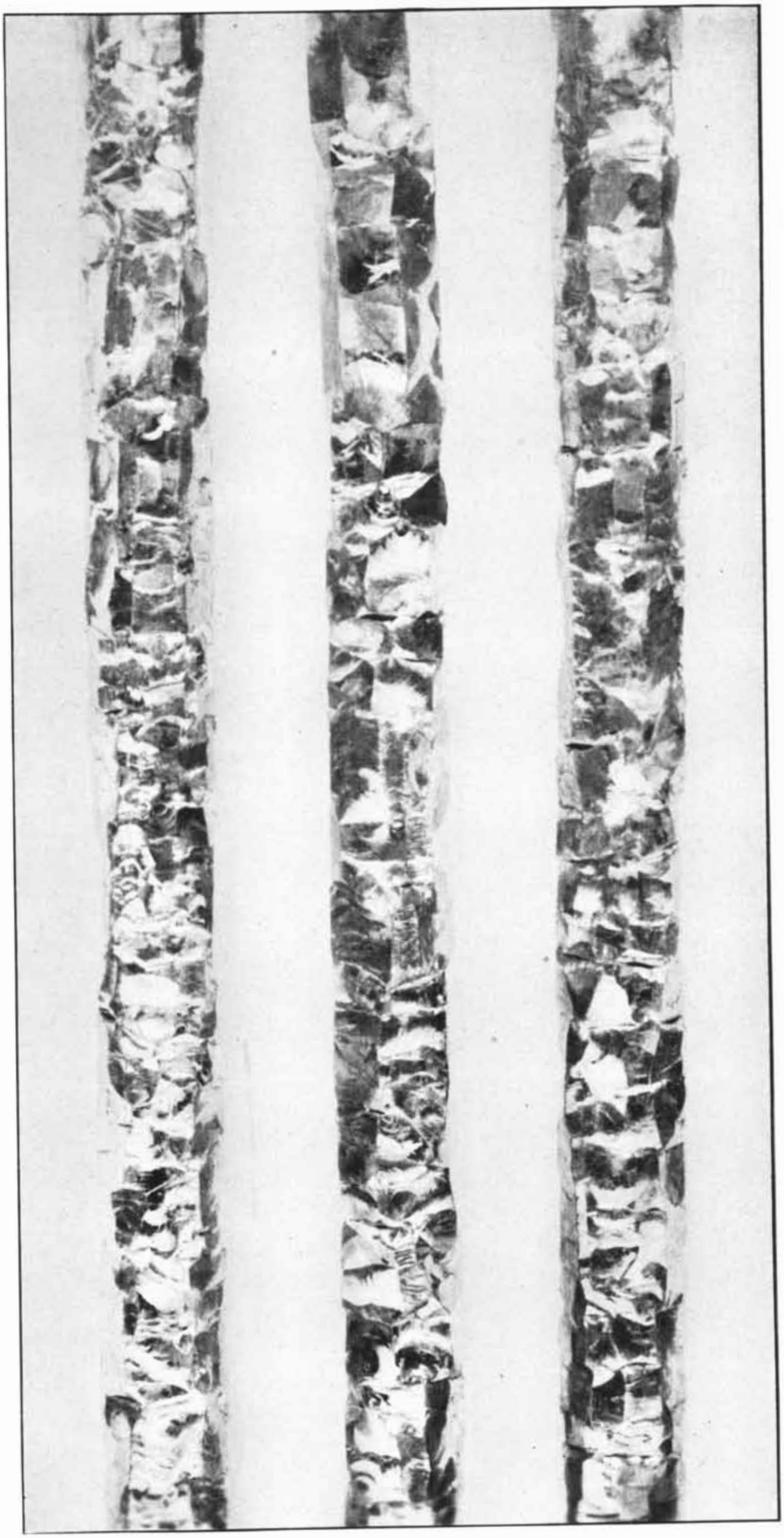
ZIRCONIUM'S affinity for gases provides another possible use for it in radio tubes. These tubes have a small piece of metal enclosed in them to help produce a higher vacuum. After a tube has been evacuated to a certain pressure by a vacuum pump, the metal, called a "getter," is volatilized by heat and in the gaseous state combines with the residual gases in the tube and takes them out of circulation. As a getter zirconium may be able to act over the entire life of the tube, absorbing any gases that may be liberated from the walls of the tube or that may leak into the tube. Thus it would increase the life and efficiency of the tube. Zirconium probably will be used similarly in fluorescent lamps.

If the chemical activity of the metal can be controlled, it will have wide application as a cleanser in metallurgical processes. It would be an ideal desulphurizing and deoxidizing agent for steel and at the same time would tie up the nitrogen and carbon, so that the steel would not age. The particles formed in a steel by zirconium—mainly nitrides, oxides and sulphides—produce nuclei; therefore the metal would refine the grain of the steel.

As an alloy, zirconium promises to be invaluable. Zirconium boride can withstand temperatures up to 6,000 degrees F., so it is a good candidate for use in rocket combustion chambers. Alloys of zirconium and copper harden with age. Zirconium imparts desirable properties to magnesium; when used in high proportions it makes the magnesium structurally strong and in lower proportions refines the grain size and improves the workability. A gold-zirconium alloy is so hard and resistant to corrosion that it may replace platinum and iridium in fountain-pen tips. These two metals also combine to form what is probably the hardest gold-base contact alloy known.

Potentially zirconium's uses are legion. Like all the new metals of the past, it will no doubt be adapted eventually to uses not dreamed of today.

Stephen M. Shelton is Regional Director for the U. S. Bureau of Mines at Albany, Ore.



ZIRCONIUM RODS were made by the Van Arkel process, in which crude zirconium is allowed to react with iodine to form zirconium tetraiodide. This gaseous compound is then decomposed by heating to form pure zirconium.

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A BRIGHT METEOR was photographed at the Oak Ridge Station of the Harvard College Observatory on December 14, 1933. The meteor was one of the Geminids, which radiate from the constellation of the Gemini.

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METEORS

The stony and metallic particles that enter the earth's atmosphere can now be perceived day or night and rain or shine by radio echo

by Fletcher G. Watson

IN THE HOURS before dawn on November 12, 1833, a shower of shooting stars as thick as a snowstorm swept across the sky in the Western Hemisphere. The spectacular show was seen by many people in various parts of the Americas, and it aroused a keen new interest in the mysterious phenomenon of shooting stars. The shower, streaming from the constellation Leo, was given the name Leonid. A search of old astronomers' diaries revealed that showers from this point in the sky had appeared many times before, with the maximum intensity occurring at regular 33-year intervals. Astronomers began to study other meteoric showers and soon found that, like the Leonids, they could be identified by the direction from which they came and showed maximum intensity in regular cycles. Some make an annual appearance; the Perseids, for example, arrive with about the same intensity each year in mid-August.

The investigations that grew from the great burst of 1833 provided the first clue to the nature and origin of meteors, which had puzzled men for centuries. Until the middle of the 18th century these fireballs had been thought to be some kind of weather phenomenon; they had been named meteors from a Greek word meaning "something in the air." Indeed they are something in the air, but they do not originate there. Even before the 1833 shower a few observers had proved by rough measurements of meteors' heights and speeds that they must plunge into the earth's atmosphere from outer space. They were eventually identified as solid particles flying at such speeds that when they hit the atmosphere they produce an incandescent trail which appears as a shooting star. Many of the particles, if not all, come from great "flying gravel banks" that swing through interplanetary space in orbits which periodically bring them close to the earth and produce showers like the Leonids.

In the past few years there has been a new burst of interest in meteors, not only for themselves but for what they have to tell us about the upper levels of the atmosphere. In part this interest stems from such practical problems as radio transmission, rockets, guided missiles, spaceships and the like. But it comes in part also from the fact that meteors can now be studied with a superior new tool—radar. Radio instruments have given us a great deal of information about meteors that cannot be obtained from photographs. To understand the meaning of these new findings we need to review what astronomers had already learned about meteors by other means.

EACH day at least a billion meteors strike the earth's atmosphere. Most of them are no bigger than a pinhead and burn up in the air. A relatively small number, perhaps one or two thousand a year, are large enough to pass through the atmosphere and fall on the earth as meteorites. Once in thousands or millions of years the earth may encounter a meteor of sufficient size to blast a crater, such as the great crater in Arizona. In the aggregate the total amount of material added to the earth by meteors and meteorites is estimated to be about five tons a day. Scattered over the whole planet as dust, this deposit of matter is not enough to be noticeable, even over the long stretch of geologic time.

Shooting stars are often seen singly, but these may actually be members of showers too weak and diffuse to be recognized. Although the meteors in a shower often fall so thickly that they seem to be bunched in a tight swarm, the individual particles in reality are widely separated; even in the great Leonid shower of 1833, probably the thickest shower ever seen, the meteors were an average of 20 miles apart.

The average speed of a meteoric particle when it strikes the atmosphere is about 30 miles per second. It becomes visible only when it vaporizes in or near the ionosphere, a region some 40 to 60 miles above the earth which reflects radio waves and has become known as the earth's "radio roof." As a meteor dashes into this region, its collisions with air atoms chip atoms from the meteor and send some of them flying out at high speed. A trail of hot gas forms in the meteor's wake. It is this incandescent cloud, not the meteoric particle itself, that we see as a shooting star. As the particle plunges on, it is rapidly consumed, and the whole show is soon over. The typical meteor appears at a height of about 55 miles and fades out at about 45 miles, but occasionally a very bright meteor flames down to about 10 miles above the earth's surface and then explodes with a thunderous rumble that may be heard for 100 miles or more.

It is now believed that many of the larger meteors are the debris of a smashed planet or planets that once revolved around the sun, and that the smaller particles occurring in meteoric showers come from the dusty trails of comets. The periods of maximum intensity of the Leonids, Draconids and several other showers have been found to coincide with the times when certain comets pass closest to the earth in their great swings through interplanetary space. For example, in 1933 the earth passed through the path of the comet known as Giacobini-Zinner, and the result was the greatest meteor shower of this century. In 1946 the earth again came through this comet's orbit, only 15 days after the comet had passed, and

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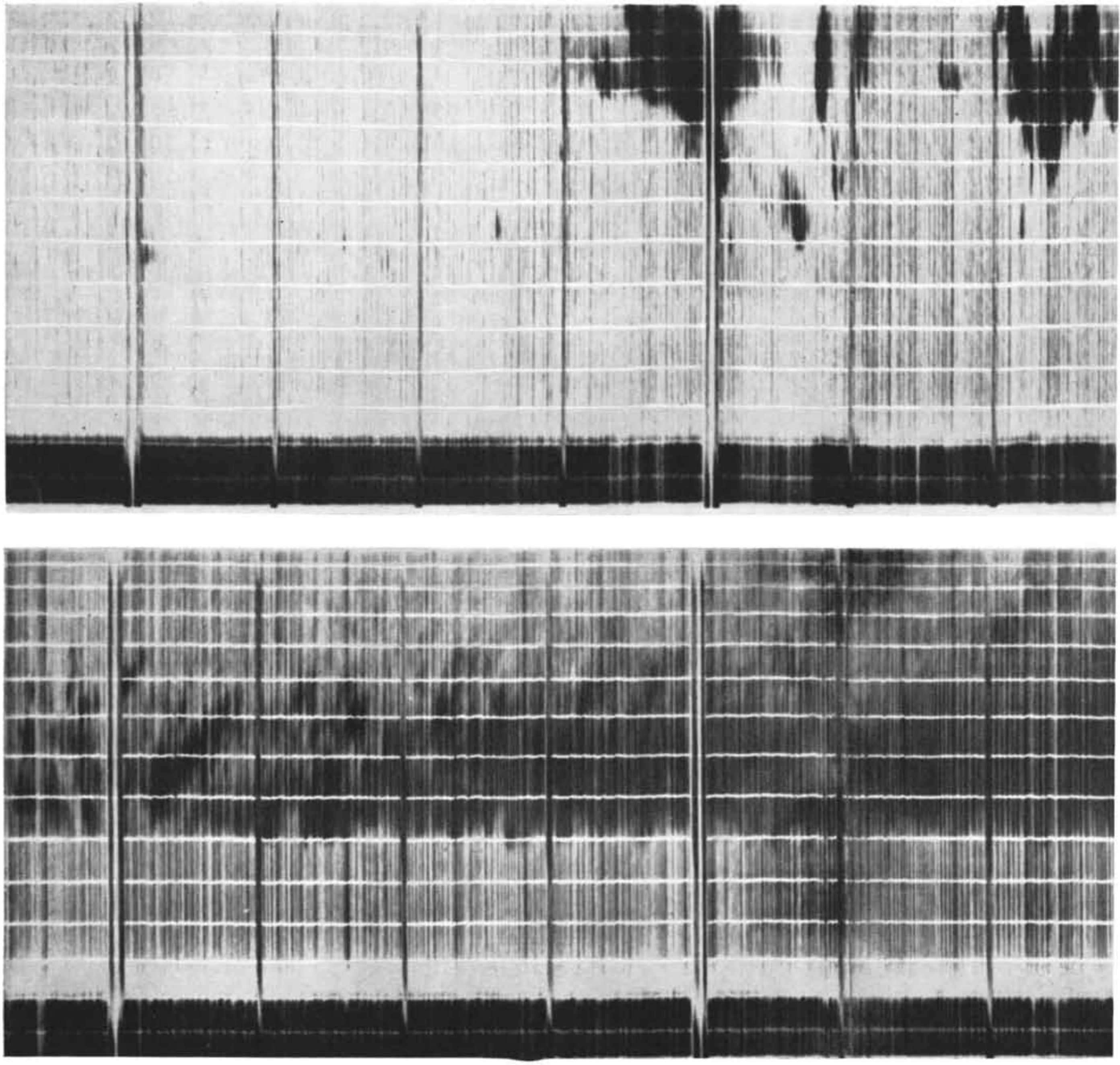

RADIO ECHOES from the upper atmosphere were recorded by J. A. Pierce of Harvard University. At the top of these two pages is a record made on the night of September 28, 1946, when there was considerable auro-

another intense meteor shower appeared.

The theory that meteors come from great clouds of matter swinging around the sun is reinforced by the fact that most of the meteor particles move in the same direction as the planets and stay close to the plane of the planetary orbits. The meteors that an observer sees about 6 p.m., when the part of the earth on which he stands is shielded from the effects of the earth's movement through space, are generally faint and traveling at low speed. These evening meteors are moving in the earth's direction and overtaking it; the earth's speed through space—18 miles per second—is subtracted from their speed. On the other hand, the meteors that one sees after midnight are much faster and brighter. Then the observer is on the forward side of the earth, so the particles hit the atmosphere at much higher speed. The best time for seeing meteors, therefore, is before dawn; about three times as many are visible then as in the early evening.

MOST of these facts about meteors were determined with the eye and the camera. In investigating the origin and behavior of meteors, and the nature of the upper atmosphere, earthbound man is limited to just a few clues—the meteoric particles' speed, height, direction, frequency and so on. A great deal of information along this line can be obtained with cameras, such as the "meteor traps" operated at the Harvard Observatory by the astronomer Fred L. Whipple. Since 1936 two wide-angle cameras stationed 25 miles apart have kept a constant watch of a section of the sky for meteors. About once each 100 hours of exposure, on the average, a bright meteor records its path on the two cameras' plates. From these records the height of the meteor can be determined by triangulation, and its speed

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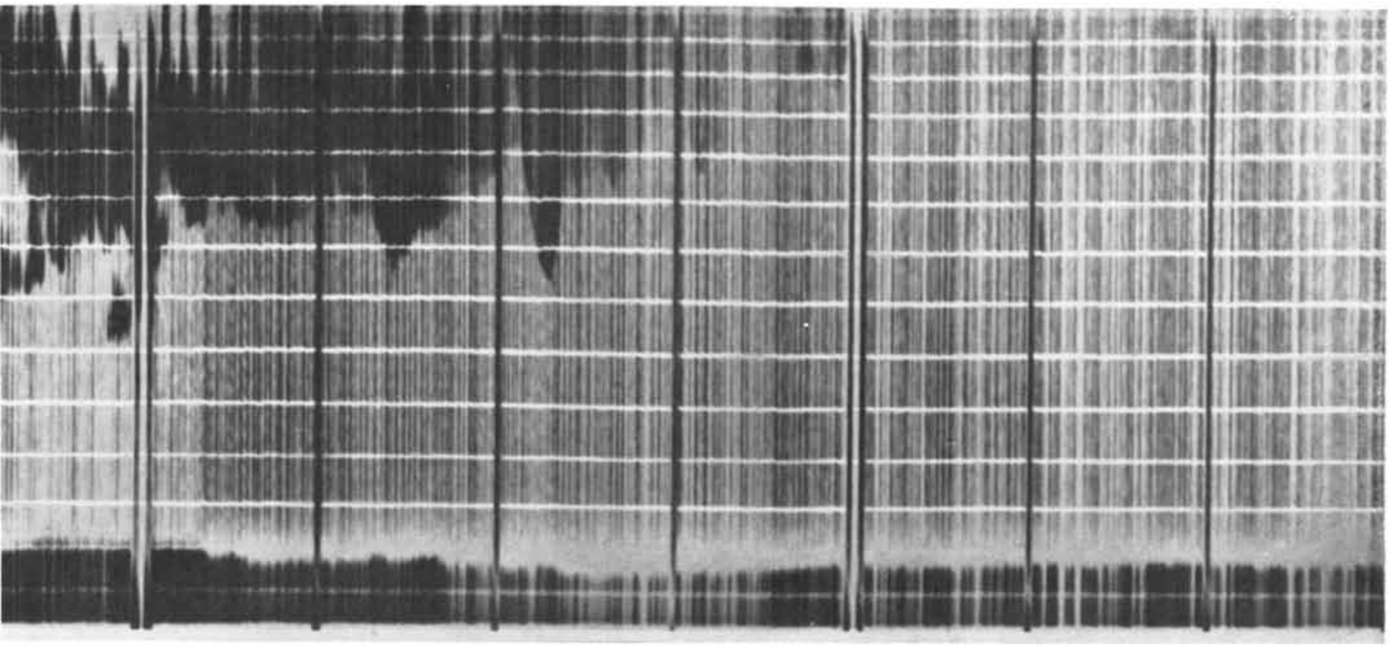

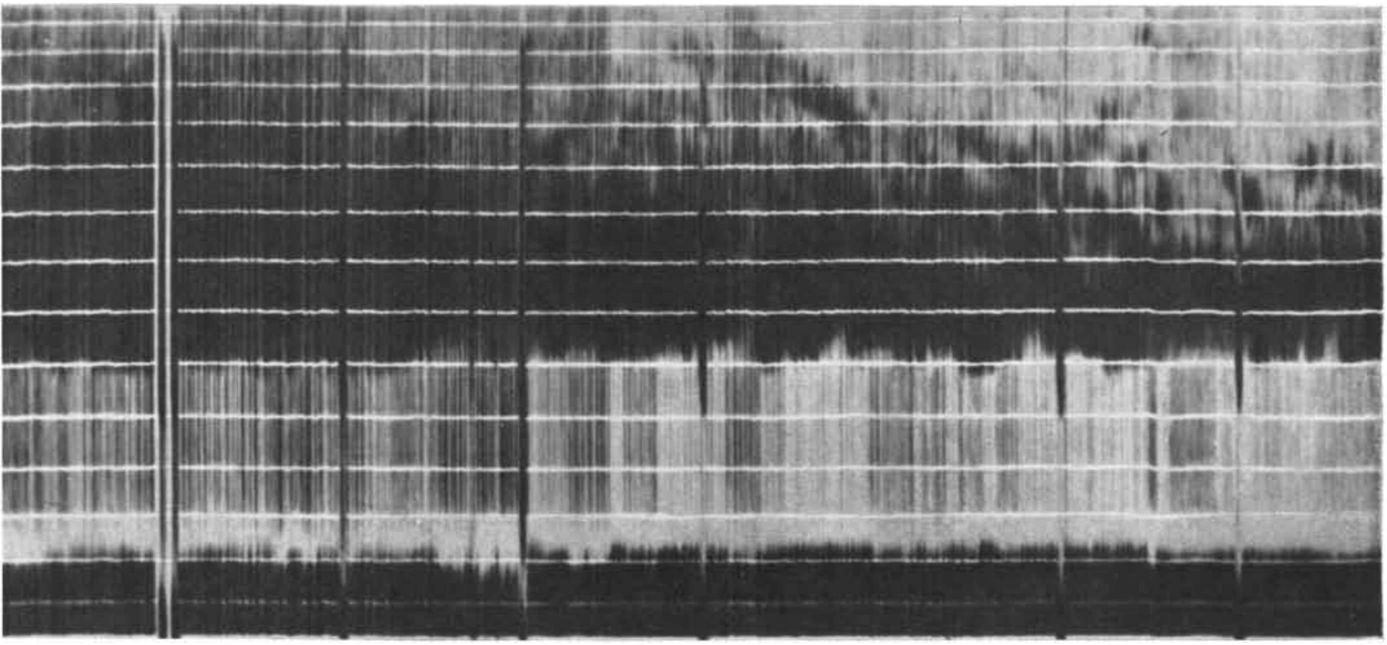

ral activity. The echoes are indicated by the dark vertical streaks on the upper half of the record. The record below was made on October 9 and 10, 1946. It shows the echoes from some 4,000 meteors of the Draconid shower.

across the sky by a shutter that chops the track into timed segments. By means of a glass prism placed before the camera, which splits the light of a meteor into its component colors, it is also possible to obtain the spectra of the meteoric gases and identify some of the substances of which meteors are composed. One significant finding from this is that nearly all shower meteors contain calcium while many of the sporadic ones do not.

But a camera can survey only a small section of the sky, and it cannot "see" meteors in the daytime or through clouds. This is the reason why radio has become such an important tool in this field. It can "see" meteors by day as well as by night, can record meteors too faint to register on a photographic plate and can furnish certain information about the upper atmosphere unobtainable by any other means.

It was John A. Pierce of Harvard who first made clear the possibilities of radar for studying meteors. In 1938, while investigating the ionosphere by bouncing pulsed radio signals from it, Pierce noticed that he occasionally got brief echoes from something else. He suspected that the echoes came from meteors and concluded that pulsed signals could be used to yield important new information about them. World War II interrupted these plans, but at the end of the war the powerful radar devices developed for military purposes became available for meteor studies and were promptly put to use.

Meanwhile, two radio operators in India had discovered another method of detecting meteors by radio. Monitoring short-wave broadcasts by the all-Indian radio station, Chamanlal and Venkataraman observed that reception on their set was sometimes interrupted by a brief whistle of falling pitch, like a Doppler effect. They too connected the peculiar interruption with meteors, and

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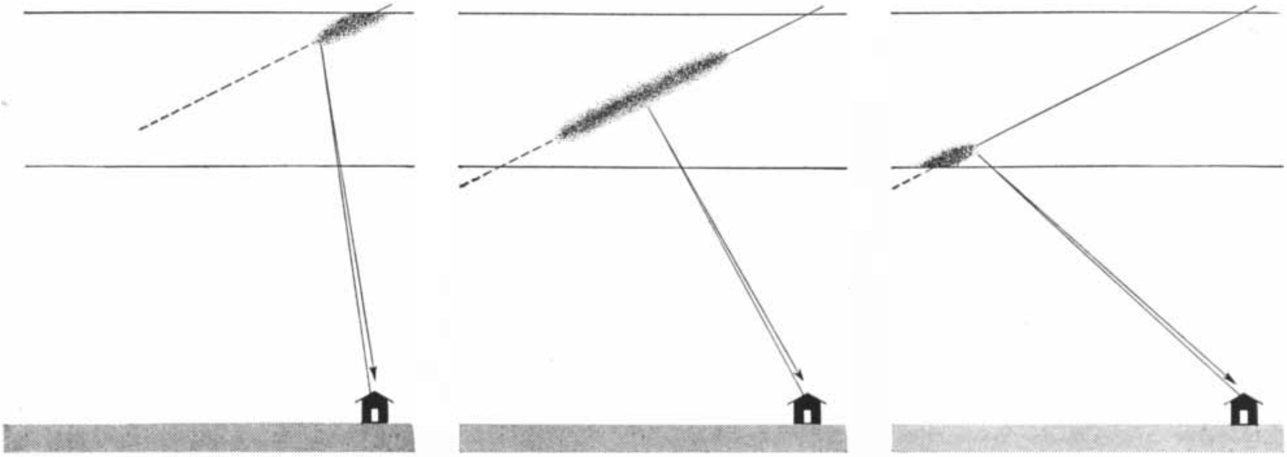

ION CLOUD of a meteor does not reflect radio waves above an approximate height; there are too few gas atoms. Below a certain height there are too many atoms; the radio waves are absorbed. In the condition shown at the left the cloud makes a down whistle in a headset; in that at center, a "burst"; in that at right, an up whistle.

BETHANY METEORITE, one of more than 50 found together in South Africa, was sawed, polished and etched with dilute acid. The result is the pattern, called Widmanstätten figures, shown in this photograph. Each short band marks a crystal that existed in the meteorite when it had a temperature of 1,000 degrees Centigrade.

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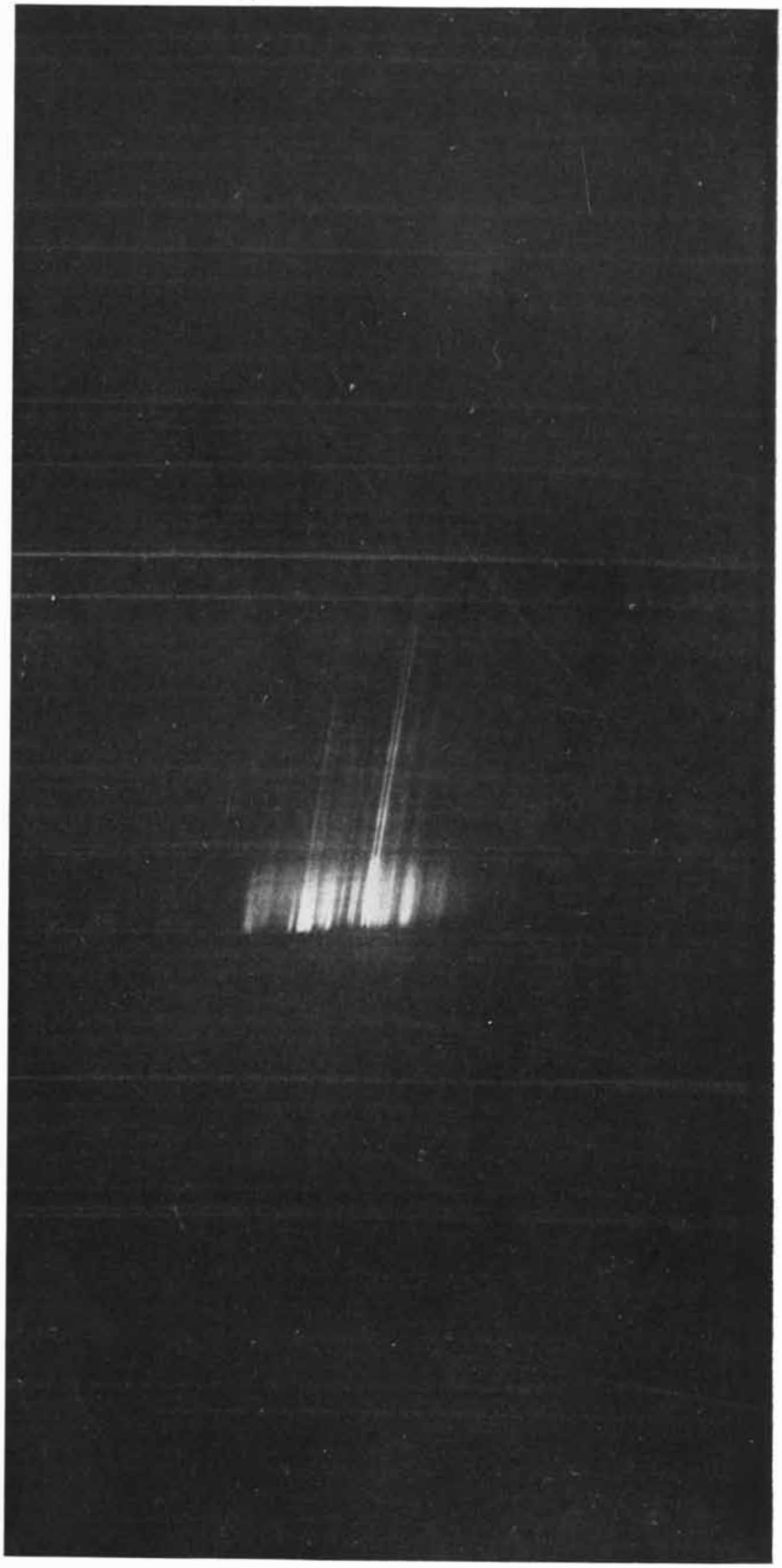
soon confirmed their guess by showing that the whistles coincided with the appearance of bright meteors in the sky. These whistles, like radar echoes, have now become a standard method for meteor study.

THE usefulness of the radio technique got its first dramatic demonstration during the Draconid meteor shower from the Giacobini-Zinner comet in 1946. On the night of this event, October 9-10, the skies in New England were completely overcast, and those of us who had waited 13 years, since the great shower of 1933, for the anticipated reappearance of the shower were sick with disappointment. But Pierce had set up a radio whistle trap, and we were able to hear the shower and count the meteors by the whistles. More than 4,000 individual meteor echoes were registered. This same shower was also recorded by radar at other stations in the U. S. and in England and the U.S.S.R. The radio records of the progress of the shower agreed closely with visual observations.

Patrolling of the skies by radio is now going on at the National Bureau of Standards, Stanford University and a number of other places in the U. S., Canada and England. Observations are being made with radio of various wavelengths and with ingenious arrangements of directional antennas. The scanning of the sky by radio has disclosed several meteor showers previously unknown, including some unexpectedly strong ones that occur during the daytime. The Bureau of Standards, which has been recording hourly meteor rates continuously for the last 11 months, has found that daytime meteor showers rise to a maximum in May, June and July. These meteors are moving away from the sun after passing the point in their orbit closest to it.

Radar measurements of the speed of meteors have gone a long way already toward settling the long-disputed question as to whether any substantial number of meteors come from interstellar space outside the solar system. In Canada the physicist D. W. R. McKinley measured the velocities of 10,933 meteors, mainly of the sporadic type which would be most likely to come from outside the solar system. Their speeds ranged from 7.5 to 50 miles per second. Less than a third of one per cent had a velocity over 45 miles per second, which is about the velocity of escape from the solar system. McKinley concluded that all or nearly all of the detectable meteors are permanent members of the solar system; very few, if any, come from interstellar space.

One reason why radar can detect more meteors than the camera is that it has a larger target. When a meteor dashes through the ionosphere, the ionized trail



SPECTRUM OF A METEOR was made by Peter M. Millman of the Dominion Observatory in Ottawa. The meteor was moving from top to bottom. The two long images near the center of spectrum are due to ionized calcium.

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CHOPPED METEOR TRAIL was made by a special camera at the Oak Ridge Station of the Harvard College Observatory. A rotating blade in front of the camera lens interrupted the image of the meteor once every 20th of a second so that the speed of the meteor could be measured. The meteor brightened several times along its path.

that it creates is much wider than the visible streak. The ion cloud trail varies from a few score feet to perhaps half a mile in diameter, depending on the size of the meteor, whereas the visible track itself, made incandescent by the fact that it is heated to several thousand degrees, is only a few feet in diameter. The apparent thickness of the ion trail of course depends on the radio wavelength used to detect it, because the trail's thin edges will let through a pulse of very short wavelength but will reflect one of longer wavelength. Indeed, extremely short radio waves generally pass through meteor tracks without being reflected at all.

It is the exploration of these ionized trails that enables physicists to learn something about the ionosphere. The radar echoes from them produce rather complex patterns, the meaning of which is not yet clear. The ionized trail often continues to send back radio echoes for several seconds after the visible meteor has vanished. After a meteor has passed, its trail of course begins to break up, but pulses of long wavelength can go on detecting it for some time. Sometimes the trail breaks up into drifting clouds that can be detected separately and followed for many seconds. The mechanism that enables these clouds to hold together is a mystery.

As the radio technique is refined and the meaning of its record is deciphered, it may become possible to determine exactly how the ion trail of a meteor is formed and to trace its life cycle. From this may come a more detailed understanding of the composition and structure of the ionosphere, particularly of the so-called E-layer in which meteors are detected.

WITH respect to the meteors themselves, radio observation thus far has made it possible to study daytime showers, to distinguish sporadic meteors from those that travel together in groups, to detect meteoric particles too small or too slow to be visualized by the camera, to obtain more accurate information on the "radiants" of showers (*i.e.*, the points from which they appear to radiate), to plot their orbits more precisely and to keep a constant watch of the meteoric sky through all kinds of weather. The chief problem at the moment is to analyze the enormous amount of new data that radio scanning has made available. In two years of intermittent operation one Canadian station alone has recorded 1.5 million radar echoes and 50,000 whistles from individual meteors. The reduction of this material to orderly information on the heights, paths, frequencies, velocities and magnitudes of meteors is an almost overwhelming task.

Fletcher G. Watson is associate professor of science in the Graduate School of Education of Harvard University.

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Photography helps analyze what's in the bottle

In identifying hydrocarbons in petroleum products by mass spectrometry, the Research and Development Laboratory of the Atlantic Refining Company runs as many as 60 samples a day.

This high speed output of data is typical of what happens when photography is put to work.

As the ion-accelerating field is varied in synchronism with the travel of a strip of Kodak Linagraph 809 Paper, light beams from four moving-mirror galvanometers swiftly trace out the concentration of each molecular species received at the collecting slit. If a strong kick throws one beam off the scale, the adjacent galvanometer next lower in sensitivity catches it. No beam interferes with another. Thus a range of 1 to 3000 is accurately covered on a single record that's sharp, clear, and easy to read.

If you have an instrument-recording problem, it will pay you to investigate how photography can simplify it. Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.

PHOTORECORDING

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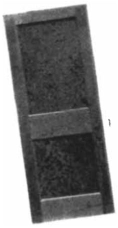
DURE Z RESINS?

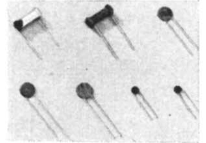
● Research on a variety of industrial fronts is finding answers to new and old problems in the versatile characteristics of Durez resins. Serving fundamentally as bonding agents, these thermo-setting phenolic resins also increase important physical, chemical, and electrical properties of various materials. Among these examples there may be the germ-idea of a product improvement, or a better method of processing, in your field of interest.



WOOD-WASTE is turned into finished products since wood industry leaders, with help from Durez on resins, found a method for producing structural sheets and molded shapes from sawdust, shavings or cuttings. The resin-bonded board sheets, trimmed topanel sizes, are uniformly thick, dense, and free from warping, highly resistant to deterioration, have excellent strength and stability, and all the workability of natural wood.

RUBBER benefits in many ways when special Durez resins are used in compounding stocks used for shoe soles, tire beads, tool handles and other moldings. In the Buna N's they contribute to vulcanization, hardness, stiffness, and resistance to abrasion, chemicals and heat. GRS and natural rubber stocks likewise benefit substantially when compounded with Durez phenolic resins.

ELECTRICAL parts such as TV and radio capacitors, resistors, and coils are simpler to assemble, safer to service when dipped in a Durez resin. The resin forms a strong, dense coating that resists the heat of soldering tools and remains stable under severe moisture and salt spray conditions.



Let us send you a pamphlet on these and other uses of phenolic resins in industry. We will gladly help with any particular applications you have in mind. Write, on office letterhead, to Durez Plastics & Chemicals, Inc., 806 Walck Road, North Tonawanda, N. Y.

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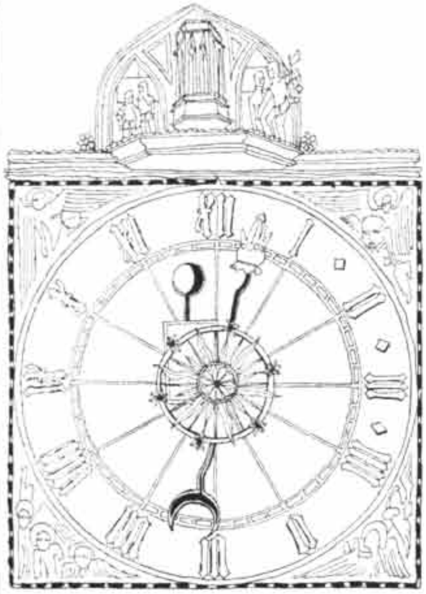

SCIENCE AND

Synthesis of a Steroid

THE Harvard University chemist Robert B. Woodward last month announced an achievement that was at once recognized as a milestone in the history of chemistry. A Harvard team headed by Woodward had accomplished the total synthesis of a steroid—a chemical structure which is the basis of many hormones and other bodily substances, including cortisone. Woodward's steroid is strictly a synthetic product, not identical with any natural substance. But since one steroid has been converted into another in a number of cases, the achievement opens the way to the complete synthesis of natural steroids. Among the natural steroids, besides cortisone, are cholesterol and the hormones testosterone, androsterone and progesterone.

What Woodward's group has already achieved is the first and most difficult step—the creation of the complex basic building block from simple industrial chemicals. The Harvard researchers are now working on the conversion phase. From the synthetic steroid it may be possible to produce cortisone in a few simple chemical steps. Cortisone is now made in 37 steps by partial synthesis from the steroid desoxycholic acid, a component of bile, which is so scarce that it takes the bile of 40 cattle to supply one day's cortisone for an arthritic patient.

The basic structure of a steroid consists of four connected rings of carbon atoms with two methyl groups (CH_3) attached in certain positions. The methyl groups are attached at the 10th and 13th carbon atoms of the 17 in the molecule. Woodward started with a simple coal-tar derivative called orthotoluidine, a single ring of six carbon atoms with one attached methyl group. By a series of chemical reactions he successively added atoms to the molecule until the steroid structure was achieved. The problem was not merely to combine the necessary atoms in the correct proportions but to attach them in the molecule in the right arrangement in three-dimensional space. It took 20 steps and a large amount of starting material to obtain a small yield of the steroid. The molecule he finally synthesized had an oxygen atom attached at position 3, as in cortisone, and a carbomethoxy group ($COOCH_3$) at position 17. The fact that it had the spatial arrangement of a true steroid was confirmed by its infrared spectrum, which proved to be the same as that of Compound F, a cortisonelike substance made from a steroid hormone of the adrenal cortex.

A great deal of work remains to be done to convert the synthetic steroid into specified natural ones, for many steroids have a large number of isomers—brother molecules that have exactly the same atoms but different spatial arrangements of them. Woodward's technique of systematically controlling the spatial arrangement of the atoms while building up a complex molecule not only should help in this task but constitutes a major contribution to organic chemistry in general. It should lead to the solution of many other obstinate problems of organic synthesis.

Open Face

THE west face of the Brookhaven National Laboratory's atomic pile, largest research reactor in the U. S., has been declassified and is now available for public inspection and for use in experiments by scientists without security clearance. This announcement was made by the Atomic Energy Commission last month. Applicants for use of the reactor must obtain the approval of the AEC and Leland J. Haworth, director of the Laboratory.

Scientific High Policy

TO ADVISE him on science and research aspects of the nation's defense mobilization President Truman has appointed a committee of 11 outstanding U. S. scientific administrators. They will be attached to the Office of Defense Mobilization under Director Charles E. Wilson. The committee is headed by Oliver E. Buckley, chairman of the board of Bell Telephone Laboratories. The other members are Detlev W. Bronk, president of Johns Hopkins University and of the National Academy of Sciences; William T. Webster, chairman of the Research and Development Board; Alan T. Waterman, director of

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THE CITIZEN

the National Science Foundation; Hugh L. Dryden of the International Committee on Scientific Research and Development; James B. Conant, president of Harvard University; Lee A. DuBridge, president of the California Institute of Technology; James R. Killian, president of the Massachusetts Institute of Technology; Robert F. Loeb of Columbia University's College of Physicians and Surgeons; J. Robert Oppenheimer, director of the Institute of Advanced Study, and Charles A. Thomas of the Monsanto Chemical Company.

The committee will also serve as a liaison agency for the various scientific agencies of the Government and as the voice of scientists on matters under the ODM's jurisdiction.

Casualty

TAKASHI NAGAI was a radiologist and a professor at Nagasaki University of Medicine. When the atomic bomb was dropped on Nagasaki on August 19, 1945, he suffered severe radiation exposure, and his wife was killed. He was already suffering the effects of previous overexposure to X-rays from his research work, and he knew that this additional dose of radiation would kill him. Professor Nagai decided to devote his remaining days to studying the effects of radiation damage on himself and others. He published a number of works on the subject, including a widely read book called *The Bell of Nagasaki*. On May 1, 1951, he died of leukemia. He was 43 years old.

A Closer Look at the Sun

THE more closely scientists examine the sun, the more puzzles it presents. Three astrophysicists, after a detailed inspection, have just discovered some interesting anomalies.

Jesse Greenstein of the California Institute of Technology, Robert S. Richardson of the Mount Wilson and Palomar Observatories and Martin Schwarzschild of Princeton University set out to check on whether the sun's energy is really produced by the famous carbon cycle, as is generally believed. In the carbon cycle hydrogen nuclei combine to form helium, with a release of energy, through the mediation of carbon nuclei. At one stage in the series of reactions the isotope carbon 13 is formed. This suggested a test of the carbon-cycle theory to the three astrophysicists; if carbon 13 was found to be more abundant in the sun than in the earth, where it constitutes only about one per cent of all carbon, this would tend to confirm the theory.

DOW CORNING SILICONE NEWS
NEW FRONTIER EDITION

Tall Tale

Speaking of sparkle, did you ever hear how Mose Humphries trapped the sun and hauled it along at the head of the fireman's parade? Took a ton of elbow grease, but Mose polished engine No. 40 till she shined so bright the sun never did set that day—it was too busy bouncing back and forth between the bell and the boiler.

to Fabulous Fact

Elbow grease used to be the most important element in any good polish—elbow grease and wax. Now polish makers add a Dow Corning Silicone product and save the elbow grease. In car polishes alone, that amounts to a net saving of about x-million tons of elbow grease so far this year. That's one of the peculiar things about these silicones. They spread themselves and polish without rubbing. Furthermore, they won't melt or freeze and they're more water repellent and more weatherproof than any organic materials. That kind of stability is one of the fabulous facts about all Dow Corning Silicone Products—fluids, greases, electrical insulating materials, resins or rubbers.

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They made an analysis of the sun's light spectrum with sensitive instruments and found no sign of carbon 13 at all!

There are two possible explanations of this observation. One is that the carbon cycle is not the main source of the sun's energy; perhaps the main energy-yielding process is the so-called proton-proton reaction, whereby protons combine directly to form helium. The other possible explanation is that carbon 13 cannot be detected because it is formed in the interior of the sun but does not reach the sun's surface. If this is the case, there must be much less flow of interior material to the surface and *vice versa* than has been supposed.

Greenstein, Richardson and Schwarzschild found some evidence to support the latter possibility when they inspected the sun for another element—lithium. This light element is destroyed rapidly by nuclear collision; in the hot interior of the sun an atom of lithium cannot last more than five minutes. Yet the investigators found traces of lithium in the sun's atmosphere. This must mean that these atoms of lithium have never gone far below the surface of the sun; in other words, that the lithium still present in the sun's atmosphere has been there since the sun was formed billions of years ago. Apparently there is remarkably little mixing between the gases in the interior and in the atmosphere of the sun.

On the other hand, new evidence that the proton-proton reaction may be more important than the carbon cycle in accounting for the sun's energy was presented recently by Lloyd Motz of Columbia University and Edward Frieman of the Brooklyn Polytechnic Institute. They carried out complex calculations which indicated that the fusion of protons would make more energy available in the sun than would the series of reactions involving carbon. Frieman and Motz described their work at a meeting of the American Physical Society.

Breakdown of a Proton

EVIDENCE that protons and neutrons are not "ultimate" particles but can break down like radioactive atoms was reported last month by Robert B. Leighton of the California Institute of Technology. Leighton also indicated that he has what may be the first photograph of the long-sought hypothetical "negative proton."

The Caltech physicist arrived at his conclusion about protons and neutrons from studies of the so-called V-particles found in cosmic rays. Named for their V-shaped tracks in Wilson cloud-chamber photographs, these particles were first detected in Britain in 1947 and rediscovered last year by a group led by Carl D. Anderson at the California Institute of Technology. It was supposed at first that they were a new type of meson, much heavier than any previously discovered. The particles are extremely unstable and decay in about one 10-billionth of a second, emitting mesons as they do so. But Leighton found that the products of this disintegration also include protons and neutrons. Since the V-particles themselves are single particles before they decay, Leighton concludes that they are protons and neutrons in a highly excited state, and that they decay into ordinary protons or neutrons by emitting energy in the form of mesons. This implies that the proton or neutron has an internal structure which permits it to change its form to correspond to higher and lower energy states.

Leighton has predicted that a negative proton will be discovered as a decay product of the V-particle, and that it should occur once in approximately 50 disintegrations. So far Leighton has obtained 53 photographs of such disintegrations, and one of the tracks looks like that of a negative proton. The particle had the mass of a proton, and the direction of its deflection in a magnetic field indicated it had a negative charge.

NAS Elections

THE National Academy of Sciences at its annual meeting elected three new officers, 29 members and three foreign associates. F. Alexander Wetmore of the Smithsonian Institution was elected home secretary to succeed Fred E. Wright, who had held that post for 20 years. Jesse W. Beams of the University of Virginia and E. C. Stakman of the University of Minnesota were elected to the Council of the Academy.

The three new foreign associates are geologist Pentti Eskola of Helsinki University, Finland; Sir Godfrey Thomson, professor of education at Edinburgh University, and Karl von Frisch, director of Munich's Zoological Institute. The Academy now has 481 members and 48 foreign associates.

The Academy's Daniel Giraud Elliot medal for research in zoology was awarded to John Thomas Patterson of the University of Texas, for a series of papers on the isolating mechanisms of the fruit fly. These were called a "highly significant contribution to research on the species problem."

Artificial Tenderloin

A NEW METHOD of making tough meat tender has been invented by an Amherst College biology professor. It may eliminate the need for the expensive process of "finishing" animals in the present method of beef production.

The invention is based on the fact that the flavor and texture of beef are greatly improved by "marbling": the accumulation of fat in the connective tissue of the meat. At present this is accomplished by final-stage fattening of grass-fed cattle on grain. The Amherst biologist, Oscar

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Once again AiResearch is the choice! Consolidated Vultee Aircraft Corporation has designated AiResearch pressurizing and air conditioning for its new Convair Liner 340 air transport.

This is the third new high-altitude commercial air transport announced in the United States in the past year to be *completely* pressurized and air conditioned by AiResearch. In addition to the Convair Liner 340, these advance aircraft types are the Martin 4-0-4 and the Lockheed 1049 series Super Constellation.

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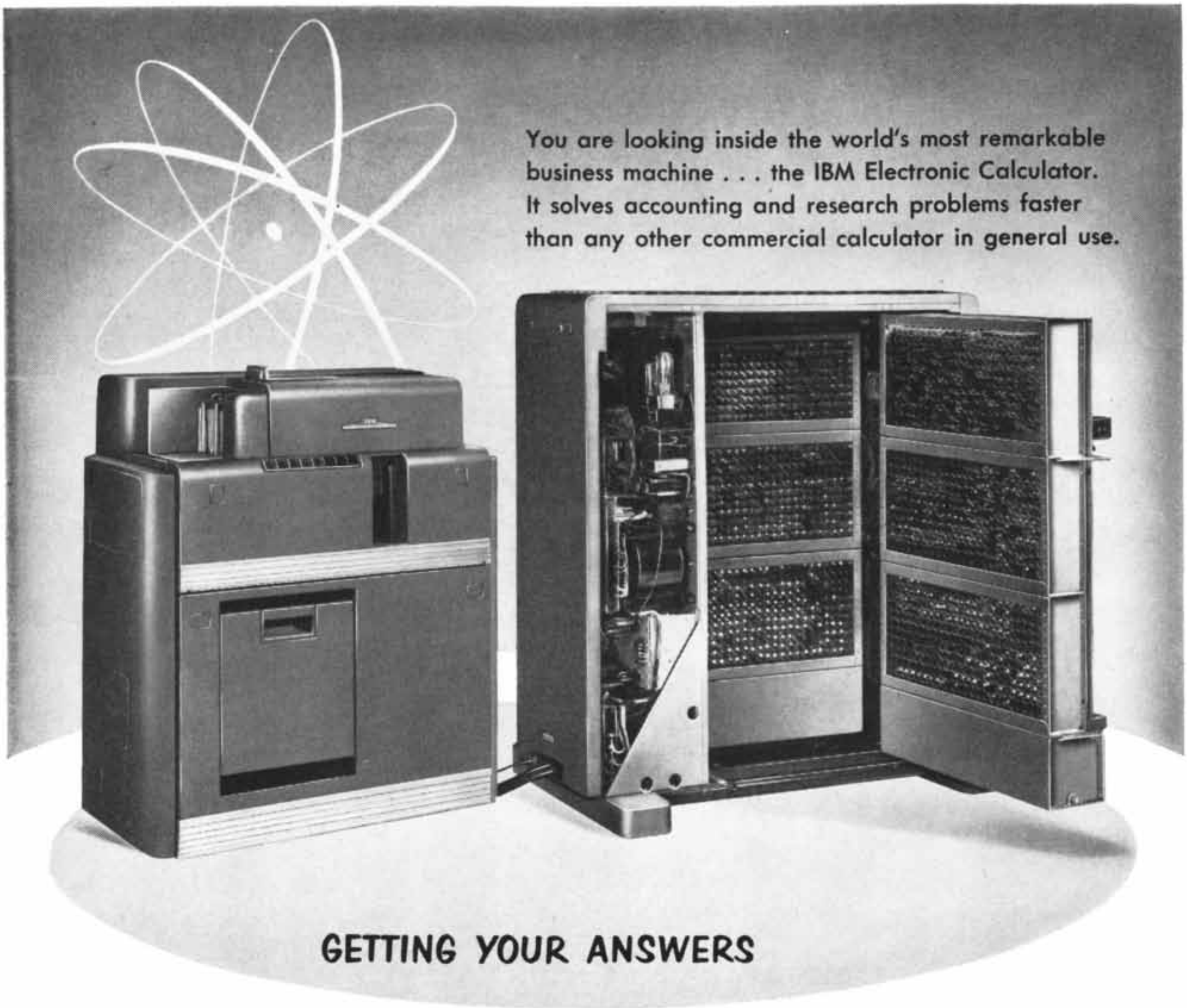

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E. Schotté, conceived the idea of accomplishing the marbling simply by pumping liquid fat through the animal's blood vessels under a pressure high enough to fill the capillary vessels that permeate the meat tissues. The animal is stunned, its chest is opened and a warm salt solution is pumped through its heart into its arteries and veins to drive out all the blood. Then melted fat is pumped in to replace the salt water. When the fat cools, a tough, range-fed animal has been transformed into tender beef.

The same process can be used to create entirely new kinds of meat by injecting taste modifiers along with the fat, or by injecting lard into beef and beef tallow into mutton.

Exploitation of the process is going forward under the auspices of the National Farmers Union, which expects to have a pilot plant operating somewhere in the Midwest this summer.

Cure for Snoring

DR. ROBERT ELMAN, a St. Louis physician, imparted the following information to the medical profession in a recent letter to the *Journal of the American Medical Association*:

"A young patient wrote me from his honeymoon expressing fear that his marriage would fail because his snoring kept his bride awake so much that they were forced to occupy separate cabins. He could not afford separate bedrooms when he returned and therefore asked my help. I had him examined and found no evidence of organic obstruction or disease in the nose or throat."

When conventional treatments—making the patient sleep on his side, keeping his mouth closed—failed to bring relief, Dr. Elman tried a new method.

"I remembered the stertor [snoring] that frequently occurs during general anesthesia when the chin is allowed to drop and that is relieved immediately by hyperextension of the neck. Acting on this idea, I had lateral roentgenograms taken of the patient's pharynx and was able to demonstrate that both the epiglottis and uvula were almost in contact with the posterior pharyngeal wall. I therefore fitted the patient with a simple, easily applied and removable Thomas collar, asking him to use it that night. When he came in the next day, he was greatly pleased, for the device had eliminated his disability, and for the first time his wife had been able to get a good night's sleep. The patient subsequently discarded the Thomas collar and merely slept on his back with a small pillow at the nape of the neck. He is now happily married and has two children."

Age of the Species

NEW evidence for the antiquity of *Homo sapiens*, modern man, has been unearthed in a cave on the shore of

something to HOWL about

"Dirt farmers are sot in their ways," people used to say. "No use trying to change 'em." Well, that old saw just *isn't true*—and no one knows it better than Spencer Chemical Company!

The facts prove farmers adopt new ideas and buy new products quickly—more quickly than any other American economic group—when the ideas or products have real merit. On the other hand, we of Spencer know farmers quickly reject a commodity or idea which is one-tenth utility, nine-tenths hot air. Farmers quickly supported mechanized equipment, scientific breeding and hybrid corn. They were great advances in farming. But in this generation, Agriculture's most astounding development has been Scientific Fertilizers—mixed fertilizers, such as those made with SPENSOL (Spencer Nitrogen Solutions) and single plant foods, such as Spencer Ammonium Nitrate Fertilizer.

During the last ten years, fertilizer consumption in America's Breadbasket has skyrocketed by 600%, as shown by the chart above. And farm production and farm profits have risen, too. Fertilizers have been good for the soil, good for the country.

If you are interested in the upward march of the fertilizer science, by all means write to Spencer Chemical Company for descriptive booklets and full information.

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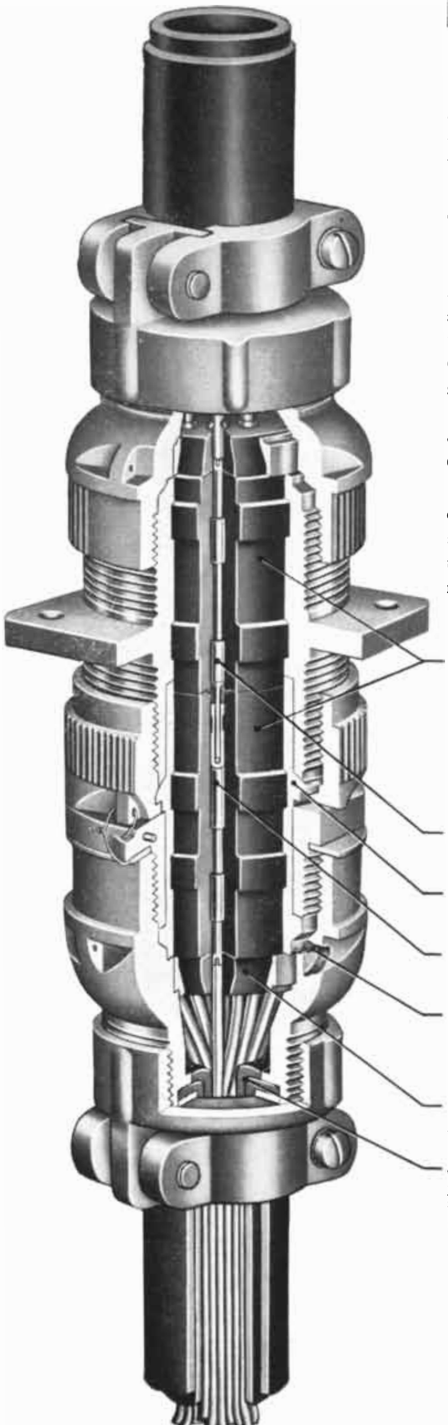

Here's another example of the meticulous care Cannon Electric uses in building connectors for highly specialized, tough jobs. This AN-"M" type connector is moisture-proof, vibration-proof and pressurized. Radio shielding is provided and every threaded part is drilled for safety wiring.

No corners are cut – nothing is overlooked to assure you outstanding performance. This connector is designed for aircraft use but there are more than 18,000 different Cannon Plugs made with the same care to serve the exacting needs of many industries. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.

Engineering bulletins describing each of the many basic types of connectors are available. We will gladly send you any of these if you will simply describe your connector requirements.

Molded Polychloreprene inserts 75-80 shore hardness provide pressure-proofing of both pin and socket contacts. Have high dielectric strength under wide range of temperatures and at extreme altitudes. Mated fittings will not show more than 10 microamperes dielectric leakage and will not arc when subjected to 7500v dc at room temperature.

Pin Contacts machined from solid brass, silver-plated. Solder cup hand-tinned.

Machined ball-in-cone joints provide radio shielding and improve vibration resistance.

Socket contacts machined from solid copper alloy with new Cannon design, silver-plated.

Matching serrations in end bell and shell make practical wrench-tightening from one side of the installation without putting strain on contacts or wires.

Polychloreprene grommets make moisture-proof seal over soldered connections.

Concentric rubber bushings under pressure of cable clamp provide snug, moisture-proof wire entry. Eliminate usual strain on outer wires. Provision is made for grounding lug.

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the Caspian Sea in northern Iran by Carleton S. Coon, anthropologist of the University of Pennsylvania, and Louis Dupree, Harvard University geologist. In a layer of gravel 39 feet deep, deposited before the beginning of the last Ice Age 75,000 years ago, they found the skeletons of three people who apparently had been sitting around a hearth when the roof caved in. The skeletons of the victims are essentially identical with that of modern man, except for a smaller brain case. At the same site the diggers found the skull of a 12-year-old girl of the Neanderthal type who lived only 10,000 or 12,000 years ago. This finding confirms earlier claims of modern-looking skeletons in strata much older than the Neanderthalers and other supposed ancestors of modern man ("Antiquity of Modern Man," by Loren C. Eiseley; SCIENTIFIC AMERICAN, July, 1948).

Coon and Dupree made other important finds at the same site. One is that agriculture was practiced here at about 6060 B.C.—1,300 years earlier than the oldest agricultural settlement hitherto known.

Happy Hutterites

WHILE one U. S. citizen in every 10 suffers incapacitating mental illness at some time in his life, there is a group of Americans among whom severe mental illness—as well as crime, juvenile delinquency and divorce—is virtually unknown. These happy people are the Hutterites, a sect of 8,500 members who live in rural settlements along the U. S.-Canadian border in the Midwest. In 75 years they have had only one suicide, one divorce, two separations and not a single case of abandonment of children, sex crime or personal violence.

The Hutterites are descendants of a group of Tyrolese peasants who were led by the 16th-century martyr Jacob Hutter. Hutter, a religious heretic who opposed private property, the use of force and the taking of oaths, was burned at the stake in 1536. His followers wandered to Hungary, Rumania and Russia, and finally settled down in the 1870s in South Dakota. The 300 original immigrants have now multiplied, by virtue of a very high birth rate and a very low death rate, to 8,500 living in 91 communities in North and South Dakota, Montana, Alberta and Manitoba.

The Hutterites live in isolated hamlets of about 15 families around a single large farmstead on which all the adults work. They own all property in common, receive no wages and eat together in a common dining room. The women take turns at cooking the meals. Children over two and a half years old go to a common kindergarten. The sick, aged, widows and orphans are supported and cared for by the community. Clothes are in the

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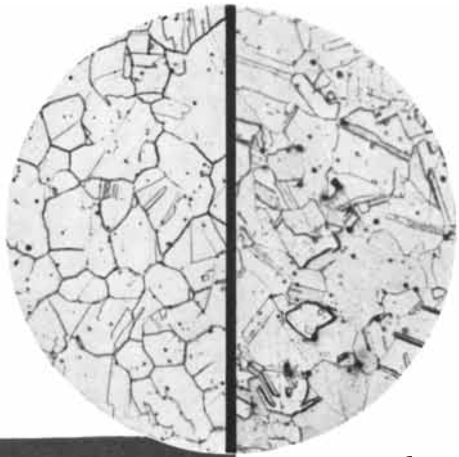
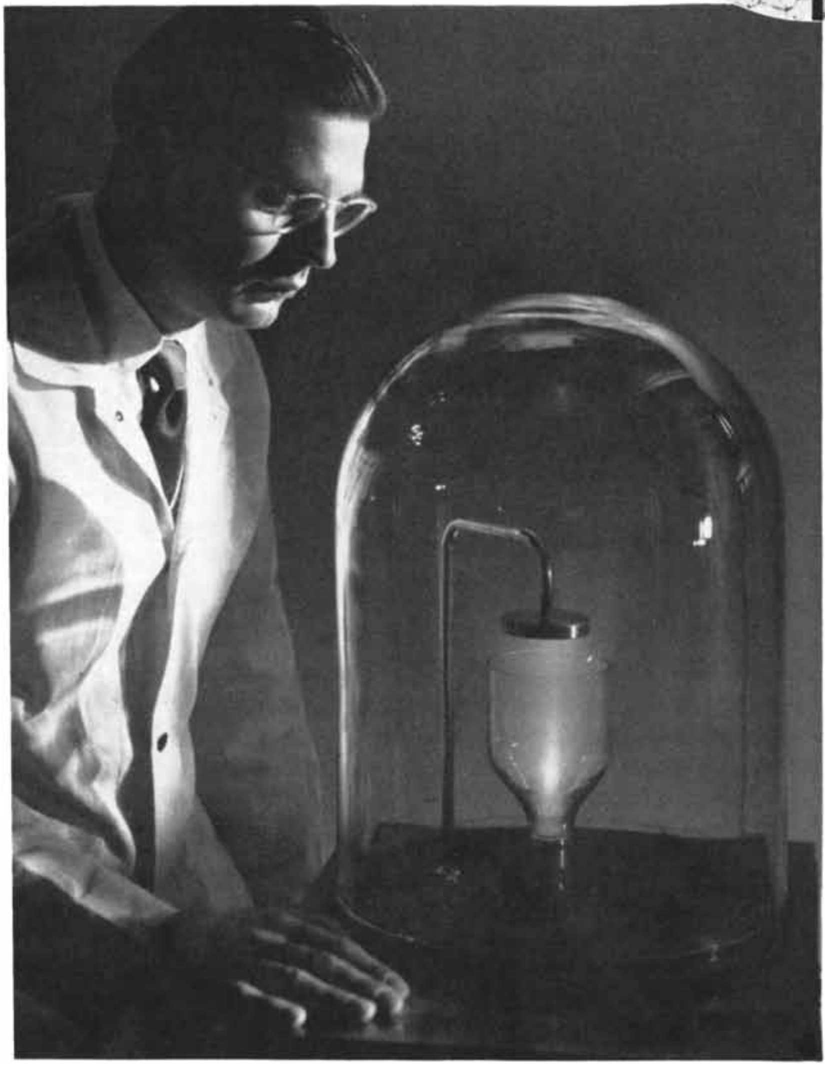
Cathodically etched in helium at 60 microns Hg and 4000 volts, this Type 303 stainless steel (X250, left) shows a well-defined grain structure quite different from— a conventional acid etch of the same specimen (X250, right). The structure uncovered by cathodic etching and the ease of preparing specimens by this method are big metallurgical news.



for the metallurgist...

a new weapon



CATHODIC ETCHING, it's called. It's a new way of preparing specimens for metallography, using ionic bombardment in vacuum, instead of chemical etchants. It points up some metallurgical facts that have been difficult to get at till now.

For example, take the case of a sticking contact point for the generator cutout in one of America's leading cars. Photomicrographs of a cathodically etched sample showed cold flow lines.

But why cold flow lines in a hot-forged part? That question cracked the case. Such lines are rarely shown by chemical etching, but cathodic etching picked them right up.

It turned out that the subcontractor wasn't hot-forging them at all, but cold-working them. As soon as that misunderstanding was cleared up, the contacts stopped sticking.

For effective industrial sleuthing and profitable scientific puzzle-solving, you need such new viewpoints. The surface structure thus uncovered may well shed meaningful new light not only in metallography but also in electron micrography and electron diffraction studies.

If you're a metallurgist and like to keep up to date, you'll do well to write for further information from ***Distillation Products Industries,*** Vacuum Equipment Department, 751 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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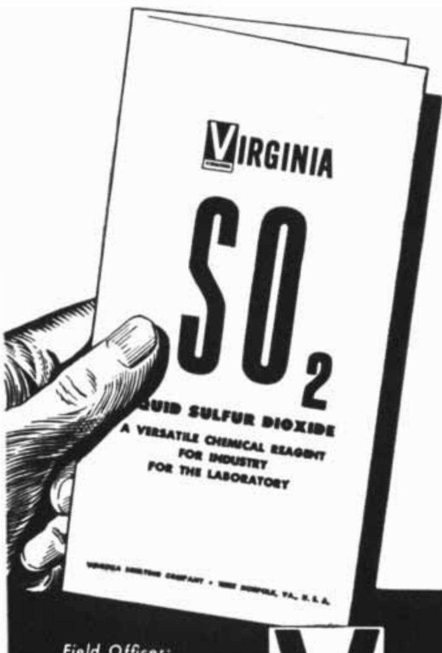

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style of the 16th century. Radios, pleasure cars and fashionable clothing are considered sinful.

How has such a group survived envelopment by the American culture? And what are the reasons for its unusual mental health and social stability? The U. S. Public Health Service is sponsoring a study of these questions. It is being made by sociologist Joseph W. Eaton of Wayne University, psychiatrist Robert J. Weil of Dalhousie University, Halifax, Nova Scotia, and psychologist Bert Kaplan of Harvard University.

The three investigators, though not yet ready to report their conclusions, have given a preliminary account of the people. They found that mental illness is not unknown among the Hutterites, but in general their mental health is exceptionally good. The Hutterites are highly inbred, so heredity may be a factor in their freedom from some mental diseases. Other features of Hutterite life that may help explain their placidity: all members have economic security; children are trained mainly by their older brothers and sisters, so there is no pressure to emulate their more accomplished parents; the people have a single, consistent ideology, free from many of the conflicting values that occur in modern American culture.

The Pains of Sam Johnson

DR. Samuel Johnson's life was so thoroughly recorded by Boswell that a Rhode Island physician has been able to write his medical history 147 years after his death. The physician, Dr. Peter Pineo Chase, writes in the *Yale Journal of Biology and Medicine* that "we can follow Johnson's case history from before birth through his autopsy two days after death."

From a medical viewpoint, Johnson's long life was highly eventful. He was born nearly dead, and was unable to cry for some time. At the age of three he was taken to Queen Anne to be cured of scrofula by the "royal touch." (It didn't work.) Childhood smallpox, almost universal in early 18th-century England, was probably responsible for his weak eyesight, deafness and bad complexion. All his life he was a psychiatric case, suffering from hypochondria, melancholy and an overpowering addiction to tea. But he lived to the ripe age of 74, and his autopsy showed nothing fundamentally wrong with his stomach.

Dr. Chase summarizes Johnson's life as follows: "severe trauma and anoxia at birth; early infection with bovine tuberculosis involving the cervical glands and possibly the eye; skin-scarring due to smallpox; cerebral irritation throughout life; chronic bronchitis; asthma; hypertension; cerebral thrombosis; his terminal condition, cardiorenal disease."

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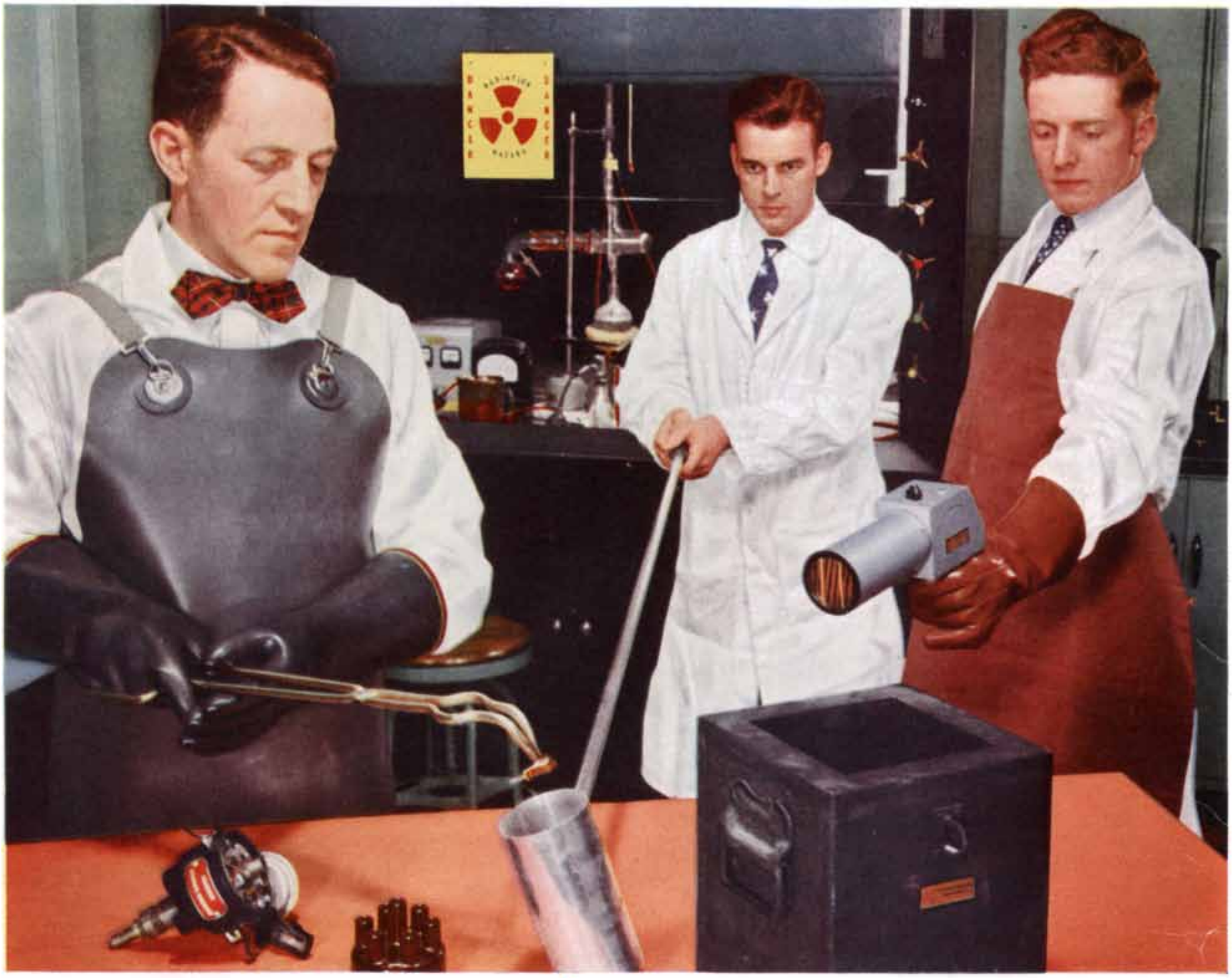

In this "Radioactive Materials Room" at Chrysler Laboratories, many stronger metals . . . better designs . . . smoother-running, longer-lasting parts have their beginning. Note the protective lead-and-rubber gloves and aprons, and the thick lead box in the foreground where "hot" parts are safely stored.

ATOMS FROM OAK RIDGE COME TO DETROIT

The men in the picture are handling "hot" or radioactive automobile parts. That's the reason for their long-handled tools, the radiation exposure meter held by the man at the right—and their caution. It's all part of a new kind of research at Chrysler Corporation.

Our engineers send engine distributor points to the U. S. Atomic Plant at Oak Ridge, Tenn., where they are made radioactive in the famous Atomic Pile.

Returned to Detroit, a "hot" point is mounted in a standard distributor, and given a test run as though in your car. Ordinarily it takes hundreds of hours of engine operation for points to wear enough to be measured. But in a *few minutes* of this test, some radioactive atoms are transferred from the "hot" point—enough to be measured accurately by sensitive Geiger Counters.

In this way, we find out where wear starts, and how and why, and thus learn to develop better points that will run much longer without replacement.

Similar tests, using "hot" piston rings, gears, bearings and the like, are helping us to develop longer-lasting parts for cars and other vehicles, and improved ways of lubricating them.

Chrysler Corporation was an auto industry pioneer in this peaceful use of atomic energy. It's one more example of the practical *imagination* that leads directly to the fine performance and long life of the products we make. And another reason why our experience and skills are always ready for a wide variety of challenging jobs—from cars and trucks and military vehicles to industrial engines, heating and cooling systems—and even railroad freight car trucks.

Practical IMAGINATION guides research at **CHRYSLER CORPORATION**

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You could express this problem as

$$\frac{(\text{Temperature}) \times (\text{Corrosion}) \times (\text{Fabrication})}{\text{Cost}}$$

It started the day after VJ-Day. Engineers from a leading appliance manufacturer showed us plans for their postwar refrigerator with a great new feature—*a king-size freeze chest.* But the size increase threatened prohibitive costs. And no combination of metals so far had satisfied requirements: fast heat transfer; corrosion resistance; ease of fabrication. They asked us, "Can we do it economically in aluminum?"

Now this freezer (called an evaporator) is simply a sheet metal box with passageways around it to conduct the refrigerant. A product of yours might present similar problems.

We knew that aluminum would conduct heat quickly. We suggested that the evaporator be made by brazing aluminum tubing to aluminum sheet. "Sounds good!" they said, and together we started designs.

Simultaneously, Aluminum Research Laboratories investigated an important question. Their research found the answer: Aluminum is compatible with most of the commonly used refrigerants.

The Alcoa's Process Development Shops suggested an amazingly simple fabrication process. "We'll place the tubing on flat brazing sheet and furnace braze the assembly. Then form the unit into box shape." The first 25 evaporators were made in this manner—a process so practical and economical that it hasn't changed since. Today, a great many of the 7,000,000 refrigerators and freezers, sold annually, have aluminum evaporators.

Now is the time for the questioning minds in your company to look hard at aluminum. To start a similar long-range program in which aluminum may reduce your costs, improve your product, lift your company above competition in the years to come.

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Among these specialists at the Development Division are men already familiar with the problems of your industry. They are your liaison with the Alcoa research, test and fabricating facilities that can be put to work on your problem. Through them the sum total of Alcoa's knowledge will be brought to bear. Knowledge of practical problems of fabrication and costs, gained in thousands of other projects, will flow toward yours.

ALCOA ALUMINUM

there are no limitations on *Imagineering*

DEVELOPMENT DIVISION

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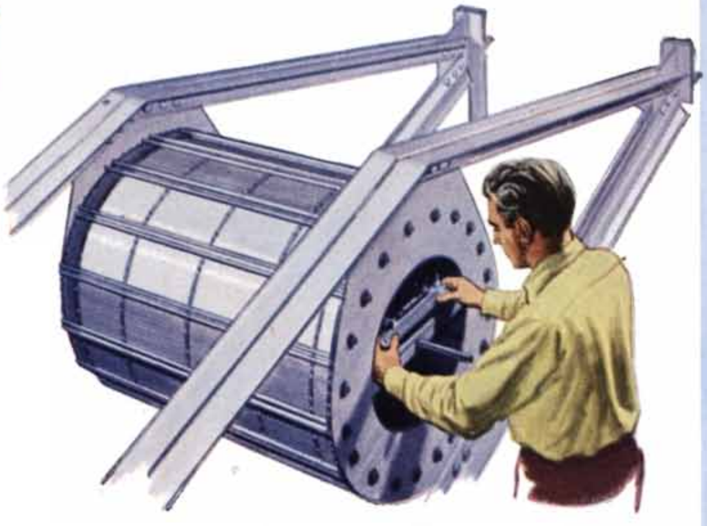
long-range projects we have these to offer:

2 FACILITIES FOR BROAD *Research*

The practicability of a project frequently hinges on the basic nature of aluminum—its alloys, its strength, its chemical and physical properties. Alcoa's Aluminum Research Laboratories have the world's most extensive light metals research facilities. Facilities like this electrolytic solution potential tester which helps determine aluminum's corrosion resistance under various conditions.



3 ADVANCED *Test* EQUIPMENT

The precision level bar used to measure torsion of an aluminum alloy cylinder is typical of the equipment which Alcoa uses to provide design information for your product. With other equipment Alcoa crams years of normal operating conditions into hours or days—to prove the theories of our basic research.

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Furnace brazing is but one of many joining processes used by Alcoa to help create a pilot model of your project and suggest practical methods for its fabrication. All the techniques of forming, machining, finishing, casting, heat treating and welding are available here.

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For more details on the personnel, research and testing, and shop facilities available at Alcoa, write for your copy of the folder, "Road Map to a Better Product." It is your first step toward putting 63 years of aluminum knowledge to work on a long-term project that may effect a major change in your company's competitive position. Address ALUMINUM COMPANY OF AMERICA, 2182F Gulf Bldg., Pittsburgh 19, Pa.

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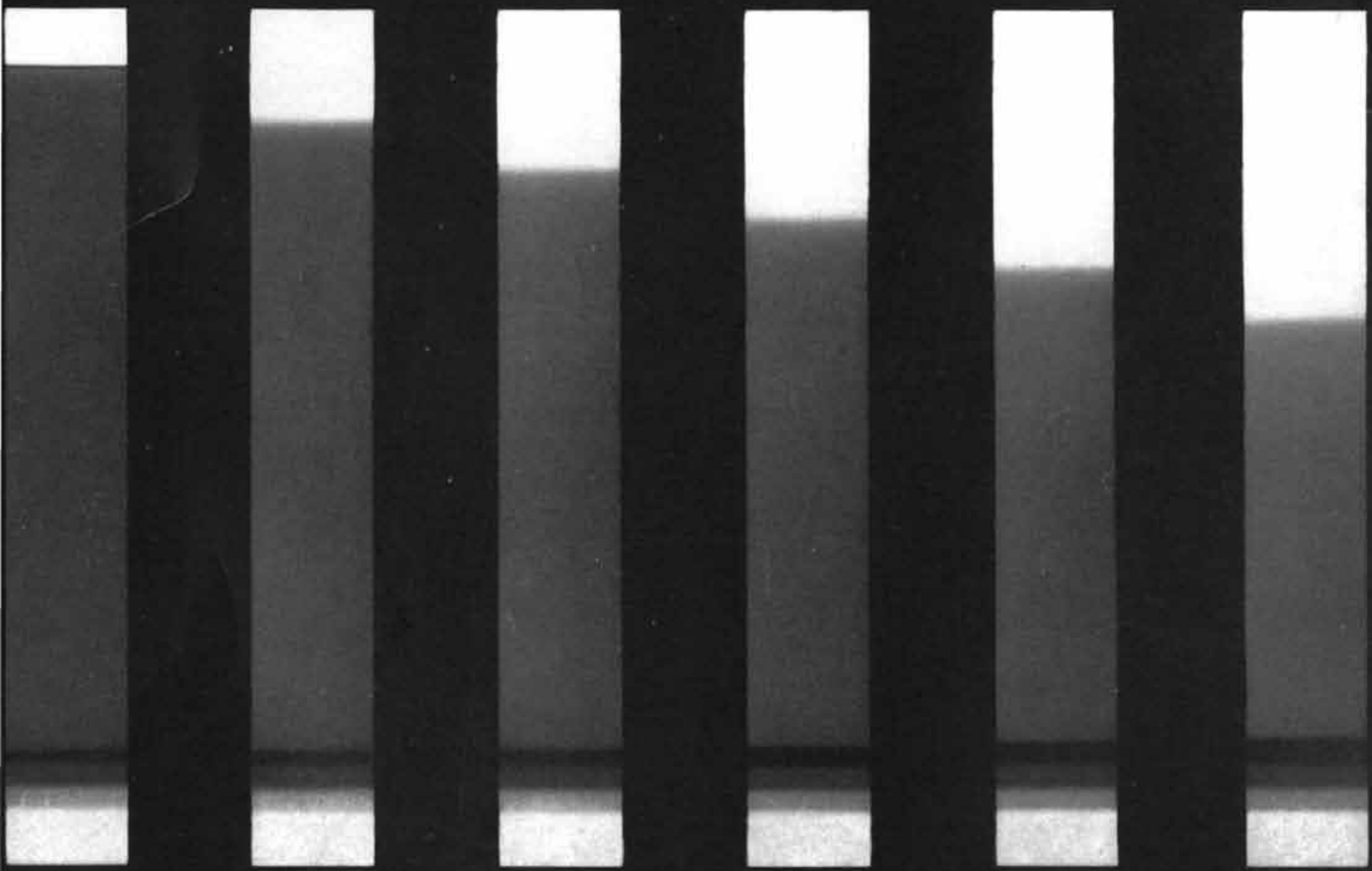
The Ultracentrifuge

By spinning a rotor at very high speed it can generate enormous gravitational forces. It has been used notably to study large molecules by causing their sedimentation

by George W. Gray



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BIOLOGICAL research, which began with the forms of plants and animals and later sharpened its focus to examine the tissues and cells of which they are composed, is occupied today with the study of still smaller units—the organic molecules known as proteins.

These structures of carbon and nitrogen interlinked with atoms of other species are the present frontiers of experimental biology. Every essential chemical reaction of life, including such fundamental processes as the fertilization of the egg, growth, nutrition, metabolism, muscular contraction, resistance to infection, nerve communication and response, is governed by one or more kinds of specialized proteins, most particularly enzymes and hormones, which the cells ceaselessly manufacture.

Proteins differ in weight, shape and electrical polarity. These physical properties critically affect molecular behavior. They determine, for example, whether or not a molecule will pass through a cell wall, whether or not it will attract, repel or be indifferent to another molecule. Biochemists long ago recognized that to understand living processes they must appraise physically the molecules that participate in those processes. And first of all, it is important to know how *large* the molecules are.

A common method of determining molecular weight is to dissolve a measured quantity of the substance in water or some other solvent and see how much the added material raises the boiling point or depresses the freezing point of the liquid. When one part of sodium chloride is dissolved in 1,000 parts of water, it lowers the water's freezing point by .061 of a degree Centigrade. Cane sugar in the same proportion lowers the freezing point by .0054 of a degree, acetic acid by .032 of a degree. There is a fixed relationship between the molecular weight of a substance and the freezing point of a solution of it, and this relationship is widely used as a means of identifying many compounds. But as the test is applied to substances of higher and higher molecular weight, the difference in freezing point becomes progressively smaller, and when the proteins are reached, the difference is so nearly infinitesimal as to be beyond measurement.

Similar limitations apply to other traditional methods of analysis. It is comparatively easy to study small molecules, but when one tackles the larger ones, the measurements grow more and more elusive. It is only within the last two and a half decades that science has acquired any reliable means of appraising the physical properties of proteins—or indeed of knowing for sure that proteins are molecules. A powerful device which reached development during this period and became one of biochemistry's principal tools for protein research is the ultracentrifuge, a machine that weighs particles by measuring their sedimentation.

THE SIX PHOTOGRAPHS on the opposite page show the sedimentation of a protein in the ultracentrifuge of the International Health Division Laboratories of The Rockefeller Foundation. The protein is hemocyanin from the blood of *Limulus polyphemus*, the horseshoe crab. In the photograph at the far left the protein is suspended throughout the whole solution. The succeeding five photographs, which were made at 15-minute intervals, show the protein settling as it is whirled at a speed of 18,000 revolutions per minute.

Sedimentation

The force of gravity has an orderly way of sorting substances out of a mixture. If, for example, you let a suspension of muddy water stand undisturbed, the fragments of rock, being heaviest, will drop first; particles of coarse sand will come out next and form a layer on top of the rock fragments; lighter sand grains will deposit in another layer above this; after several hours particles of clay will follow, and eventually still finer clay will form a top layer. But no matter how long the solution stands, there are some motes that will never settle. They are too light for gravity to overcome the upward recoil from countless collisions with the perpetually moving water particles—the so-called Brownian movement.

The laws of sedimentation and diffusion have been the subject of much mathematical research. One of the basic approaches to the problem was a joint study by Max Mason and Warren Weaver at the University of Wisconsin in the early 1920s; they solved the problem for sedimentation in a uniform gravitational field. Physicists have used gravity to study the behavior of particles in a vacuum. Biochemists, on the other hand, have usually found that the Earth's pull is too weak to assist their molecular studies. Consequently they have turned to centrifugal force, which closely parallels gravitational force in effects and can be magnified to any degree by increasing the speed of rotation.

The separation of substances by centrifugation is an old story: a thousand years ago tung oil was extracted in this way, and the principle is familiar to everyone in the form of the dairyman's cream separator. The principle of a centrifuge of course is that under centrifugal force the heavier particles in a mixture tend to move farther out toward the periphery than the lighter ones, and as rotation continues they pile up against the outer wall and are separated. Sedimentation here means the movement of particles outward toward the rim of the centrifuge.

In the laboratory chemists began early in this century to use centrifugal force to fractionate colloidal suspensions. Even the best of their centrifuges, however, were of limited velocity and were subject to incalculable fluctuations. They could separate gross particles, like hookworm eggs and blood cells, but were unable to sort out molecules or determine their dimensions.

To separate and measure molecules chemists needed not only centrifuges with faster and steadier rotational speeds but also an optical means of recording the behavior of the mixture during rotation and a mathematical formula by which to interpret the behavior in units of molecular weight. The first to bring about this partnership of mechanics, optics and mathematics was Thé Svedberg, professor of physical chemistry at the University of Uppsala, Sweden.

Svedberg

From his student days Svedberg had been fascinated by the performance of particles in emulsions, the state of dispersion between the solid and the liquid states in which matter is called colloid. He became widely known for these studies, and in 1922 the University of Wisconsin invited him to spend a year on its campus as visiting professor of colloid chemistry. During this visit he began to try out an idea that had long been hatching in his brain. He enlisted the help of a graduate student, J. Burton Nichols, and together they built a rotating machine from the professor's specifications. Because the apparatus included a system of lenses for viewing and photographing the sedimentation through a window in the rotor, Svedberg called it an "optical centrifuge."

This optical centrifuge of 1923 could turn only a few hundred revolutions per minute, but it provided a means of studying the conditions that had to be fulfilled in harnessing centrifugal force to the exacting tasks of molecule measurement. The fundamental problem was to attain rotation without heating, for heat stirred up convection currents in the whirling liquid, and these currents, no matter how slight, distorted the sedimentation.

Returning to Uppsala after his American sabbatical, Svedberg began a comprehensive survey of the conditions for convection-free sedimentation. He and H. Rinde experimented with different rotor sizes and investigated ways of removing heat from bearings and of reducing air friction. Within a few months they had built a machine with a rotor installed in a sealed chamber filled with hydrogen gas at low pressure. This arrangement reduced friction and at the same time insured that whatever heat

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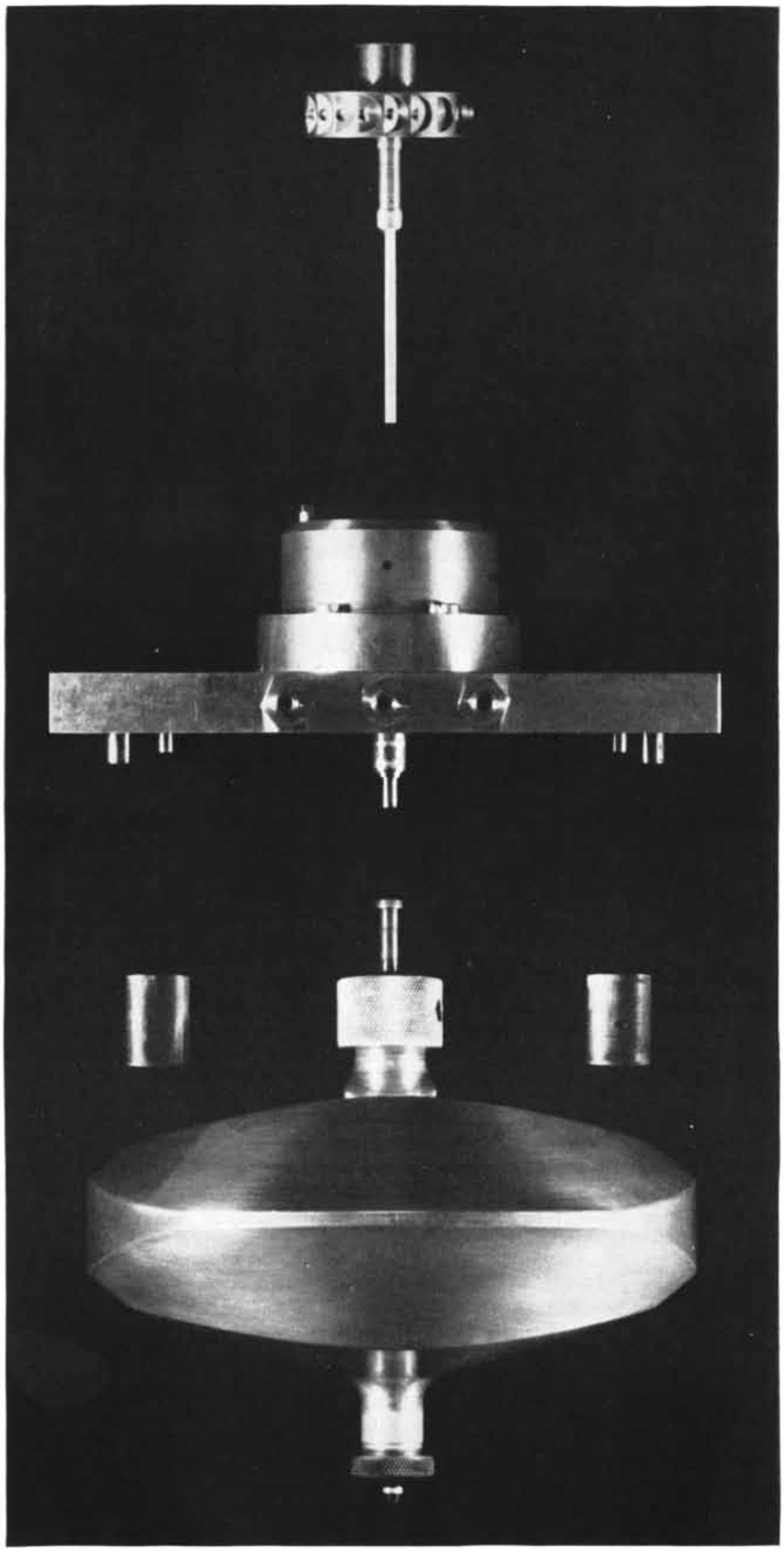

DISSECTED VIEW shows the principal parts of the ultracentrifuge of the International Health Division Laboratories. At the top is the rotor of an air turbine; the stator is below it. At the bottom is the rotor of the ultracentrifuge and its two cells. The two rotors are connected by a shaft.

was generated by the rotation would be quickly conducted away. The motor-driven rotor, 45 millimeters in radius, whirled at 10,000 revolutions per minute and produced a centrifugal force 5,000 times gravity. It was the first centrifuge to give quantitative data of sedimentation. Svedberg named it the "ultracentrifuge."

With their new machine Svedberg and his associates soon determined the molecular weight of hemoglobin and certain other proteins of the blood. They employed a measurement criterion known as sedimentation equilibrium, which depends on two opposing effects: sedimentation and diffusion. As the large molecules move outward toward the periphery of the rotor, they collide repeatedly with smaller molecules, and many are driven back against the urge of centrifugal force. Under certain conditions, after a long period of continuous rotation, the particles streaming outward in sedimentation and those streaming inward by diffusion establish an equilibrium. The greatest concentration of heavy particles will still be at the outer rim of the container, with the concentration progressively less all the way in toward the center, but the concentration at each stage remains constant. The molecular weight of the large molecules can then be determined by comparing their concentration at two distances from the center and calculating the result with a mathematical formula devised by Svedberg.

The equilibrium method gave reliable results for relatively small proteins such as hemoglobin, but Svedberg found it less successful with larger molecules. Moreover, it consumed a lot of time. Days, even weeks, of continuous rotation were required to obtain a single determination. He therefore began to explore the possibilities of a different procedure, which has come to be known as the velocity-of-sedimentation method. The idea here was to rotate the material so fast that sedimentation would predominate over diffusion. Then all, instead of merely a preponderance, of the heaviest molecules would be thrown into the zone nearest the outer rim of the rotor. Theory said that there would be a definite boundary between these heaviest particles and the adjacent inner zone of the next heaviest, and that this boundary would shift progressively outward with continued rotation. By measuring the rate at which the boundary moved toward the periphery, it should be possible to determine the velocity of sedimentation. Using this velocity as one factor in an equation, it should then be possible to calculate the molecular weight. Such was the reasoning back of the new approach in ultracentrifugation which Svedberg and his associates entered upon in 1925.

The first requisite was a means of rotating liquids not at 10,000 but at

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many tens of thousands of r.p.m. without stirring up convection currents. Such velocities were beyond the powers of the 1924 ultracentrifuge, and Svedberg turned his thought now to the design and construction of a faster instrument.

The Oil Drive

The first high-speed ultracentrifuge was completed in 1926. Its rotor, like that of the older, slower machine, was whirled in a sealed chamber of hydrogen. The engine that turned it, however, was a tiny turbine driven by a stream of oil under pressure, instead of an electric motor. Svedberg has said that he chose the turbine because it was more efficient for high-speed rotation, and he chose oil to drive the turbine because it threatened no serious danger of contaminating the atmosphere around the rotor by evaporation. Moreover, there was an added advantage in the fact that the compressor which pumped the oil stream served also to deliver oil for lubricating and damping the bearings. With this apparatus he turned a 52-millimeter rotor at 45,000 r.p.m., generating centrifugal forces that were 100,000 times gravity.

The greater the radius of the rotor and the faster the velocity, the greater are the centrifugal forces. As these are accelerated to higher and higher magnitudes, even the toughest metal will fly to pieces. Svedberg and his co-workers progressively modified the 1926 design and pushed centrifugation to unprecedented dimensions. By 1931 they were generating forces 200,000 times gravity with an oil-driven rotor of 65-millimeter radius; early in 1932 they obtained 260,000 g, and in the spring of 1933 this whirligig was still holding together at 400,000 g. In later experiments to see how far centrifugation of liquids could be pushed, the group reduced the radius and finally, in 1934, produced 900,000 times gravity. But all except one of the rotors used in the superspeed experiments exploded into fragments after a few runs.

Svedberg finally fixed on the 65-millimeter radius (about seven inches overall diameter) as the most satisfactory, and this dimension has since become standard in machines built for biochemical research. For that size, the maximum safe operating speed is about 67,000 r.p.m., producing 350,000 g. Even so, ultracentrifugers never operate without barricading the instrument with a protective wall of heavy timber, concrete or other shock-absorbing material.

In the midst of his experimenting with whirling rotors, Svedberg was awarded the 1926 Nobel Prize in Chemistry. In its citation the Nobel Committee made no direct reference to ultracentrifuges, merely stating that Svedberg was chosen because of "his writings on dispersive systems." Increased support for his work now came from many directions. In 1928 the Swedish Government allotted funds to build an Institute of Physical Chemistry at Uppsala. The same year the Rockefeller International Education Board appropriated $50,000 toward equipping the new institute. This initial aid has been followed by further grants from The Rockefeller Foundation totaling over $200,000 and by additional grants from the Nobel Foundation and other Swedish trusts.

Most of these funds went to finance studies of proteins. In the course of the research the Uppsala group thoroughly demonstrated that the protein particles were giant molecules and determined the weights of several hundred of them. The success of this work electrified physical chemists all over the world. From many quarters came requests for this powerful research tool. In the course of the years Svedberg's shop built six high-speed, oil-driven ultracentrifuges for outside clients in addition to the three installed in the Uppsala laboratory. The six went to the Universities of Gothenberg and Copenhagen, the Lister Institute in London, the Biochemical Laboratory of Oxford University, the Du Pont Laboratories at Wilmington, Del., and the Laboratory of Physical Chemistry at the University of Wisconsin. Workers in many other institutions yearned for a molecule weigher, but the oil-driven ultracentrifuge is an intricate and costly machine, and no one outside Svedberg's group has yet succeeded in building one. With a view to simplifying the engineering problems and lessening the cost, American efforts to design ultracentrifuges turned to pressurized air as a motive force.

The Air Drive

Two Parisian scientists, E. Henriot and E. Huguenard, are the pioneers of the air drive. Their first machine, details of which were published about the time that Svedberg was deciding on the oil drive, consisted of a solid cone-shaped rotor which was both supported and turned by a whirling layer of air discharged under pressure from properly directed jets. It was, in effect, a spinning top. In their early experiments Henriot and Huguenard made no attempt to exploit the device beyond demonstrating that it could provide high rotational speeds. Later they harnessed their spinning top to a narrow cylindrical centrifuge and got it up to 65,000 r.p.m. Then they mounted a small mirror on top of the rotor and spun the mirror at 360,000 r.p.m.

Publication of these results caught the attention of a young physicist at the University of Virginia who was working on an experiment which required very rapid reflections of light. Applying the Henriot-Huguenard principle, the Virginian, Jesse W. Beams, rigged up an air-driven top 30 millimeters in diameter which rotated a mirror 180,000 times a minute. That was the beginning of a lifelong, imaginative interest in whirling mechanisms for Beams. In the years since 1930, when he made his first machine, he has lavished much of his time, thought and inventive skill on studies of high-speed rotation. Practically all current American development of the ultracentrifuge stems from the work of this Virginia professor, his students and his associates.

Beams was interested in the sheer physics of centrifugation—to see how high it could be pushed and to test its effects on materials. He enlisted the interest of a graduate student, Edward G. Pickels, and soon Pickels became captive to the subject that was fascinating his professor. They whirled many a piece of metal to destruction and thereby learned what to do as well as what to avoid. Before the end of 1933 they had mounted a 10-millimeter rotor and driven it up to one million r.p.m. Later, using compressed hydrogen in place of air as the motive power, Beams and Pickels spun a nine-millimeter rotor at better than 1,200,000 r.p.m. These devices were essentially spinning tops. When the time came for Pickels to concentrate on a subject for his doctoral thesis, Beams suggested that he study the application of the spinning-top principle, either to the measurement of the velocity of light or to the ultracentrifugation of biological materials. Pickels chose the latter alternative. He was just beginning to explore the requirements when a visitor arrived who was especially interested in biological ultracentrifugation—Johannes H. Bauer of The Rockefeller Foundation.

Bauer was a yellow-fever researcher, a former member of the Foundation team in West Africa which had identified the virus of yellow fever. Nothing was then known of the weight, shape or other physical characteristics of the yellow-fever virus, and Bauer was interested in any device that might throw light on virus properties. Could the ultracentrifuge be useful? Beams and Pickels demonstrated their spinning tops, pointed out the limitations and suggested the possibilities.

At Bauer's invitation Pickels visited the Foundation's International Health Division Laboratories in New York in the summer of 1934. He spent two months there getting acquainted with the particular requirements of virus research. This convinced him that the spinning-top technique was impractical: the spinning tops were too small to provide sufficient distance for virus sedimentation to take place at a measurable rate. Moreover, since the spinning top whirled in the open air, enlarging its diameter would cause it to heat up substantially and would require a prohibi-

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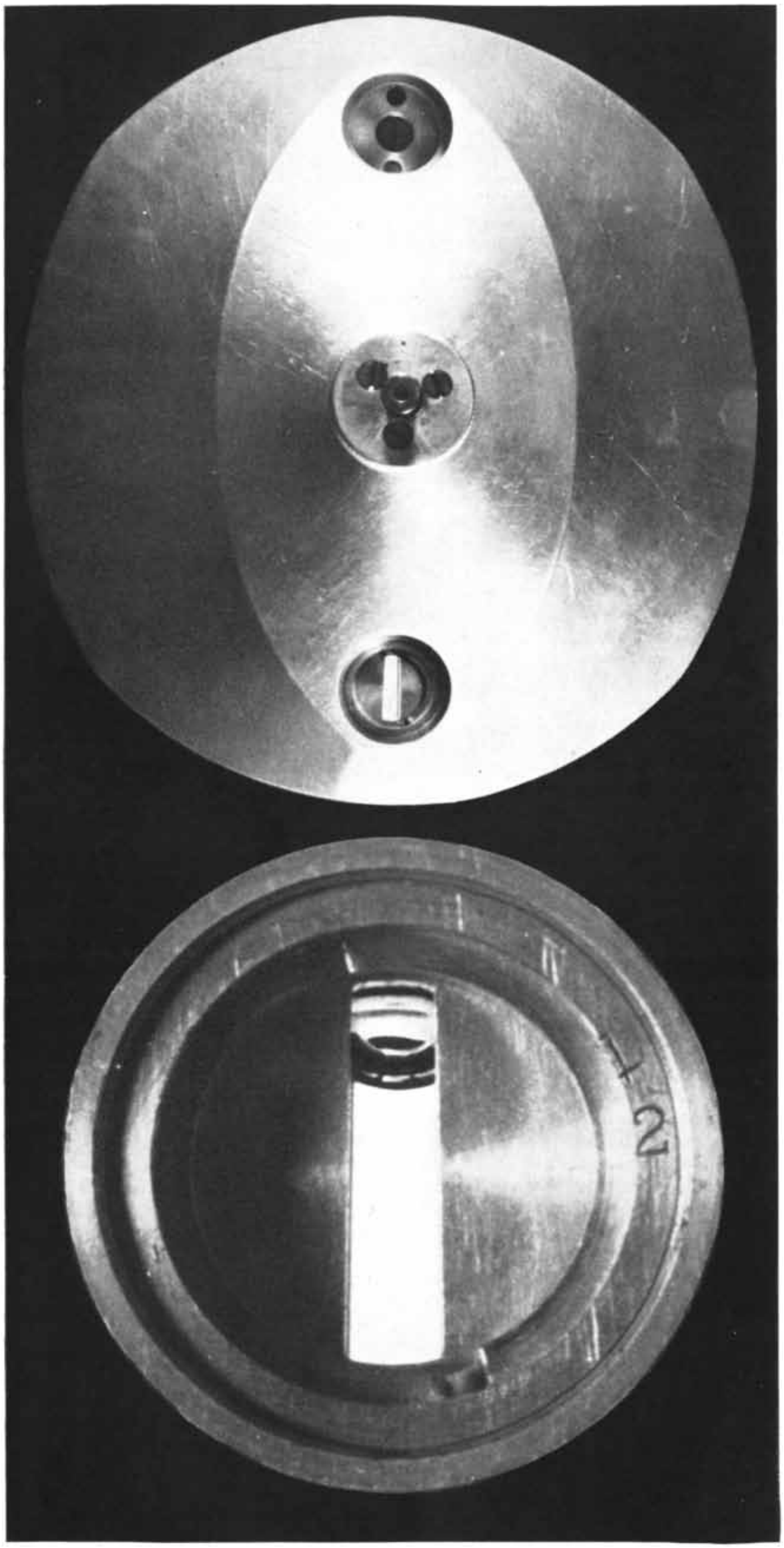

ULTRACENTRIFUGE ROTOR on page 44 is shown from the top. The cell that contains the solution to be centrifuged is at the bottom of the rotor; an enlarged view of it is below. When the centrifuge is in operation, the curved surface of the solution flattens. The rotor is some seven inches in diameter.

tive multiplication of power, due to the increase in air friction.

Would it be possible to rotate the thing in a vacuum? Back at Charlottesville Pickels and Beams took up a serious study of that question. Before the winter was over their answer was yes. In April they published in *Science* an account of the first vacuum ultracentrifuge.

The Vacuum Ultracentrifuge

What Pickels and Beams did was to separate the driving element of the spinning top from its virus-carrying element. The driving element was made into a tiny air turbine which operated in the open air. Suspended from the turbine by a short stretch of piano wire was a larger rotor, hollowed out to accommodate a tiny cell carrying the solution. This rotor hung in a sealed chamber from which air was evacuated; the piano wire passed into the chamber through an airtight oil gland. The wire served both as a support for the rotor and as a vertical driving shaft to whirl it under the torque of the turbine.

In June, after Pickels had received his Ph.D. degree at Virginia, he agreed to join the staff of the Foundation's International Health Division. Thereafter for a full decade this laboratory in New York was the principal developmental center of the vacuum type of air-driven ultracentrifuge. Pickels, whose interests were primarily mechanical, optical and mathematical, became a close collaborator of Bauer, who approached the problem from the biological point of view. Many improvements in design and advances in application came out of the joint efforts of these two men. The Rockefeller Institute for Medical Research also was interested in the possibilities of ultracentrifugation as a laboratory tool, and members of its staff, notably Ralph W. G. Wyckoff and Jonathan Biscoe, joined forces with Pickels and Bauer in the developmental research.

Primarily the research was aimed at duplicating with the air drive the kind of performance that Svedberg had already accomplished with the more costly oil-driven machine. Within less than a year the group was able to report the attainment of an ultracentrifuge built in their own shop with materials (including the lenses) which cost less than $1,000. It had an oval-shaped seven-inch rotor made of aluminum alloy. "In designing this ultracentrifuge," Pickels, Wyckoff and Biscoe reported, "we have sought to utilize, to the greatest possible extent, the experience embodied in the publications of Svedberg. We have therefore copied his optical system directly and have employed large rotors capable of giving the 6.5-centimeter distance between cell center and rotation axis which he has adopted for his most accurate measurements." This was the

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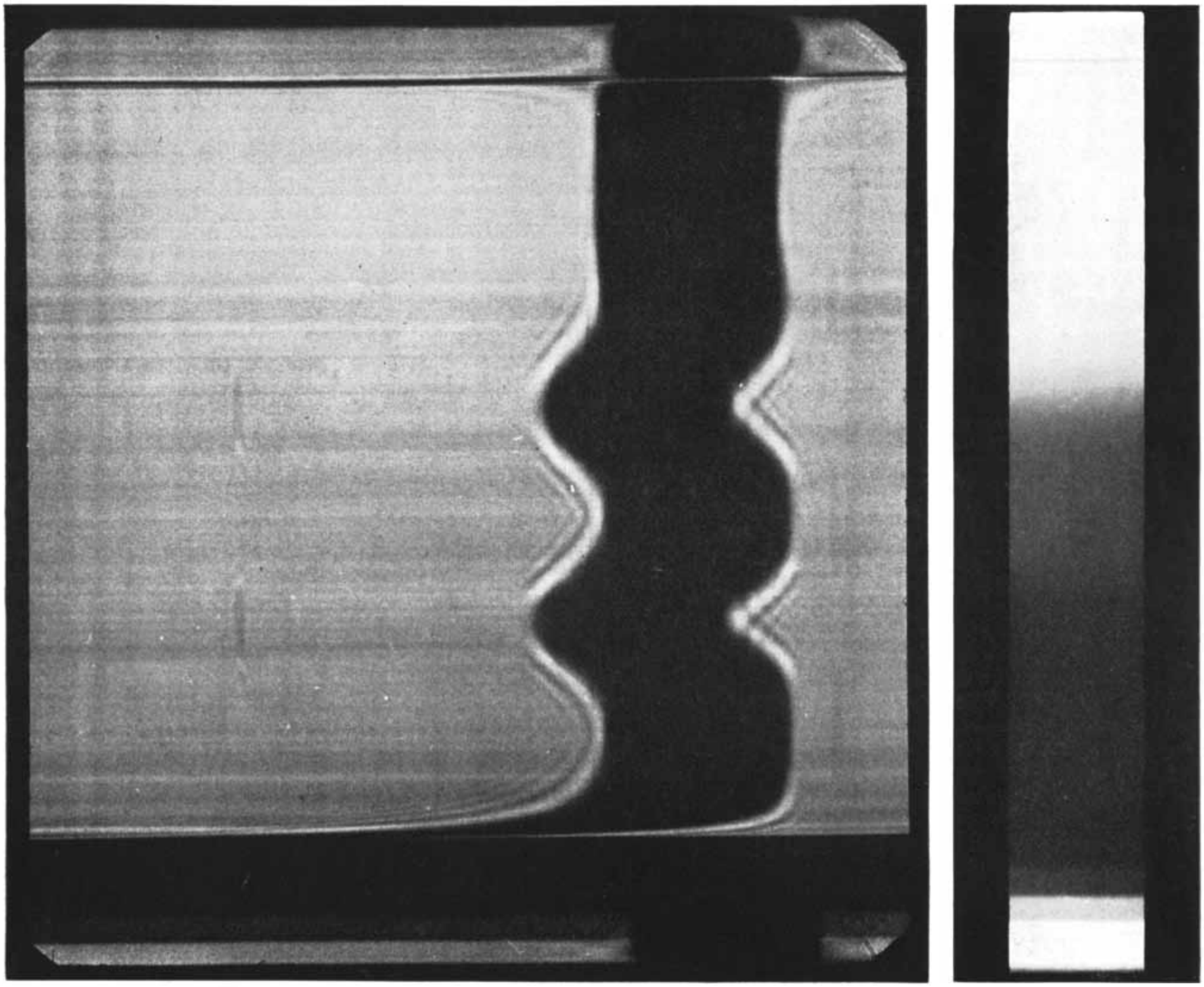

REFRACTIVE-INDEX METHOD of photographing the sedimentation of a protein shows the boundary of the protein as a horizontal peak. At the right is a photograph of two protein constituents by the absorption method. The corresponding photograph made by the refractive-index method, showing two peaks, is at the left.

first time that a full-size rotor had been driven by air, for even in their vacuum-type machine of the previous year Beams and Pickels had tried nothing larger than a 3.5-inch rotor. With their new seven-inch whirler molecular sedimentation was easily demonstrated, first with horse hemoglobin and then with the tobacco-mosaic virus which had recently been crystallized by Wendell M. Stanley.

By certain modifications in the oval shape of the rotor Bauer and Pickels increased its safe operating velocity from 54,000 r.p.m. to 60,000. They also improved the air drive and the air bearing which supported the entire rotating assembly. By adding reverse vanes to the turbine they provided an air brake by which the rotor could be brought to rest from full speed in 20 minutes. By these and other modifications of the basic design, the air-driven ultracentrifuge was made more nearly an instrument of high precision for biological research, especially for virus research.

The Bauer-Pickels collaboration came to an end in 1945. Bauer went abroad on a war-relief mission, and a few months later Pickels resigned to engage in the commercial manufacture of ultracentrifuges. His company, the Specialized Instruments Corporation, which opened for business in California in 1946, has built more than 70 analytical ultracentrifuges for laboratories in this country and abroad. These Spinco machines are of the vacuum type but are driven by electric motor instead of compressed air.

The Next Decimal Point

Ultracentrifugers are perfectionists, continually striving to heighten the vacuum, lower the friction, reduce the fluctuation. Bauer and Pickels, never satisfied with the precision of their instrument, were always reaching for the next decimal point. So too with Beams. A recent visitor to Charlottesville found Beams engrossed in a coasting type of ultracentrifuge. Its seven-inch rotor is supported by magnetism and is driven by air to the top speed of 60,000 r.p.m., after which the air turbine drops off and the rotor whirls in the vacuum under its own momentum. Friction is so slight that at the end of 10 hours the rotor has lost only one revolution per second, and more than a year would be required for it to come to rest. Since it rotates by inertia, with no propulsion from outside, this coaster represents the ultimate in steadiness of motion, Beams believes.

Meanwhile John C. Bugher, who two years ago was placed in charge of the Rockefeller Foundation ultracentrifuge, has been exploring ways to better that instrument's performance. The vacuum in which its rotor whirls has been improved and is now down to one ten-millionth of an atmosphere. During an hour of running in this highly rarefied air at 60,000 r.p.m., the rotor temperature rises by only half a degree C. For most of the virus studies, however, the speeds required are not over 45,000 r.p.m., generating forces of 147,000 g.

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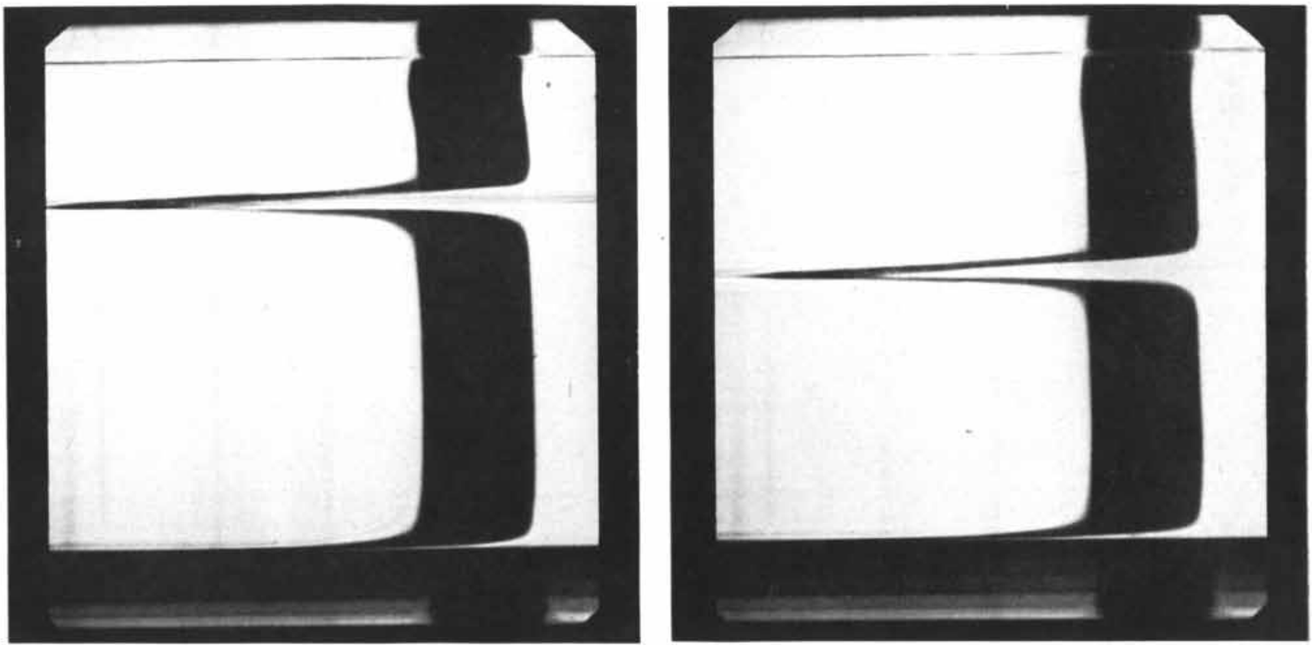

SEDIMENTATION OF A PROTEIN is shown in four photographs made by the refractive-index method. The first photograph shows the hemocyanin of *Limulus polyphemus* after centrifugation for an hour; the sec-

Steadiness of rotation in this machine has been greatly enhanced by the addition of an electronic control. Under the old system it was necessary for an operator to keep a weather eye on the air drive and give it attention whenever the rotor began to speed up or slow down. Bugher has surrounded the air turbine with an electromagnet controlled through electron tubes which are synchronized with time signals received by radio continuously from the Bureau of Standards in Washington. If the rotor tends to race, the controlled magnetic field restrains it by dragging against the turbine; if it tends to slow down, the field puts in added power and speeds up the turbine. The pulsations necessary to provide these corrections are so slight that their heating effect is insignificant. The entire hookup is automatic and, once set in motion, requires no attention. Under the earlier system the rotational speed was known to an accuracy of 99 per cent; with the electronic control it is known to an accuracy of 99.999 per cent.

This never-ending solicitude for constancy is understandable when we remember that the whole purpose of running the ultracentrifuge is to measure the rate at which the particles sediment, and that the accuracy of this measurement depends on correct knowledge of the rotational speed. The measurement is made by photographing the state of sedimentation at intervals of time. The state of sedimentation is indicated by the position of the boundary between the zone of concentration of heavy particles and the zone of lighter particles left behind. As each picture is taken, it records the position of the moving boundary at that moment. Thus it discloses how far the boundary has progressed toward the rim of the rotor in each interval.

There are two ways of photographing the boundary. One, known as the absorption method, makes use of the fact that any given substance selectively absorbs light of a certain wavelength or band of wavelengths. To photograph the boundary of yellow-fever virus concentrated in the rotor, for example, one sends a beam of the particular "color" of light that the virus is known to absorb most strongly through the quartz windows which face each other on opposite sides of the rotor. Since the virus absorbs this light, the zone it occupies appears black on the photograph.

Absorption photographs usually show a fuzzy band rather than a sharp boundary. But even more serious is the wide margin of probable error in interpreting the optical density in terms of the actual concentration of material. These uncertainties have led to another stratagem: the refractive-index method. It makes use of the fact that when light passes through a transparent fluid which has zones of different density, the boundary between these zones bends the light. The boundary between heavy-weight and light-weight particles operates like a refraction lens; when the rays that pass through it are photographed, they describe a "peak." In practice the optical system turns the refracted image in such a way that it is projected on the photographic plate with the peak pointing to the left, and as sedimentation progresses the peak moves downward. The rate at which the peak moves is a measure of the rate of sedimentation.

The absorption method was introduced by Svedberg; the refractive-index method by a Swedish colleague, O. Lamm. Both techniques are widely used, but the refractive index is more often preferred, particularly when complex mixtures are to be investigated and it is desired to measure the concentrations of several components. Bugher is using this refractive-index method in current studies of 18 unknown viruses which the International Health Division picked up in the course of its yellow-fever surveys in Africa and South America. Two of the unknowns—Bwamba fever virus and Semliki Forest virus—have been subjected to preliminary ultracentrifugation. Bwamba shows up as a particle approaching the large virus of influenza in weight and size, whereas Semliki Forest virus is smaller, like that of yellow fever. Bugher reports that in 15 minutes of ultracentrifugation at 12,000 r.p.m., the boundary of Bwamba fever virus moved four millimeters, whereas that of yellow fever took 100 times as long to sediment that distance.

Mathematics

This business of weighing molecules requires more than centrifuging them at constant speed and measuring the rate at which their boundary moves. All that such a measurement gives is the sedimentation velocity, which is but one of six terms in the equation that determines the molecular weight. The other terms are the gas constant, the absolute temperature, the diffusion coefficient, the partial specific volume of the material being studied and the density of the solution.

In the summer of 1950 a three-day conference on ultracentrifugation was

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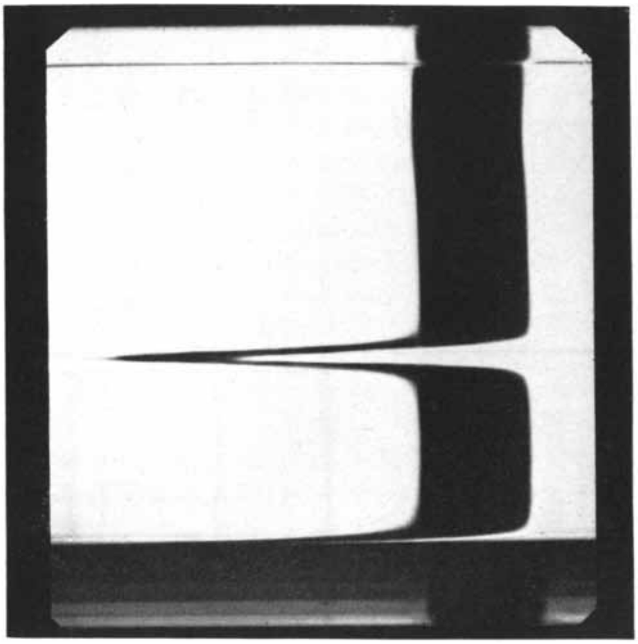

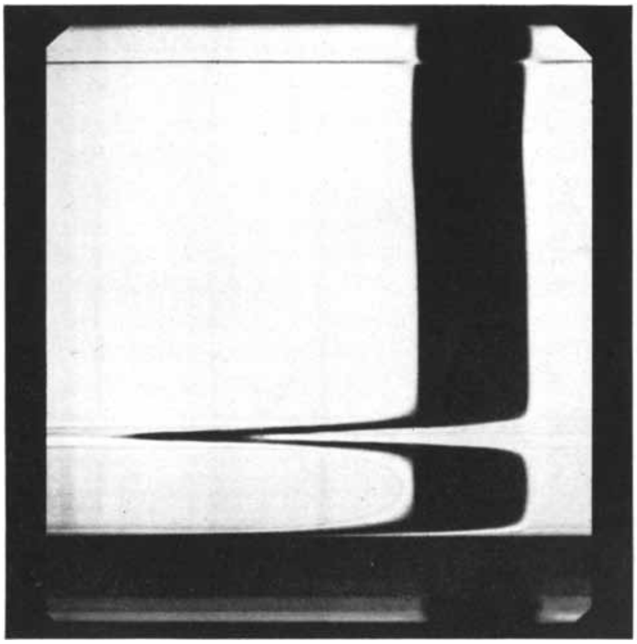

ond, after an hour and a half; the third, after two hours; the fourth, after two hours and a half. The line at the top was made by the surface of the solution containing the protein; the long horizontal peak, by the protein itself.

held at Shelter Island, N. Y., under the auspices of the National Academy of Sciences. Leading workers in this field of physical chemistry participated, and most of the time was occupied by discussion of the terms of the equation. The gas constant you get out of a book, but all the other factors have to be determined by actual measurement, as the sedimentation velocity is. For example, to obtain the diffusion coefficient you place a solution of the protein in contact with a buffer solvent with a sharp boundary between them, and then measure by optical means the rate at which the boundary disappears as the protein diffuses into the solvent. The partial specific volume and the density are particularly critical terms in the equation, for a slight error in these measurements can make a very large difference in the result. The partial specific volume of the protein, which is the reciprocal of its density in the solution, is commonly calculated from measurements of the density made with a pycnometer (measuring flask) at different concentrations. Karl Drucker, of Svedberg's group, has increased the precision of this measurement by recent improvement of the technique, but here as in other areas the biochemists are still reaching for the next decimal point.

One of the subjects discussed at the Shelter Island conference was Svedberg's equilibrium method of determining molecular weight. This method, which employs a somewhat different mathematical equation from the sedimentation-velocity method, has the advantage that the diffusion as well as the sedimentation data are provided by the ultracentrifuge itself. The great disadvantage is that it requires long periods of low-speed rotation. However, one of the participants in the conference, W. J. Archibald of Dalhousie University in Nova Scotia, reported that he had worked out a scheme for shortening the process. He does not wait for the attainment of equilibrium between sedimentation and diffusion but takes observations of the concentration gradient at fixed intervals in the early stages of ultracentrifugation. These readings provide the points for defining a series of curves, and from these by extrapolation the equilibrium figure is computed. In a few hours Archibald's method can get a result which would take weeks by the full equilibrium process.

Giants and Supergiants

A complete review of the gains that have accrued to science from the development of the ultracentrifuge would fill many pages. The primary contribution is the higher precision it has brought to our knowledge of molecular biology. In some cases it has corrected, in others confirmed or extended, the testimony of other instruments and techniques. The biochemist, indeed, has many tools for studying molecules: osmotic pressure measurements, filtration through pores of progressive sizes, electrophoresis, electron microscopy, spectroscopy, chromatography, X-ray diffraction. Each is, in a sense, a different window on the world. And the view from one window is not enough; usually it opens in only one direction. The biochemist wants to see in every direction, to examine all properties of molecular structure and molecular reaction, to measure their magnitude and elucidate, if possible, the part they play in the scheme of life. The ultracentrifuge is only one of these instrumentalities, but it is a powerful one.

Before the development of the ultracentrifuge there was widespread doubt among chemists as to the existence of giant molecules. Diffusion data, viscosity measurements, osmotic pressure determinations and other indirect evidence had indicated that protein particles were of tremendous size. But the general opinion held that proteins were not strictly unitary structures, like the molecules of acids and sugars, but were merely clusters of small molecules bunched together to form composite particles of heterogeneous mass. Svedberg's very first determination showed that the particles of hemoglobin were of uniform weight and that their weight was around 69,000 times that of a hydrogen atom. A little later he subjected hemocyanin to ultracentrifugation and found that its weight was about five million units. This measurement seemed utterly unbelievable. Such a molecule would consist of hundreds of thousands of atoms, and how could so huge a structure hold together?

But Svedberg and his associates continued to spin solutions of proteins and weigh their molecular masses, and soon the new technique of electrophoresis began to confirm the testimony of the ultracentrifuge. When the Royal Society of London held its symposium on "The Protein Molecule" in 1938, it invited Svedberg to open the discussion. He was able to point to some 60 proteins which had been run through his molecular weighing machine with results so consistent that he could declare: "The pro-

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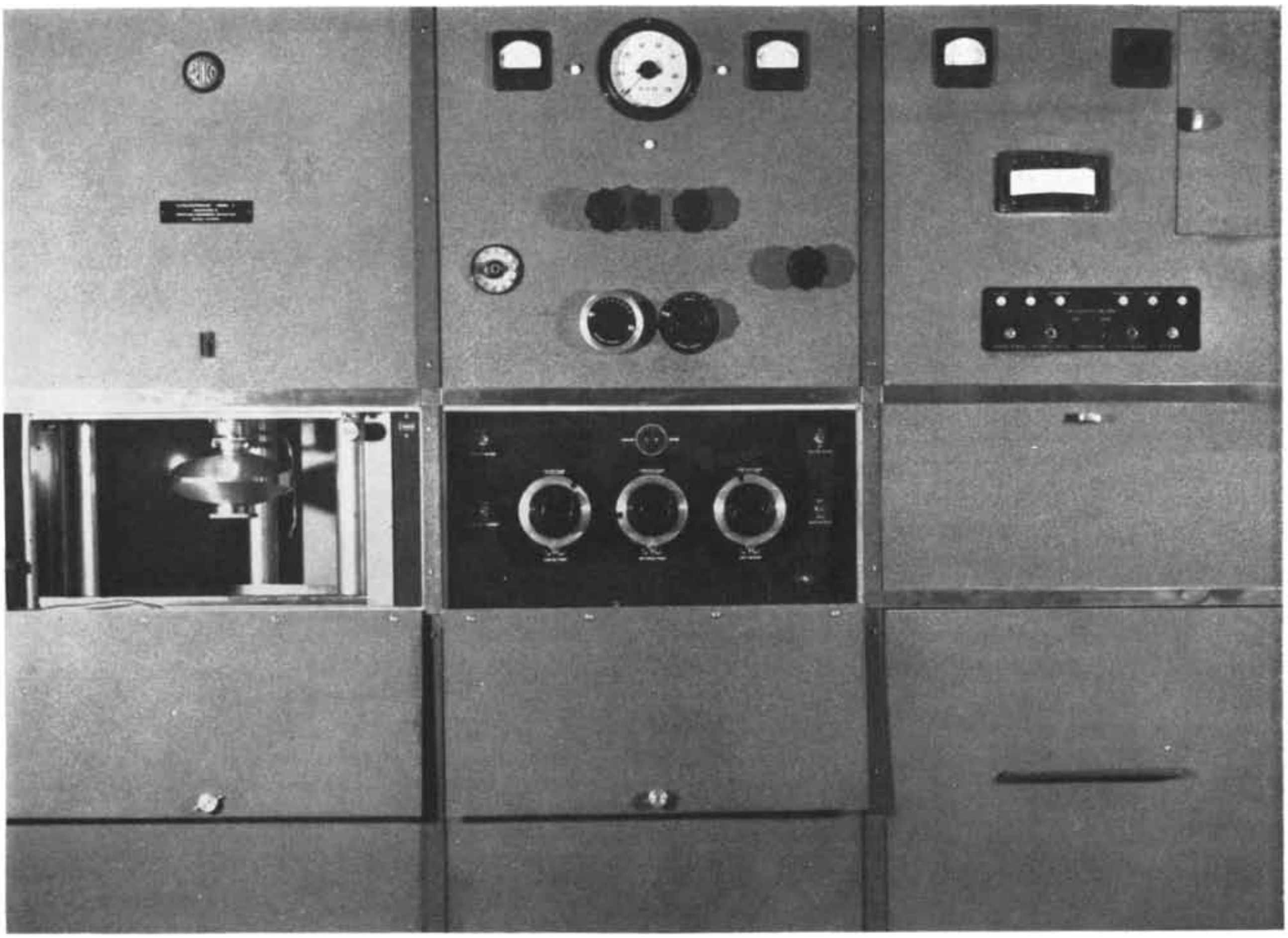

COMMERCIAL ULTRACENTRIFUGE was designed by Edward G. Pickels, one of the pioneers of ultracentrifuge development. It is driven by a geared-up electric motor instead of an air or oil turbine. The rotor of the machine, which is located at the Sloan-Kettering Institute for Cancer Research, may be seen at left center.

teins are built up of particles possessing the hallmark of individuality and therefore are in reality giant molecules."

In addition to the Uppsala determinations, important ultracentrifugal measurements of proteins have been made by chemists in Stockholm, London, Oxford and Berne. Among the successful protein weighers in the U. S. are J. L. Oncley of the Harvard Medical School, who employs an air-driven instrument of the Beams-Pickels-Bauer type, and J. W. Williams of the University of Wisconsin, who uses an oil-driven ultracentrifuge of the Svedberg type. There is only one other oil-driven ultracentrifuge in the U. S.—at the Du Pont Laboratories in Wilmington, where it has been operated for a number of years by Svedberg's former student, J. Burton Nichols. Nichols specializes in the study of high polymers, those long chainlike molecules of which rubber and cellulose are examples. They present a striking contrast to the predominantly globular or ovoid shape of the proteins, but Nichols and his associates find that "whirl is king" among the filamentous molecules no less than among those of more rounded form.

Apart from a few striking exceptions, such as tobacco-mosaic virus and the vaccinia of smallpox, the viruses have presented peculiar problems in sedimentation studies. Their extreme biological activity may be a reason for this. Bauer and Pickels found the sedimentation of yellow-fever virus exceedingly difficult. Often, after centrifuging the serum of sick monkeys to obtain a workable concentrate, they would end with an amount of active virus that was little more than they had started with. It was only by centrifuging the material again and again that they were able to obtain a sufficient concentration to put in the ultracentrifuge for sedimentation measurements. Their determination gave the molecular weight of the yellow-fever virus as 2,930,000. This truly is a giant when compared with familiar proteins such as hemoglobin, weight 69,000, and egg albumin, 44,000. But it is dwarfed in turn by the influenza virus, a super-giant weighing 650 million units.

Separators

The ultracentrifuge is often confused with the centrifuge; strictly speaking they are different tools. The ultracentrifuge, as defined by Svedberg, who coined the term, is "an instrument by means of which sedimentation in a centrifugal field is measured quantitatively." A centrifuge, on the other hand, separates substances of different particle weight but cannot weigh or measure them. No matter how high its speed or how elegant its mechanical design and operation, the centrifuge is simply a glorified cream separator. It has no optical system, requires no observation of the rate of sedimentation, is not seriously affected by fluctuations in its rotational velocity. The development of the ultracentrifuge has, however, contributed enormously to the improvement of centrifuges. High-speed ordinary centrifuges capable of 40,000 or more r.p.m. are becoming quite common items of biochemical research equipment. In the current lingo of the laboratories these centrifuges are called "preparative ultracentrifuges," meaning that they serve to concentrate substances out of mixtures in preparation for more refined analysis in the ultracentrifuge. The true ultracentrifuges are called "analytical ultracentrifuges." Some manufacturers are making combination machines which can

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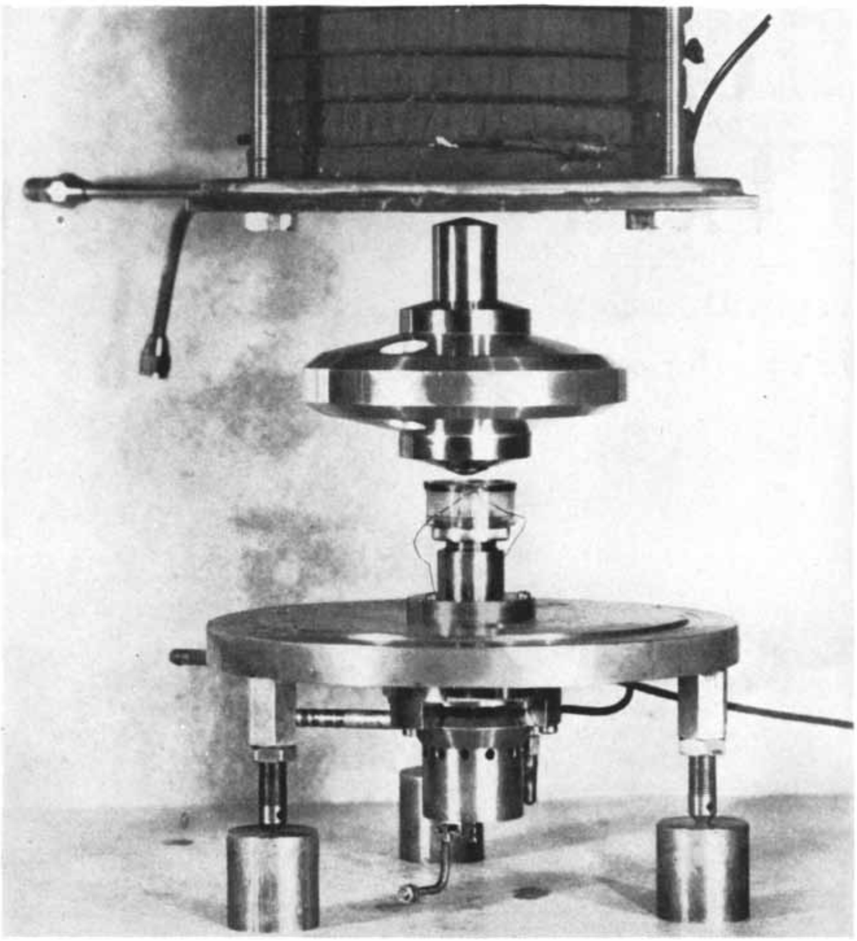

MAGNETICALLY SUSPENDED ROTOR is the principal feature of the new ultracentrifuge designed by Jesse W. Beams of the University of Virginia. The rotor is driven by an air turbine, disengaged and allowed to coast.

be used either to weigh molecules or as preparative separators.

An interesting example of the use of centrifugation in medical research comes from the University of California. In the Donner Laboratory of Medical Physics there, John W. Gofman and a group studied the blood of patients suffering from arteriosclerosis. They found that at high speeds a centrifuge was able to separate from the blood of these patients a substance that was rarely found in the blood of healthy persons. The new-found substance was put through an analytical ultracentrifuge and found to have a molecular weight of about three million. Other medical researchers are studying this phenomenon. If it should turn out that the presence of the Gofman factor provides early evidence of the onset of disease, the results will be far-reaching. Perhaps eventually we may have diagnostic centrifuges.

The marvel is that despite the tremendous forces to which molecules are subjected by centrifugation, they suffer no mutilation. This is especially surprising because proteins, for example, are notoriously vulnerable to many of the chemist's customary reagents, such as acids, alkalies and heat. Under the circumstances, the centrifuge is rapidly gaining favor in laboratory use as a reliable means of extracting protein substances intact from a mixture.

It is also remarkable that living cells can survive these forces. At the University of Iowa T. J. MacDougald, H. W. Beams and R. L. King centrifuged fragments of an embryonic chick heart at velocities which generated 400,000 g. After half an hour of this treatment the heart tissue continued to pulsate; when cultured, it grew at the same rate as other fragments of the same heart which had not been centrifuged.

Centrifugation can separate mixed gases of different weight. The possibility of using this property to separate fissionable uranium 235 from uranium 238 was explored in the wartime atomic bomb project. In *Atomic Energy for Military Purposes* Henry DeWolf Smyth reported: "The first experiments with centrifuges failed. Later development of the high-speed centrifuge by J. W. Beams and others led to success. H. C. Urey suggested the use of tall cylindrical centrifuges with countercurrent flow; such centrifuges have been developed successfully." But in the final competition of techniques for separating uranium, it was the gaseous exchange method and the electromagnetic method that won acceptance for large-scale application. Although a pilot plant for the centrifuge method was constructed at Bayway, N. J., and "operated successfully and gave approximately the degree of separation predicted by theory," this plant was later shut down.

Before the war Beams had experimented with cylindrical rotors and declared them preferable to conventional rotors for processing a large quantity of material. His studies showed that a "tubular centrifuge," as he called it, would do the work of 40 ordinary centrifuges. But since the tubular centrifuge has become a subject of classified military research, Beams has ceased to work with this type of rotor.

His laboratory at Charlottesville is giving much attention today to experiments with an electromagnetic drive with which he began to work in the 1930s. The rotor is a solid steel ball. Suspended in a vacuum and supported by a magnetic field, it floats in space like Mohammed's coffin. It has no need for axles, bearings, lubrication, air valves, mechanical switches or other ponderable parts. It is driven simply by the pulsations of a rotating electric field generated by electron tubes and controlled by vibrating crystals. Thus suspended, supported and driven, with friction almost zero, the ball whirls millions of revolutions per minute.

Beams is using these rotating balls to study the properties of solids. "Metals break at a tensile stress below that predicted by theory," he explained, "and to find out why they do so we are coating steel balls with other metals by electrolysis and then rotating the balls at increasing velocity until the plated film is thrown off. In an experiment with a coating of antimony it took 400,000 g to fling the antimony off the steel."

Beams is still trying to see how far he can push rotation. Recently he made the electric pulses drive one of the diminutive steel spheres to the unbelievable velocity of 48 million r.p.m.! The microscopic ball, only one twelve-thousandth of an inch in diameter, generated 500 million g. At that acceleration a drop of water would press out with a force equal to the weight of a locomotive.

This is the top attainment in rotational speed to date, so far as any published record shows. Beams has set his goal at 60 million r.p.m.—a million rotations a second—and admits that he won't be happy until he achieves it.

George W. Gray, the author of The Great Ravelled Knot *and other articles that have appeared in this magazine, is a member of the staff of The Rockefeller Foundation.*

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THE FERTILIZATION OF FLOWERS

The rich and beautiful variety of floral color, odor and anatomy is due to the evolutionary adaptation of plants to the specialized creatures that pollinate them

by Verne Grant

WHAT is a flower? How is it constructed, how does it function, how did flowers originate and evolve into the more than 150,000 species found on earth? Although man has always lived in a world of flowers, as recently as 200 years ago their biological meaning was still a mystery. Today, thanks to two centuries of patient work by many botanists all over the world, the mystery is to some extent explained.

Flowers are the reproductive structures of plants. The structures consist of pollen-bearing stamens (the male organs) and carpels (the female organs) containing pollen-catching stigmas and ovules, the plant's "eggs." A union of the pollen with the ovules produces seeds. Most of the flowers with which we are familiar have both organs, the stamens and the carpels, in the same flower. It would be most convenient for the plant if each flower's pollen fertilized its own ovules, but many flowers cannot pollinate themselves. They are fertilized by pollen from other individuals of the same species. From an evolutionary standpoint this has advantages, for it produces a combination of different heredities and yields more variable and more flexible progeny.

In the animal kingdom this kind of union poses no special difficulties. Impelled by an urge to mate, the male and female swim, crawl, walk or fly until they find each other. But the union of two flowering plants, anchored by their roots to separate spots of ground, presents a problem that can be solved only by the intervention of some third party. The pollen of one plant must be carried to the ovules of the other by an external agent—the wind, water currents, an insect or some other animal. Obviously if this is to occur it must be advantageous or inevitable for that agent to carry the pollen. In the long course of evolution the flowers of plants have become adapted through natural selection to the characteristics of their pollinators. Thus the various species of flower owe their structure, shape, color, odor and other attributes to the particular agents that cross-pollinate them. The flowers of the earth group themselves into several broad classes depending on how they are pollinated. There are the bee flowers, the moth flowers, the fly flowers, the beetle flowers, the bird flowers, the bat flowers, the wind flowers, and so on.

THE bee flowers include some orchids (*see cover*), verbena, violets, blue columbine, larkspur, monkshood, bleeding heart, many members of the mint, snapdragon and pea families, and a host of others. All of them offer nectar as a reward to the bees, and all advertise their presence by showy, brightly colored petals and a sweet fragrance. The bee flowers and bees are beautifully adapted to each other in biological construction and habits. Most bee flowers are blue or yellow or some mixture of these two colors, and experiments show that the vision of bees is mainly in this part of the spectrum; they are colorblind to red. Bees respond to sweet, aromatic or minty odors and apparently are not stimulated at all by foul ones. Bees fly only by day, and bee flowers are always open in daytime but often closed at night.

In visiting a flower a bee habitually alights first on a petal. Many bee flowers provide a protruding lip as a landing platform. The bee then pushes its way into the region of nectar and pollen. Bee flowers secrete nectar from special glands which often lie at the base of a tube of petals. Bees, with their long, slender tongues, can reach the nectar, but most other insects cannot. As the bee takes the nectar, its body hairs inevitably pick up pollen from the flower's stamens. In some bee flowers the stamens have special lever, trigger or piston devices for dusting pollen on some particular spot of the bee's body. When the bee has finished working on one flower, it flies rapidly on to another. Bees have an instinct to confine their attention to flowers of one species at a time; they recognize a species by its characteristic odor, form and color. This is very convenient for the flower, since it assures that the bee will deliver its load of pollen where it will do the most good, namely, to another flower of the same species which the pollen can fertilize. Since the stamens and carpels are grouped together in the flower, the bee simultaneously delivers its load of pollen to the carpels and picks up a new load from the stamens at each visit. It delivers enough pollen grains to fertilize a large number of ovules, and most bee-pollinated plants do in fact ripen numerous seeds in each flower.

Bee flowers thrive best in arid, semi-arid and sunny parts of temperate regions, where bees find the climatic conditions to their liking. Many bee-pollinated plants are unable to reproduce themselves in areas that lack certain kinds of bees. For example, monkshood, a bumblebee flower, does not occur naturally outside the range of bumblebees in the Northern Hemisphere. Alfalfa, a cultivated species of the pea family, is often infertile in California, where the proper kinds of bees are scarce under the highly artificial conditions of cultivation.

THE moth and butterfly flowers also are very numerous. Among the moth flowers are the morning-glory, tobacco, yellow columbine, datura, white catchfly, yucca, phlox, some evening primroses and many orchids; the butterfly flowers include the carnation, red catchfly and many lilies. Nearly all species of moths and butterflies have a long tongue for sucking nectar; in tropical hawk moths the tongue is sometimes as long as 25 centimeters. Unlike bees, moths do not settle down on the flower during feeding; they hover above it with the tongue inserted in the nectar. They are guided to flowers by a combination of sight and smell, but most of them fly

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during dusk and at night, so that moth flowers run mainly to white shades and a very heavy fragrance. Many of these flowers open only in the late afternoon or evening and are closed through the hours of bright sunshine. Butterfly flowers, on the other hand, often have red or orange colors, since butterflies feed during the daytime and some of them, unlike bees, can see the red part of the spectrum.

The nectar of moth and butterfly flowers is secreted at the base of a long slender tubular spur, where it is accessible only to the long-tongued moths and butterflies. In many species of moths the length of the tongue closely matches the length of the spur in the particular flower that the species visits. Like bees, moths and butterflies tend to feed on one kind of flower at a time.

Moth flowers apparently are most plentiful in tropical and warm temperate latitudes. They are common at high elevation on temperate mountain ranges, but are absent from the Arctic and Antarctic.

THE flies that feed on flowers fall into two classes: long-tongued and short-tongued. The long-tongued flies, such as the syrphids and bombylids, in the main visit the same types of flowers as bees, since they are well adapted in bodily structure, habits and sensory perception to live on the nectar of these flowers. The truly distinctive fly flowers, therefore, are those that feed the short-tongued flies.

These flies, consisting of some 30 or more families, are a diverse and miscellaneous lot, and they have no particular specializations for feeding on flowers. Most of them probably derive their nourishment mainly from other sources, notably carrion, dung, humus, sap and blood. The flowers that attract them are those that carry similar odors. Unlike bees, moths and long-tongued flies, the short-tongued flies are attracted to flowers not primarily by vision but by their sense of smell. The fly flowers, consequently, are generally dull of color and rank in odor. Rafflesia, a large-blossomed fly flower of Malaysia, smells like putrefying flesh; another fly flower, black arum, has the odor of human dung; another, the lily *Scoliopus bigelovii,* smells like fish oil; there is a species of Dutchman's-pipe that smells like decaying tobacco and another that smells like humus.

The performance of short-tongued flies on flowers may be described as unindustrious, unskilled and stupid. Some fly flowers obtain the pollen-carrying services of flies without even expending any nectar on them. In this case the flies are attracted to special glistening streaks, spots or bodies, as in the saxifrage *Parnassia,* the lily *Paris* and the orchid *Ophrys.* The flowers of Dutchman's-pipe

BEETLE, WIND AND BIRD FLOWERS have been molded to the means by which they are pollinated. At the top of this illustration is a flower of the sweet shrub Calycanthus. Purple and wine-scented, it attracts beetles and traps them for about a day until they are doused with pollen. In the middle is a flower of the sedge Cyperus. It has neither petals nor odor; its pollen is scattered by the wind. At the bottom is a flower of Strelitzia, a member of the banana family. It has a landing platform at right for the sunbird.

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EVOLUTION OF COLUMBINES illustrates the specialization of pollination. At left is *Isopyrum thalictroides*, pollinated by flies and bees. Third from left is *Aquilegia ecalcarata*, pollinated by bees. Second is *A.*

and arum not only fail to feed the flies but actually imprison them for a day or two in a floral trap while they are being doused with pollen. After the flies escape from one flower, they may go on to a second trap, where they have the opportunity during another day or two to pollinate the flower thoroughly.

The American floral ecologist John Lovell once remarked upon the vast difference in the reception that flowers accord to bees and to flies. The efficient and constant bees are offered nectar, pollen, shelter, a landing platform, bright colors and sweet odors, and their competitors for the limited supply of food are excluded from the floral chamber. For the stupid flies, on the other hand, there are pitfalls, prisons, pinch-traps and deceptive nectaries!

Fly flowers are especially common in plants of arctic and high mountainous regions where other types of animal-pollinated flowers are infrequent or absent. They are also found in shady woods of the temperate and tropical zones.

THE beetle flowers also attract their insect pollen-carriers chiefly by odor rather than by sight. The flower-visiting beetles with rare exceptions are not specially adapted for feeding on flowers and may derive most of their nourishment from other sources, such as sap, fruit, leaves, dung and carrion. They may be attracted to flowers by fruity, spicy or sweet odors. There are two general types of beetle flowers. One group has large, solitary blossoms; among them are magnolias, pond lilies, California poppy, sweet shrub (Calycanthus) and wild rose. The other has clusters of small flowers; examples in this group are dogwood, elder, spirea, buckthorn and some members of the arum, parsley and sunflower families.

The beetles not only lap up the nectar and other juices of a flower but also feed on the tissues of petals and stamens. To protect the ovules from the chewing jaws of their pollinators, most beetle flowers have the ovules well buried beneath the floral chamber. Several of them hold the beetles in a trap while the stigmas receive pollen and the stamens sprinkle a fresh supply onto the bodies of the prisoners. They then open up an exit by which the beetle escapes. On the other hand, many beetle flowers have a shallow, open basin freely accessible to all comers. This makes them a common camping ground for many other kinds of small insects, including flies, wasps, bugs and bees.

Beetle flowers are most abundant in tropical latitudes and diminish toward the colder parts of the earth.

IT IS a common notion that insects are by far the most important animal pollinators of flowers, but actually in some parts of the world, particularly in the tropics and Southern Hemisphere, birds may be even more important. Hummingbirds in North and South America, sunbirds in Africa and Asia, honey eaters and lorikeets in Australia, honey creepers in the Hawaiian Islands, and several other groups of birds regularly visit flowers to feed on nectar, flower-inhabiting insects and pollen.

Birds have powerful vision and only a feebly developed sense of smell, so the bird flowers rely mainly on color to attract their pollinators. Most of them are large and colorful and many are odorless. The sensitivity of the bird's eye, like that of man, is great in the red end of the spectrum but relatively weak in the region of blue and violet. Hence the most frequent colors in bird flowers are red and yellow. The bird flowers include red columbine, fuchsia, passionflower, eucalyptus, hibiscus and members of the pea, cactus, pineapple, banana and orchid families. Bird flowers are most common in tropical and south temperate latitudes.

Hummingbirds commonly suck the nectar of flowers on the wing, and the flowers that they visit most often are of the hanging type. On the other hand, the flowers favored by sunbirds, which settle on the plant, usually stand erect and provide a landing platform. A bird probes into the chamber of a flower with its sharp-pointed bill. This frequently causes considerable mechanical damage to the inner floral parts. The bird flowers therefore put their ovules out of harm's way in an ovary under the floral chamber, behind a sheath or at the end of a special stalk.

The petals of bird flowers are fused into a tube which holds copious quantities of thin nectar. The proportions of the tube often correspond to the length and curvature of the bird's bill. The stamens are usually brightly colored, numerous and turned out so that they touch the bird on the breast or head while it feeds. The pollen adheres in sticky masses or threads. A single pollinating visit thus suffices for the fertilization of scores or hundreds of ovules. The impor-

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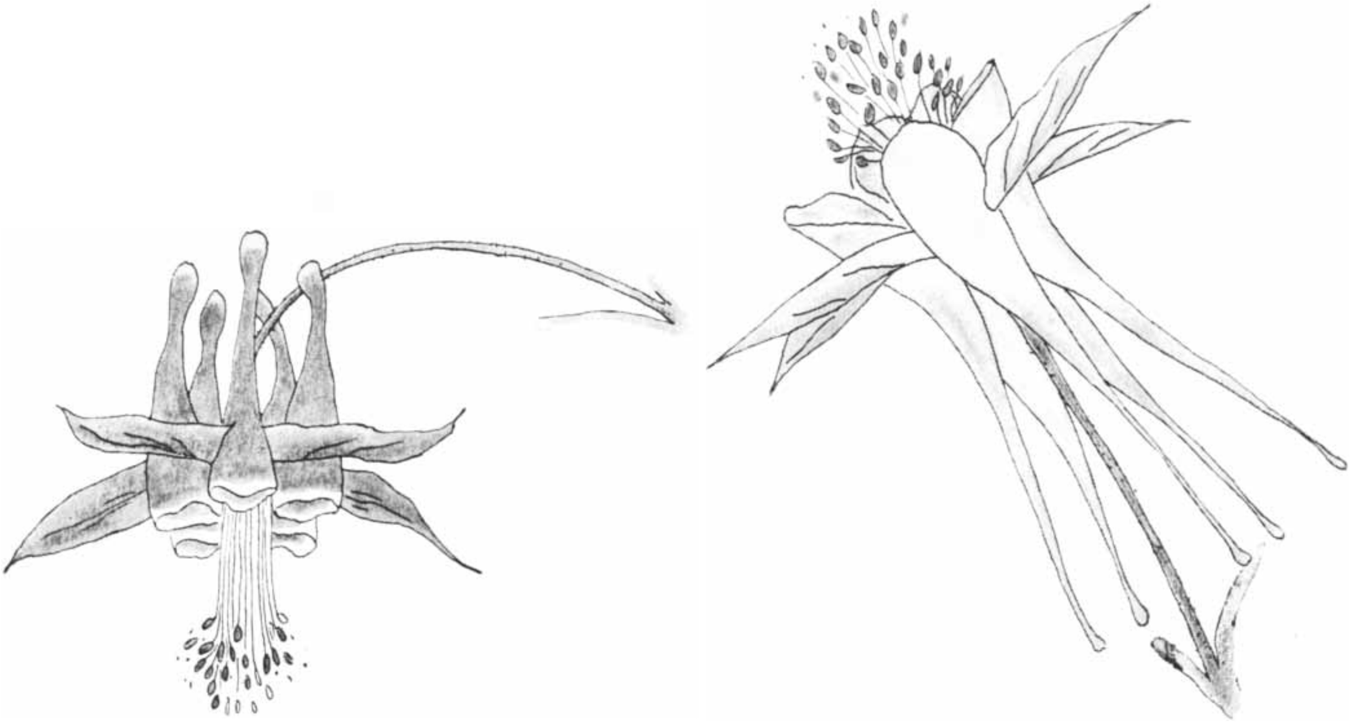

***nivalis*, pollinated by long-tongued bees. Fourth is *A. vulgaris*, pollinated by two species of long-tongued bumblebees. Fifth is *A. formosa*, pollinated by hummingbirds. Last is *A. pubescens*, pollinated by the hawk moth.**

tance of birds as pollinators is indicated by the fact that the Mexican century-plant, whose pollen is carried by hummingbirds, is barren when transplanted to Europe, where hummingbirds are absent. The flower is abundantly visited by bees, but without hummingbirds it remains sterile.

The bat flowers are pollinated by certain species of tropical bats with long, slender muzzles, extensile tongues and shortened or missing front teeth—all adaptations that enable the bats to feed on flowers. They feed at night and are probably guided to the flowers chiefly by their well-developed sense of smell. They clamber on the flower, hold on with their claws and extract nectar or small insects from the floral chamber with the tongue or chew the pollen or succulent petals. The tree-borne bat flowers of the tropics are large, frequently dirty white in color and open only at night. They attract the bats by a fermenting or fruitlike odor, which is given off at night. Examples of bat flowers are calabash, sausage tree, candle tree and some other members of the trumpet-vine family, various members of the sapodilla family and areca palm.

THE flowers pollinated by the wind need no bright colors, special odors, nectar or other attractions, and they have none. Most of them even lack petals. Instead their stamens and stigmas are exposed as freely as possible to the air currents, and they provide huge masses of light, smooth-skinned pollen that can be scattered far and wide. Pollen grains borne by the wind have been collected in air traps over the middle of the Atlantic, hundreds of miles from their source.

Because there is no special need for the stamens and carpels to be grouped together in the same flower, as in animal-pollinated plants, the sexes in the wind flowers are often separated into staminate and carpellate flowers, which are borne either in different parts of the plant or on different individual plants. The stigma is feathery, brushy or fleshy, so that the wind-carried pollen will stick to it. The pollen of a wind flower usually fertilize only one ovule in each flower, and most wind-pollinated plants have single-seeded fruits: the oak flower produces one acorn, the grass flower one grain.

Wind flowers are most common in the Arctic and Antarctic, where most insects cannot live, and also play a very important role in the cold temperate zones. Among the wind-pollinated plants are the grasses, sedges, rushes, cattail, dock, goosefoot, hemp, nettle, plantain, alder, hazel, birch, oak and poplar.

Many flowers, of course, fall into more than one category. Corn plants, for example, are pollinated primarily by wind but also sometimes by bees. Some European heaths are pollinated by bees in the spring but cease producing nectar and commit their pollen to the wind at the end of the season. Phlox flowers, normally pollinated by moths, may occasionally be fertilized by thrips. Some European species of gentian and violet are pollinated by bees in the lowlands and by butterflies in the Alps. Similar variations occur among the different species in a genus or family of plants. In short, the classes are not static. Changes in the method of pollination have occurred with considerable frequency during the history of the earth. These changes, and the nice adaptation of the flowers to their pollinators, show clearly that the pollinating agents have played the chief active role in the evolution of flowers.

THE fossil record indicates that flowers originated sometime during the middle of the Mesozoic Era, about 150 million years ago. Flowers, like mammals and birds, probably made their first humble appearance in the age of conifers, cycads, dinosaurs and beetles. Most of the seed-bearing plants of that age were probably pollinated by wind. They possessed the same kinds of reproductive structures, including separate sexes and in some instances winged pollen, that are associated with wind pollination in their modern survivors. The ovules were borne in cones or on leaves and exuded drops of sap. In the course of time beetles, feeding on the sap and resin of stems and on leaves, must have discovered that the liquid droplets from the ovules and the pollen in the male cones were nutritious foods. Some of these beetles, returning regularly to the newly found source of food, would have accidentally carried pollen to the ovules. For some Mesozoic plants this new method of pollination may have represented a more efficient method of cross-pollination than the releasing of enormous quantities of pollen into the air. Through natural selection they would develop adaptations to the potentialities of beetle pollination. The ovules, first of all, must be placed behind some protective wall to prevent their being chewed up by the beetles. One means

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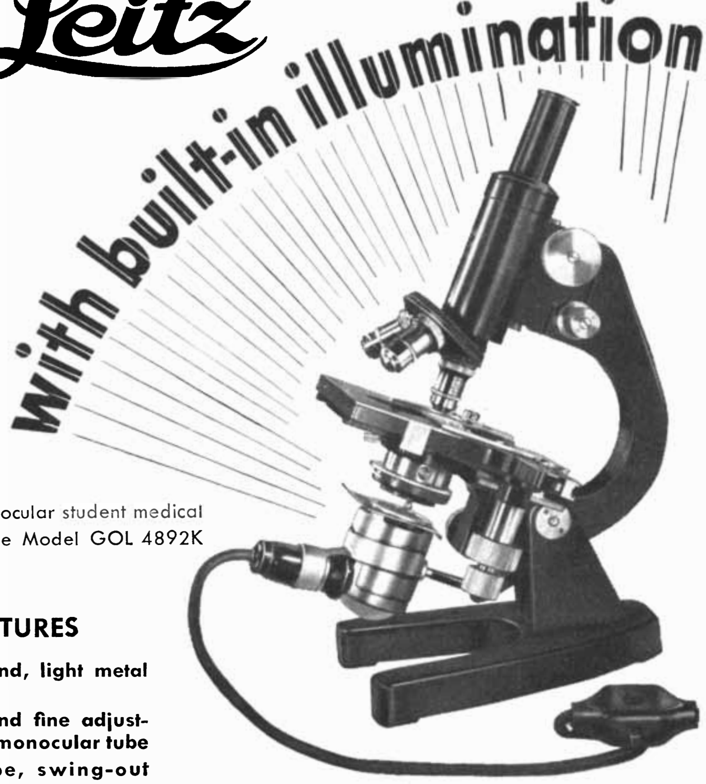

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of accomplishing this would be to fold the ovule-bearing leaf or branch into a hollow, closed carpel. The pollen-collecting function would then have to be transferred from the individual ovules to a central stigma serving all the ovules in the carpel.

The beetles could be drawn to the stigma by a special secretion of nectar which would replace the droplets previously given off by the individual ovules. A beetle visiting the stigma would be apt to leave behind sufficient pollen for the fertilization of numerous ovules. The number of seeds formed in a single pollination would no longer be one, as in the wind-pollinated ancestor, but 10 or 20. So the transition from wind to beetle pollination would increase the fertility of the plant.

The chances that the beetle would bring pollen to the stigma would be increased if the stamens were in close proximity to the carpels. The stamens and carpels might even be advantageously grouped within the same cone. The stamens would have to be present in large numbers so that they would not all be devoured by the beetles. In the course of time the outer stamens might become sterilized and pigmented and transformed into a set of showy petals. When these conditions had been fulfilled, there would have come into existence a structure possessing all the essentials of a modern flower.

This, in all likelihood, is how the evolution of flowers began. The most primitive type of flower of which we have any knowledge is a beetle flower, and it seems altogether probable that the selective factor that called flowers into being was beetle pollination. From these early flowers probably are descended most of those modern families that have separate petals and open nectar. When the insects, birds and mammals arrived on the earth at the beginning of the Tertiary Period, some 70 million years ago, the evolution of flowers was greatly broadened. In flowers pollinated by the long-tongued insects the petals became fused into a tubular corolla with a supply of nectar concealed at its base. The carpels were similarly fused into a compound ovary with a more localized and centralized stigma. The tubular structure of the corolla tended to screen out the beetles and small flies and restrict visitors to those insects—the bees, moths and long-tongued flies—that fly regularly from flower to flower of the same species. This was a great step forward in floral design: it marked a transition from promiscuous pollination by miscellaneous unspecialized insects to restricted pollination by specialized and flower-constant animals.

Verne Grant is biosystematist of the Rancho Santa Ana Botanic Garden in Anaheim, Calif.

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MOVING THE OBELISK

The Egyptians left no record of how they transported their massive stone shafts, but an engineering classic tells how the feat was accomplished by man and horse power in 1586

by Bern Dibner

THE OBELISK was one of the three forms of monument that evolved during the long history of the Egyptian state and religion, the other two being the sphinx and the pyramid. Because it was tall and attractive, and yet not too massive to be moved, the 200- to 500-ton stone was a challenge to victorious invaders and their engineers. That is why these superbly carved granite shafts, intended for some Nile necropolis or temple, can be seen today as trophies in Rome and as gifts in London, Paris and New York.

Within the last century three obelisks were moved from Egypt. One was transported from Luxor to Paris in 1836, one from Alexandria to London in 1877 and one from Alexandria to New York in 1880. The engineers who moved them had at their disposal steam engines, hydraulic jacks, steel cables and steel structural members. The engineers of the ancient world who originally cut and erected the obelisks and sometimes moved them later obviously did not have such conveniences. How they did it was modestly kept from the record. There are thousands of sculptures, bas-reliefs, gems, paintings, papyri and models of the religious, regal and domestic life of Egypt, but little of its advanced technology is recorded by them. We must reconstruct their tools and methods from the results they achieved.

In addition to accounts of the moving of the Paris, London and New York obelisks, we are fortunate to have clear records of the moving of the Vatican obelisk in 1586. Standing today in the Piazza of St. Peter's, this shaft was moved by means that must have resembled in some measure those used by the Roman engineers, if not by the Egyptians themselves.

With only the main arches and walls of St. Peter's completed and the dome still unbuilt, the College of Cardinals met in 1585 to elect a new pope. The choice was Cardinal Montalto, who ascended the pontifical throne as Sixtus V. It was his firm intention to make St. Peter's the most beautiful building in the world, and as part of this plan it was proposed to utilize the majestic old obelisk that had stood since Caesar's time behind the sacristy of the new structure. Alone among the obelisks of Rome, it had stood erect while the Circus of Nero crumbled.

Three elements combined to transform the plan into reality. The first of these was the appearance of a small book written by one Camillo Agrippa, con-

DOMENICO FONTANA was the engineer who moved the obelisk now on the Piazza of St. Peter's in Rome.

taining his proposals for transporting the giant stone. The second was the ascension of Cardinal Montalto. The third was the engineer and architect Domenico Fontana.

Agrippa's book had been in circulation for two years before Montalto had risen to the papacy. It was dedicated to the son of the previous pope, and must have excited the attention of the ambitious cardinal. One of Montalto's first official acts was the appointment of a special commission to make a recommendation for the moving of the obelisk. The commission called in engineers, architects and mathematicians. The subject excited the interest of learned men everywhere; the commission's meetings were attended by some 500 theoretical and practical construction men from all over Italy and from such remote places as Rhodes and Greece. The proposals were as varied as the men proposing them. Some wanted the obelisk moved vertically, others horizontally, and those who wanted to be different suggested moving it inclined at 45 degrees. All the prime mechanisms then known were recommended—levers, pulleys, jacks, cradles, rollers and combinations of them. The commission listened to everyone but was most impressed by Fontana. After he had demonstrated with models how the monolith could be lowered, moved and lifted by a combination of a wooden tower and ropes and pulleys, the commission appointed him engineer in charge of the project.

In addition to doing a workmanlike job, Fontana left for posterity a record which in format, type and engraving is one of the handsomest and most complete records of any engineering problem. His book, *Della Trasportatione dell' Obelisco Vaticano*, printed in Rome in 1590, is a classic of engineering literature.

Fontana's primary engineering element was a twin tower erected on both sides of the obelisk. This *castello* was designed to support the pulleys and tackle which were gently to lower the obelisk into a prone position, and later to raise it at its new location.

Fontana set April 30, 1586, as the date for the lowering of the shaft. The tower was complete, blocks were in position, capstans and ground tackle fixed in their places. The men were divided into crews, assigned to their posts and drilled in their special tasks. An air of expectancy fell upon the metropolis.

The day before the lowering was given to devotion and prayer. The workmen attended confession and were given the sacrament. Two hours before dawn of the 30th, two final masses were celebrated; by sunrise every man and horse was at his post. The great personages

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of Rome and the nobility of all Italy were present.

Fontana's first command was for the workmen to kneel in prayer with him. Then at his signal a trumpet sounded and the 900 men and 74 horses strained at their equipment. The gear groaned, ropes tightened and the great stone budged with a rumble that Fontana compared to an earthquake. Now a bell was rung and the workmen held their positions as the foremen inspected the equipment. In 12 more moves the shaft was raised more than two feet above its pedestal. A timber carriage was then moved beneath it on rollers.

The shaft was lowered on May 7. The same signals were used, but in reverse order. At the trumpet blast one set of capstans paid out rope while another took it in in such a way that the base of the obelisk was pulled to the west. As the bell sounded work stopped, the gear was examined and the ropes were tightened. By 10 o'clock that night the obelisk rested horizontally on its carriage. Fontana went home with an honor guard of drums and trumpets.

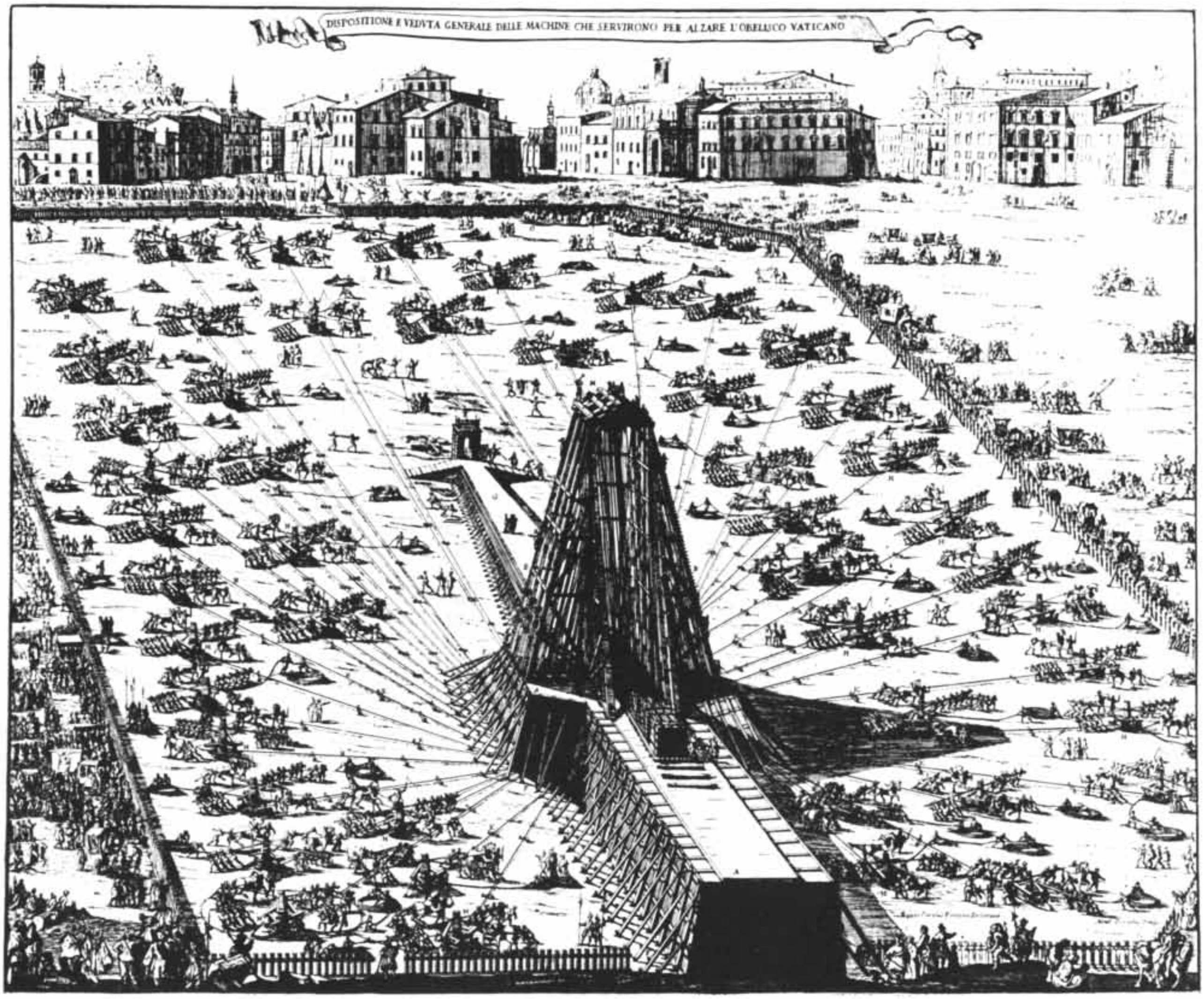
The distance between the old location of the obelisk and the new was 275 yards, over which there was a drop of some 30 feet. This was a great advantage, enabling Fontana to bridge the distance by a causeway of increasing height. Thus the obelisk would arrive at a point above its reconstructed pedestal and would not have to be raised to the corresponding height.

The procedure for resetting the obelisk was just the reverse of that for first lowering it. The wooden tower and its tackle were set up again at the new site on a broadened section of the causeway. Then the carriage bearing the obelisk was moved over the causeway on rollers.

The dawn of September 10 found every man ready for the raising. The crews were again confessed and the capstans turned. At sundown, after 52 pulls and pauses, the shaft hung vertically over its pedestal. The crowd was jubilant.

The next day, again as in the lowering stage, levers were in use to raise the shaft over the pedestal. While the obelisk was lifted, blocks and wedges were driven between its base and pedestal; the carriage was thus free to be rolled out of the way. The capstans were then tightened and bronze astragals in the form of lions were set in stress-equalizing lead at the four corners of the pedestal. The tower was dismantled and on September 28, 1586, the obelisk appeared in full view and was duly consecrated. It had taken Fontana just one year from the time of winning his commission to complete his task and to leave the obelisk standing practically as we see it today.

Bern Dibner is president of the Burndy Engineering Co.



THE OBELISK IS RAISED over its reconstructed pedestal on the Piazza. At this point the shaft lay on the causeway over which it had been moved on rollers from its original site. Standing above it is the great wooden tower from which the pulleys were suspended. The ropes from the pulleys were attached to 48 capstans.

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Calcium and Life

The 20th element is responsible not only for the structure of bones and teeth but also for the firmness of soft protoplasm

by L. V. Heilbrunn

THE protoplasm of men and whales, of bedbugs and orchids, of all living things, is composed essentially of the same sort of chemicals. Most of the chemicals are organic; that is to say, they contain carbon. If we burn any living thing, the bulk of it vanishes into thin air: the water goes off as steam and the organic materials are changed for the most part into carbon dioxide and water vapor. There is left a little ash—in the case of a human body, only enough to fill a small urn. Most of this ash comes from parts of the bones and teeth which are not really alive. The tiny remainder comes from the truly living tissues. It makes up only about one part in a hundred of the living material. And yet this ash, which consists of various types of salts, is a very important part of protoplasm, and there can be no life without it.

Living material is of course the most precious of all the materials of the world, but the stuff of which it is made is of the very cheapest. Its salts are the commonest varieties—mainly sodium chloride, or common table salt, and salts of potassium, magnesium and calcium. These are the very salts that are in sea water; the ash obtained from the burning of an animal is essentially the same as sea salt. This is only to be expected, for life began in the sea, and the first living things had to be composed of the sea water that surrounded them.

All the cells in the body—the units of life—are accustomed to being bathed in a salt solution. If they are exposed to water without salt or with too low a concentration of salt, they swell up and die rapidly. If too much salt is present, they shrink and lose their water to the fluid around them. Our blood is about one third as salty as sea water, and no matter how much water we drink, it preserves just about the same saltiness. The cells themselves also require the same salts as the body fluids.

Each of the salts the body needs has its own importance. But perhaps the most essential of all is calcium.

Without calcium the higher animals of course would have no bones or teeth. These hard parts owe their rigidity to calcium salts; if the salts are dissolved in strong acid solutions, bones lose their stiffness and become quite pliable. But beyond this calcium has other important roles in the body. In the soft tissues as well as in the bones and teeth it is a vital structural material: it is an essential ingredient in the cement that binds cells together in tissues, and it gives firmness to the membranes that enclose the cells themselves.

ITS binding property has been demonstrated very clearly in experiments on sea-urchin eggs. Like all animals, the sea urchin begins life as a single cell. After this egg cell has been fertilized, it divides into two, then into four and so on until there is a great mass of cells, all clinging together. But if a sea-urchin egg in the two-cell or four-cell stage is placed in a solution of a substance that removes calcium, the clinging cells tend to fall apart.

Proof of the fact that the firmness of a cell's membrane depends on calcium has come from studies on the amoeba. This wonderful little animal is a single large cell consisting of a droplet of protoplasm surrounded by a relatively rigid cortex. When the cortex contracts, it pushes out fingerlike projections and the animal slowly flows into these and moves forward. The contribution that calcium makes to the stiffness of the cortex can be measured by comparative tests of the cortex's viscosity before and after removal of the calcium. One test of a material's viscosity is the resistance it offers to the movement of particles through it; for example, one can test the viscosity of an oil by observing how rapidly small steel balls fall through it. In the amoeba experiment the measure of viscosity used was the movement of granular particles of protoplasm through the cortex. Ordinarily these particles cannot move in the cortex, but the test is made possible by the use of a centrifuge (*see page 42*). When amoebas are centrifuged at several thousand revolutions per minute, under conditions which give forces some thousands of times gravity, the granules in the cortex pass readily through the cells. By noting the length of time it takes for the particles in the cortex to move a given distance, one can obtain a measure of the cortex's viscosity. With centrifugal forces 5,000 times gravity it normally takes about 100 seconds for the granules to move through half of the cell. But if the calcium is chemically removed from the cortex, the granules traverse half the cell in only 10 to 20 seconds. In other words, the removal of calcium makes the cortex much less viscous, *i.e.*, much more fluid. Conversely, if the amoeba is placed in a solution especially rich in calcium, the cortex becomes much stiffer than normal; now it takes about 130 seconds for the granules to pass through half the cell.

There is a still more conclusive proof that calcium is essential for the formation of a limiting membrane or film around the cell. Ordinarily when one breaks the membrane of an amoeba or a sea-urchin egg, the outflowing protoplasm soon forms a new membrane. But if the cell is kept in a solution completely lacking in calcium, after its membrane is broken all the protoplasm flows out of the cell and scatters through the surrounding solution. No new membrane forms. This is also very well illustrated by experiments on the stentor, a lively little single-celled pond animal. When the stentor is crushed in ordinary pond water, which contains a little calcium, the emerging fluid protoplasm is immediately closed off by a new membrane. But in a laboratory solution from which calcium is excluded the protoplasm disperses completely.

THE reaction whereby a broken cell forms a new membrane in the presence of calcium is called the surface precipitation reaction. It occurs in various types of cells, and indeed it is a characteristic of living substance generally. The reaction of blood to calcium ion is very similar to that of protoplasm. When blood flows from an artery or vein, it

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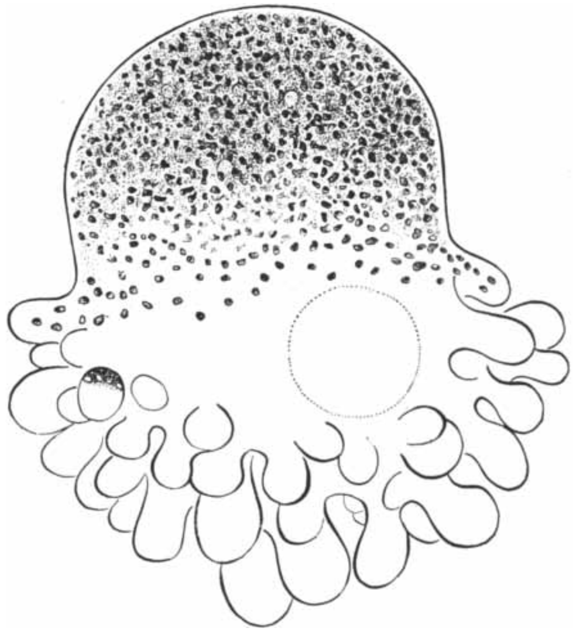
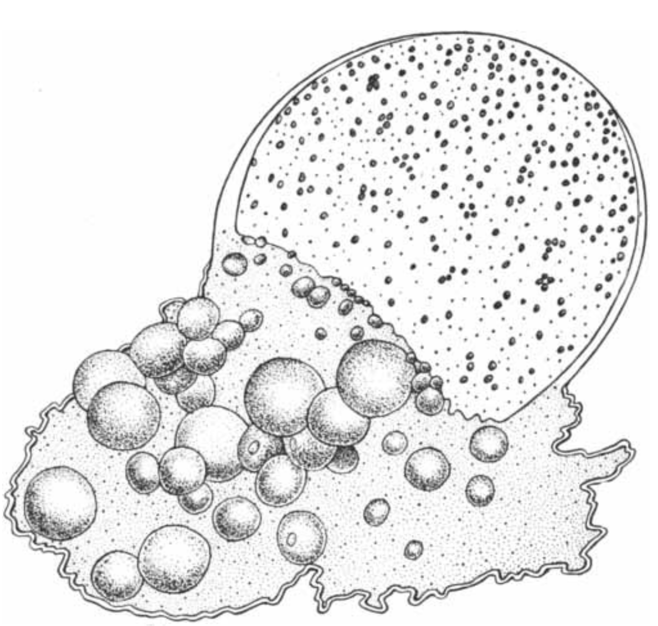


AMOEBA has been centrifuged. The rate of movement of granules through it is a measure of its viscosity.



SEA-URCHIN EGG has been broken. The protoplasm flowing out of it is quickly covered with a membrane.

clots. But this clotting does not occur if the blood flows into a solution from which calcium is absent. Blood that has been mixed with a little oxalate, which removes calcium from solutions, never does clot, unless a supply of the natural blood-clotting substance called thrombin is added.

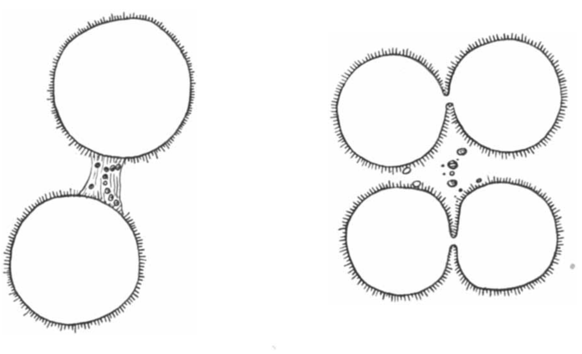
Actually the surface precipitation reaction in protoplasm is a form of clotting, and there are many similarities between blood clotting and protoplasm clotting. If a little fluid from clotted blood, which always contains thrombin, is added to a fresh sample of blood, the new blood clots even in the absence of calcium. Similarly a little injured cell material taken from a suspension of smashed or otherwise injured cells can cause a surface precipitation reaction in another suspension of cells in the complete absence of calcium. On the other hand, an overabundance of calcium can prevent clotting, both in blood and in protoplasm. Incidentally, the curdling (clotting) of milk, like that of protoplasm and blood, also is a calcium-influenced process.

The fact that the clotting of protoplasm is similar to the clotting of blood is further indicated by the fact that smashed or injured protoplasm produces substances which can clot blood as well as protoplasm itself. One of the great pioneers in the study of blood clotting, the Esthonian physiologist Alexander Schmidt, demonstrated this fact many years ago. He and his students found that living material of all sorts—muscle, brain, yeast cells, and so on—when damaged gives off substances which greatly hasten the clotting of horse blood. Furthermore, it has been found that heparin, a substance which prevents blood clotting and is widely used in the treatment of thrombosis, can also prevent the clotting of protoplasm.

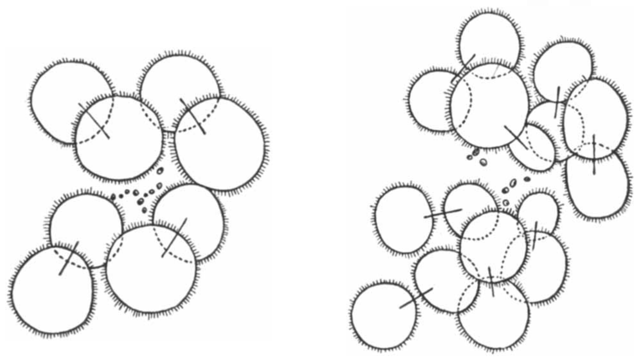
Protoplasm is strikingly similar to blood in another respect. Like blood, which contains both clotting and anti-clotting substances and is constantly on the verge of clotting, protoplasm is always in a delicate state of equilibrium between a fluid and a clotted state. Living cells are extremely sensitive to outside influences. And the transition from a fluid to a clotted state is one of the most important factors in the activity of the living material.

CONSIDER a muscle cell. A tiny electric shock will make the muscle respond by contracting. So will a sudden impact or a sudden exposure to heat or cold. What happens in a muscle cell when it is thus aroused to activity?

Until very recently no one really knew whether muscle protoplasm was fluid or solid. Nearly 100 years ago the famous German physiologist Willy Kühne saw a small worm swimming in a frog muscle fiber and suggested that the protoplasm was fluid. But others objected that a fiber with a worm in it was hardly normal. The question was argued back and forth for many years without a conclusion. Centrifuge tests were of no avail. A year or two ago the issue was



SEA-URCHIN CELLS normally stick together as they divide into two cells, four cells and so on. When the



dividing cells are placed in sea water free of calcium, however, they tend to float away from one another.

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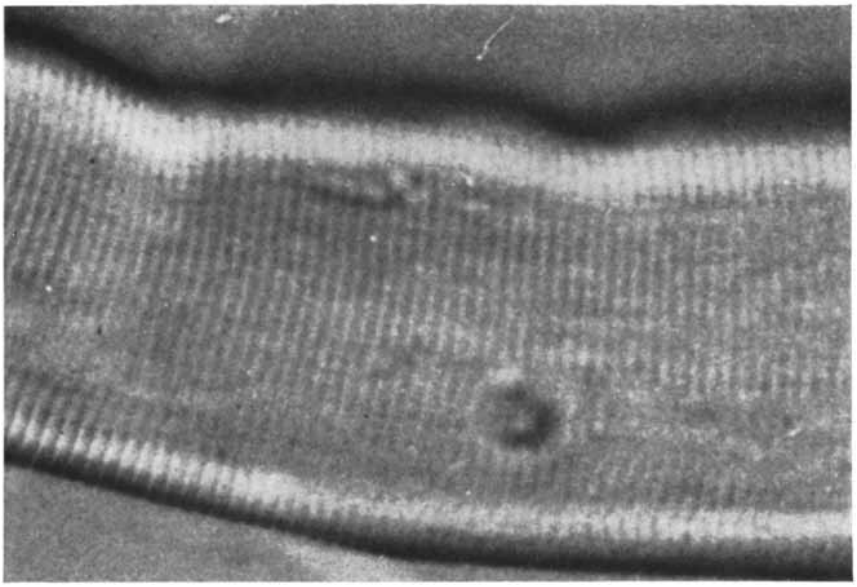
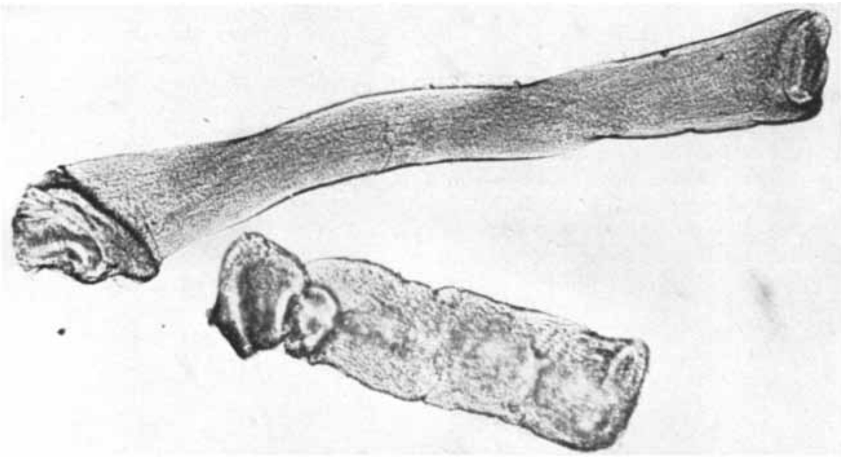
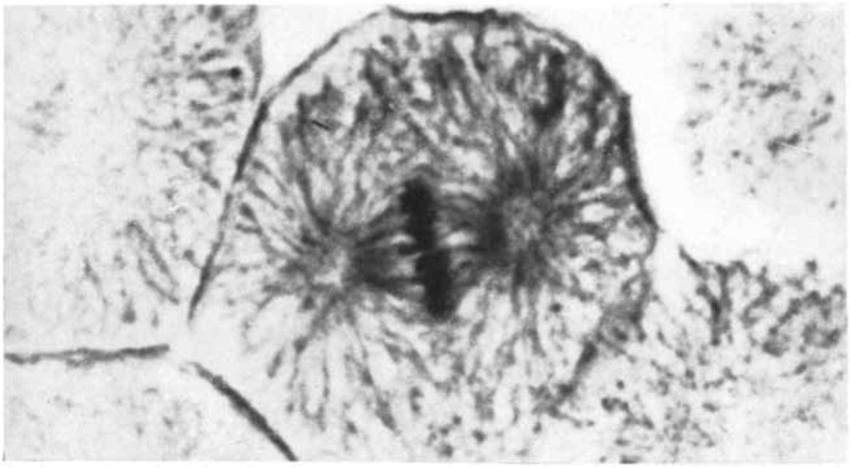


MUSCLE CELL has been injected with a droplet of oil, the rate of movement of which is a measure of the cell's viscosity. This study and this photograph were made by Peter Rieser, now of Fordham University.



MUSCLE FIBER contracts when calcium is injected into it. At the top is a relaxed fiber; at the bottom, a fiber containing calcium. This study and this photograph were made by Floyd Wiercinski of Hahnemann Medical College.



MITOTIC SPINDLE, the spindle-shaped object in the center of this photograph, appears in a cell as its chromosomes are marshaled for cell division. The formation of the spindle is encouraged by the presence of calcium.

finally resolved by a young physiologist, Peter Rieser, at the University of Pennsylvania. He inserted small oil drops into the interior of frog muscle fibers. He was able to observe in a number of instances, when the injection did not damage the muscle, that the oil drop rose toward the top of the cell. It rose because it was lighter than the cell material. From the rate of this movement he was able to calculate the exact viscosity of the protoplasm. As a result of this work, we now know that the interior protoplasm in muscle is fluid and that there is a rather thick cortex through which no oil can move. A muscle cell has the same essential physical structure as the cell of an amoeba or a sea-urchin egg: it is composed of fluid protoplasm surrounded by a stiff cortex.

When the interior protoplasm of a muscle fiber clots, the fiber as a whole shortens. What induces the clot, and why does an electric shock or sudden exposure to heat or cold make the muscle shorten? The answer is relatively simple. Muscle protoplasm, like the protoplasm of cells in general, is extremely sensitive to calcium ion. When a muscle fiber is cut, the cut surface immediately produces a plug, very like the new membrane that forms at the surface of an exuding droplet of protoplasm as it emerges from an amoeba, a stentor or a sea-urchin egg. The more calcium is present in the surrounding fluid, the more rapidly the plug forms. As the calcium enters the cut surface of the muscle fiber, the fiber shortens.

The sensitivity of muscle protoplasm to calcium can also be shown by the injection of small amounts of calcium directly into the interior of a muscle fiber. This is done with an injection needle of very fine bore. The injection of a very dilute solution of calcium salt makes the muscle contract.

We are thus in a position to explain the sensitivity of the muscle to the agents that cause it to contract. When an electric current is sent through a muscle, the muscle contracts at the point where the current emerges, that is to say, at the cathode. Now it is to the cathode that the calcium of a calcium salt migrates. Moreover, we know from the work of Virginia Weimar in our laboratory that heat and cold release calcium from its bond with muscle protein. The outer cortex of an amoeba consists of protein bound with calcium, and almost certainly the cortex of a muscle fiber has the same constitution. Various agents cause the release of calcium from its binding with the protein of the cortex. The agents that arouse the muscle fiber cause calcium to enter the cell. Clotting and shortening then result.

Various other types of cells are affected in the same way. There is some evidence, for example, that the protoplasm of a nerve fiber, like that of a muscle fiber, clots when the fiber is aroused. This is not, of course, the only

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change that occurs, but it may well be the most significant one.

CALCIUM is also important for the division of cells. The mechanism of cell division is a particularly important problem because it has a bearing on cancer. Cancer is essentially due to the initiation of division in cells that do not ordinarily divide. The simplest cells in which to investigate the division process are marine egg cells such as sea-urchin eggs. These eggs can be induced to divide by various artificial means, such as strong salt solutions, heat, ultraviolet radiation, acids. All of these agents can be considered to cause a release of calcium from the cortex of the cell. The calcium that is released enters the cell and causes a clotting there. The clot results in the formation of a beautiful spindle-shaped structure—the mitotic spindle. In frog eggs, the formation of the mitotic spindle and cell division can best be induced by the injection into the egg cell of a trace of thrombin, the substance that induces clotting in blood. Similarly, substances extracted from injured cells can cause the appearance of a mitotic spindle in sea-urchin eggs.

Thus the clotting that precedes the appearance of the mitotic spindle (a process I have called mitotic gelation) can be induced either by calcium or by thrombin or thrombin-like substances. And the anticlotting substance heparin can prevent this mitotic gelation and the division of the cell. There are a large number of heparin-like substances, many of them produced by bacteria. At least one of these, a bacterial polysaccharide isolated by M. J. Shear and his associates at the National Institutes of Health, has quite a favorable effect in causing regression of tumors in rats and mice. Unfortunately it is too toxic to use properly on human patients, but there is always a hope that some other naturally occurring polysaccharide may prove more successful for cancer therapy.

Calcium plays many other roles, of course, in the vital process. For example, there is increasing evidence, notably from the work of Albert I. Lansing at Washington University in St. Louis, that the aging of cells and the aging of men and animals is due to accumulation of calcium in cells in an insoluble form. Calcium is known to be important in a great variety of ailments, from acne to hardening of the arteries. We have confined our attention here to the relation of calcium to the physical properties of protoplasm. The major conclusion from our work is that calcium is not only important for the rigidity of animals and cells; it is the prime instigator of vital activity.

L. V. Heilbrunn is professor of zoology at the University of Pennsylvania.

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Animal Intelligence

Philosophers and pet lovers have debated the subject for centuries; now psychologists have developed some objective tests to rate the capacity of various species

by Carl J. Warden

MAN has never doubted that he is the most intelligent member of the animal kingdom, but he has been in some dispute as to how to rate the relative intelligence of his subhuman inferiors. Many great thinkers have been interested in the question of whether animals reason and how much intelligence they possess. The first to deal systematically with the subject was Aristotle. In his *Historia Animalium* he contended that the dog, the elephant and some of the other higher mammals approached the mental level of the human child. At the other extreme, Descartes argued that even the highest forms below man are only rather complex living mechanisms with little or no real intelligence. Opinion has fluctuated between these poles: in modern times Charles Darwin and his followers have tended to agree with the anthropomorphic view of Aristotle, while the physiologist Jacques Loeb and his disciples supported the mechanistic interpretation of Descartes.

Darwin, who sought to support the doctrine of evolutionary continuity by showing that the animals akin to man possess the rudiments of human intelligence, based his case largely on stories of unusual mental exploits by the higher animals. At the end of the 19th century comparative psychologists rejected this anthropomorphic, anecdotal approach and began to study the question by objective experimental methods.

Intelligence may be defined as the capacity of an organism to learn to adjust successfully to novel and difficult situations. It involves the ability to solve new problems by drawing on past experience. Those who consider that animals below man are mere mechanisms place great emphasis on a supposed distinction in methods of learning, as between human beings and animals (the word animals will be used here to mean the nonhuman ones). In animals learning is mainly by trial and error. When a cat, for example, is confined in a latched box that acts as an obstacle preventing it from reaching food outside the box, it tries all sorts of measures to solve the problem. It claws at various parts of the box, attempts to shake the box to pieces, tries to push the door open, and so on. After many such fumbling trials, it eventually learns to throw the latch and open the door without fumbling. Man, on the other hand, can solve such simple problems almost immediately, with a minimum of trial and error. This "insight learning" is commonly supposed to show a qualitative difference between men and animals, but actually some of the higher animals are capable of it. Moreover, man often uses the trial-and-error method, particularly in forming new motor habits such as typing or playing golf and in solving mechanical puzzles. Hence it would seem that the true measure of intelligence is the capacity to learn, regardless of the method involved.

WE must distinguish, however, between adjustments that are learned and those that occur naturally without involving learning. The latter include responses of the simple reflex type and the more complex activities commonly called instincts. Reflexes, which are set off automatically by appropriate environmental stimuli, do not involve the brain; hence they are clearly below the level of intelligent behavior. Similarly such basic instinctive behavior as reproduction, nest-building, protection and food-searching also comes into play without learning. At the proper time the animal simply does "what comes naturally." Take the nest-building instinct, for example. In early spring, when an outpouring of sex hormones into the bloodstream gives birds a strong sex drive, they pair off, pick out a well-protected place for the nest and begin to build it. They construct it on a plan that is peculiar to their own species, selecting certain materials and rejecting others. When the nest is finished, it turns out to be just the proper type for the given species of bird. To the layman it looks like an intelligent job from first to last. But birds hatched in an incubator and never allowed to see their parents build a nest will instinctively build one of their own species type when they grow up.

Aristotle, observing that some spiders spin very complex and beautiful webs, ascribed this ability to intelligent designing, like that of a human weaver. He failed to see that each species of spider is able to spin only a certain type of web. The reason why instincts appear to involve intelligence is that they are highly adaptive; evolution has provided each species with certain urges nicely designed to help it survive. Instincts are wonderful devices that enable the animal to carry on the main business of life without the bother of having to learn and think.

The general intelligence level of an animal depends in the first instance on the complexity of its body organization and the relative size and specialization of its brain. The more specialized its sense organs, nervous system and appendages, the greater is its sensitivity to stimuli and the better it is able to integrate its activities and manipulate its environment. The single-celled amoeba has a very limited set of natural responses and can learn only simple acts. After a number of trials it can learn to turn directly away from an annoying beam of strong light thrown across its path. The common angleworm, much more complex in structure and response system, can learn a T-maze rather readily. Still more complex organisms, such as the ant and other insects, are able to learn complex mazes with a dozen or more blind alleys or culs-de-sac. A rough, convenient measure of intelligence among vertebrate animals is the ratio of the weight of the brain to that of the spinal cord, the basic reflex center. In fishes the brain weighs less than the cord; in the cat it weighs four times as much as the cord; in the monkey the ratio is eight to one, and in man, 50 to one. This increase in brain weight is accompanied by a corresponding increase in specialization of the brain and its functions.

From these purely biological facts we

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can say that the mammals, the animals that suckle their young, rank highest in intelligence, and among the higher mammals the ranking is: 1) the primates, including the monkeys and the great apes; 2) the carnivores, which include the dog, cat, fox, raccoon, lion, tiger and bear; 3) the ungulates, or grazing animals, among which are the elephant, horse, pig, cow, deer, zebra and the like.

LET us now see what laboratory tests show as to the relative intelligence of various animal species. Serious experimental work, which began about 60 years ago, has been limited largely to birds and mammals. The general plan of all such experiments is to set before the animal some task that seems suitable to the species to be tested. The drive to work at the problem is aroused by a period of fasting, and the animal is given a morsel of choice food after each trial. Several trials per day are usually given, and the series of trials is continued until the animal either fails or solves the problem. Such an experiment may run for only a few days or for weeks, depending on the difficulty of the task and the degree of progress shown.

In tests to compare the intelligence of different species we begin with a simple problem, and when this has been mastered we increase the complexity of the task by gradual stages up to the point where the problem is too difficult for the animal to master. As the tests progress, the less intelligent species drop out. The stage each species reaches before failing marks the "limit score" for that species.

One test used in the Columbia University laboratory is known as the multiple-plate problem box. The apparatus consists essentially of a large mesh cage with a small cage for food in the center and three plates in the floor. In the first stage of the test the animal is required to learn to step on one plate, located at the right of the entrance compartment in the large cage, to open the food cage and get its reward. When this act has been well learned, the animal is submitted to the second stage: it must step on two plates to open the food cage. The experimenter adds one plate at a time to the test. He trains the animal to step on the plates in a given order, reversing its direction after each three-plate sequence until it reaches its learning limit. Hundreds of trials are given at the failure point to make sure that the animal cannot master it.

The limit score for the guinea pig is one plate; for the white rat, two plates; for the cat, seven plates; and some monkeys were able to learn to step on 22 plates in the given order. A human child old enough to count presumably could go on indefinitely on such a test.

Then there is a delayed-response test. With the animal watching, the experi-

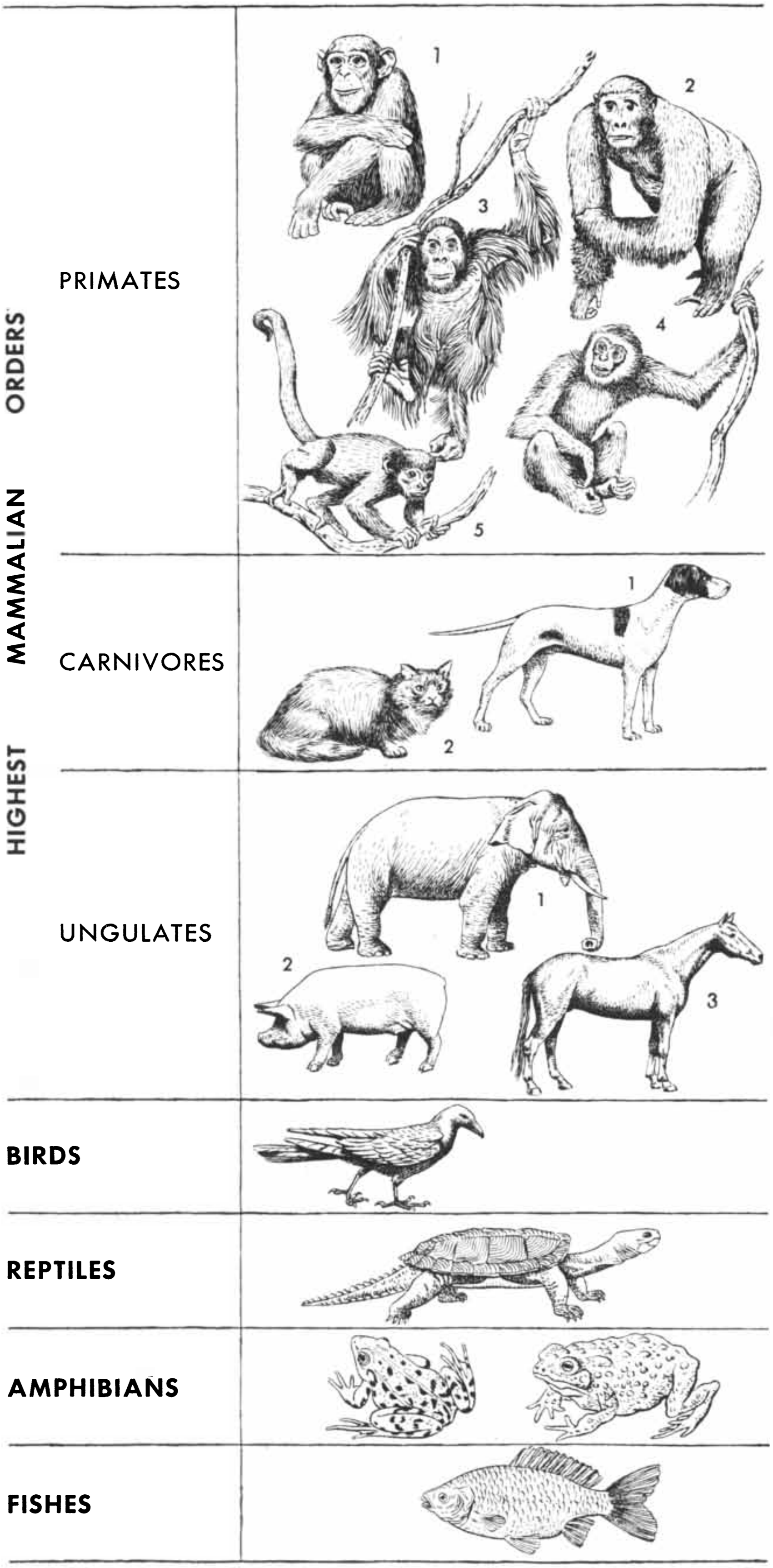

CHART compares intelligence of animals and groups of them. Primates rank: (1) chimpanzee, (2) gorilla, (3) orangutan, (4) gibbon, (5) monkey; carnivores: (1) dog, (2) cat; ungulates: (1) elephant, (2) pig, (3) horse.

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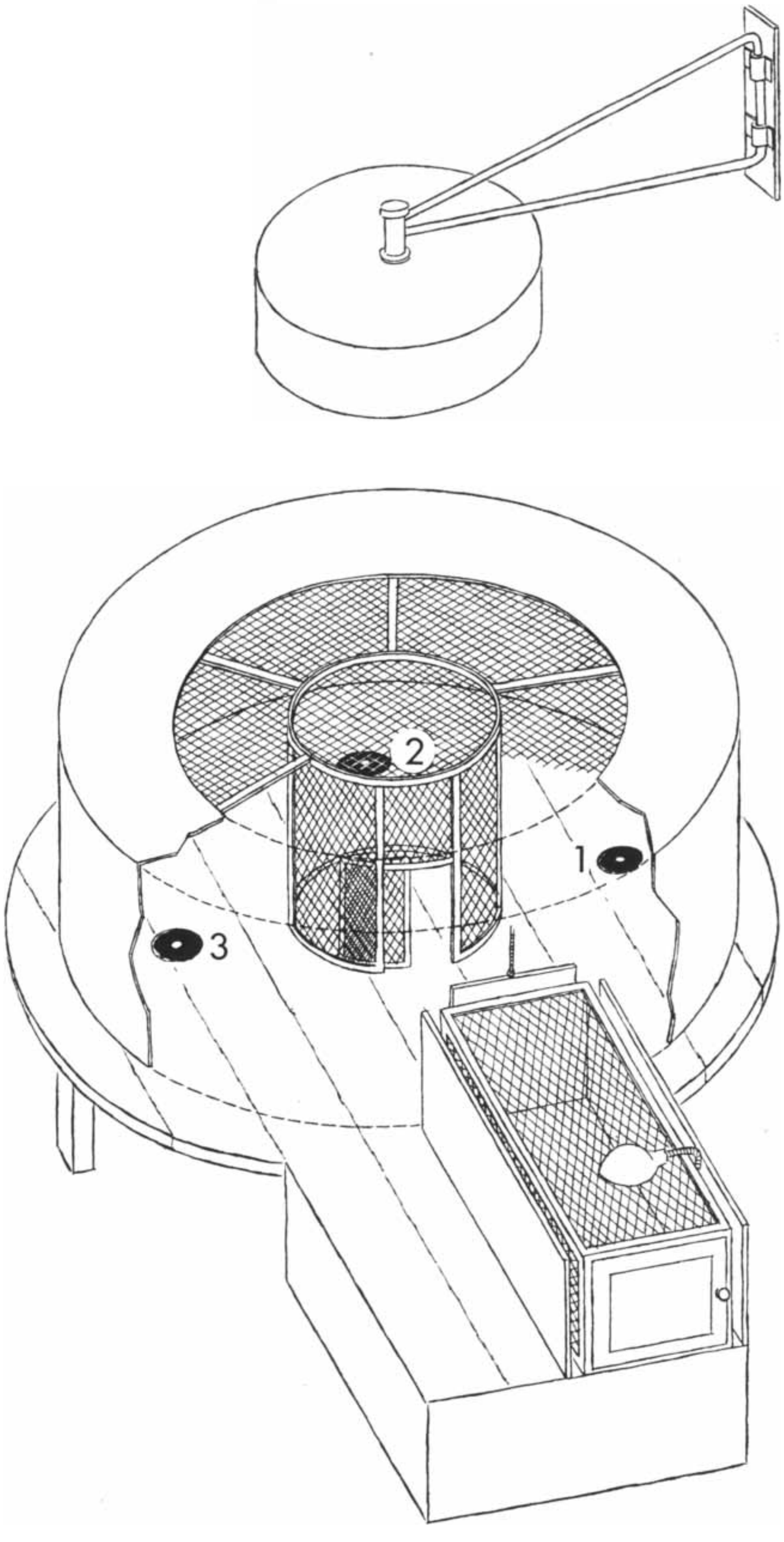

PROBLEM BOX is essentially an apparatus which opens the door of the small cylindrical cage in the center when the switches 1, 2 and 3 are pressed in a given order by the hand, foot, nose or beak of an animal. Before the animal is tested, it is placed in the cage at lower right, the door of which is opened by hand. Part of the screen about the cage has been cut away to show its interior. Above the cage is a light that is lowered during a test.

menter places some food in one of three cans that look exactly alike. The animal is then taken from the room and after a period of delay is brought in again to see if it can identify the can with the food in it. The animal fails the test unless it goes directly to the baited can without trying any of the others. This is a memory test in which the cue is the serial position of the baited can: was it the left one, the right one or the middle one? The scoring criterion is how long the animal can remember the correct can. The experimenter begins with short delays and increases these gradually until the animal reaches the limit of its memory span. Cats can identify the baited can after a delay of 16 hours. Monkeys can remember readily for at least 20 hours (their maximum span was not determined), and chimpanzees for 48 hours or more.

A THIRD experiment is called the quadruple-choice test. This is perhaps more a test of stupidity than of intelligence. The animal is presented with four boxes, each of which has an open front door and a closed back door. All four boxes look alike as they are approached, but in three the back doors are locked from behind, while in the fourth the back door can be pushed open so the animal can obtain food behind it. The animal can try all four doors. The experimenter flips a coin to determine which door is to be left open on each trial, but he arranges that it shall always be one that was not open on the preceding trial. In other words, the same door is never left open twice in succession. It is obvious that under these conditions the animal cannot select the proper door except by chance. The problem is insoluble, since the correct door may be any one of the three that was locked on the previous trial. The aim of the test is to see the degree of stupidity or intelligence that the animal will exhibit in attacking the problem. The stupidest type of behavior would be always to go to the door that was correct on the previous trial and ignore the other three doors. Such a stereotyped error would mean failure on every trial. The most intelligent course would be to avoid every time the door that had been open on the preceding trial and to try only the other three doors: this would be as near a solution of the problem as could be worked out.

This test has been given to a number of mammalian species, including human beings, who were asked to press a key instead of going through a door. The stupidest performers are the rodents—mouse, rat, gopher. They almost invariably attack only the door that was open on the preceding trial. Other animals, going up the scale of intelligence, show an increasing percentage of flexible and variable kinds of response. They tend to try all the boxes, either in random order or according to a set system, such as

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from right to left or left to right. Such flexibility of behavior in adjusting to a new and difficult situation is one of the marks of high intelligence.

On this test the species studied ranked in intelligence as follows, from low to high: gopher, mouse and rat, horse, cat, dog and monkey. None of the animals succeeded in discovering the most intelligent possible response, namely never to try the door that was open on the previous trial. Nor did very young children, even after a long series of trials. But normal children eight years of age or older were able to draw this inference.

In general the results on these tests bear out the evolutionary and biological findings; that is, the carnivores rate higher in intelligence than the grazing animals, and the primates far ahead of the carnivores.

WHAT are the 10 most intelligent animal species? According to the best evidence now at hand, the chimpanzee stands at the top, and the next nine are all certainly primates. The gorilla, orangutan and gibbon come right after the chimpanzee. These great apes are, of course, man's next of kin. Then there are at least six species of monkeys that rate higher than any of the carnivores.

Monkeys and apes have a very complex body organization and a superior brain and nervous system, similar in most respects to that of man. They also rank much higher than other animals in manual skills. They can use sticks to draw food beyond arm's reach into the cage, and they even learn to use a short stick to draw in a series of longer sticks until they get one long enough to reach the food. The exceptionally clever "chimps" can manipulate well enough to stack as many as five boxes under a banana hung from the ceiling, climb on top of the boxes and snatch the lure from this position. They readily learn to ride tricycles and kiddy-cars and to pull small sleds and wagons with children in them. They can be trained to manipulate a toothbrush, hairbrush, spoon and cup, faucets and ordinary toilet facilities. They can also smoke cigars and cigarettes in human fashion. A chimp can learn to operate a set of simple latches merely by seeing another do the act—this capacity to learn by mere observation has not been found in any sub-primate animal. Chimpanzees learn to accept poker chips in lieu of food as reward during an experiment, and they will cash in the chips for food by dropping them into a slot machine or "chipomat." When they have eaten their fill, they will drop in a special chip which yields a "jackpot" of chips and then store these in their living quarters for later use. A pair of chimpanzees will cooperate in trying to pull a heavy food box into their cage. The chimp has a good sense of rhythm and can readily learn to beat a bass drum

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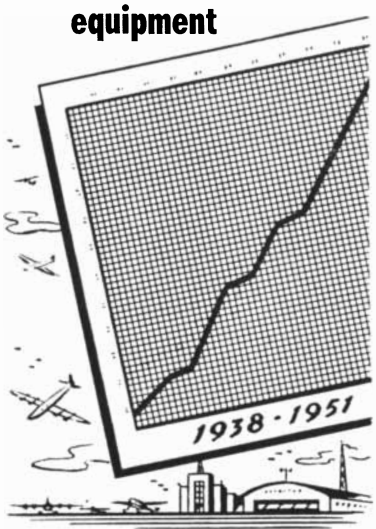

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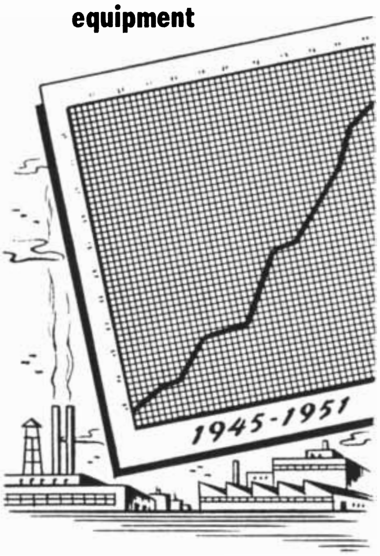

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in time to simple jazz music. Chimpanzees are probably the only animals that have even a crude sense of humor. Some of them learn to play practical jokes of the "hotfoot" type on human beings. There is a known case of a "spitter" chimp that would lure zoo visitors close to his cage and then shower them with saliva, and of another that liked to sling handfuls of muck at bystanders. These animals would then caper about the cage in high and noisy glee. The capacity for humor represents, in my opinion, the apex of intelligence in an evolutionary sense.

THE intelligence of carnivores has been studied mainly in the dog and cat; for obvious reasons little work has been done on such wild types as the lion, tiger, bear, leopard or fox. Probably none of the wild types would rate higher in intelligence than the domestic dog and cat. The truth seems to be that wildness makes for stronger instincts, arising out of competition in nature, rather than for higher intelligence. On the tests here described the dog and cat rate next to the monkeys. In the quadruple-choice test dogs scored higher than cats. This agrees with other evidence that the dog outranks the cat somewhat in intelligence level. For one thing, the dog is willing and cooperative, whereas the cat tends to be shy and aloof. The dog also takes a greater interest in objects and people—a trait which, along with docility, is one of the marks of high intelligence.

Dogs can be taught to perform many acts on the command of the master. Some years ago I tested the famous German Shepherd named Fellow, which has the best record to date on this type of performance. His master had trained the dog to associate objects and acts with the names we give them in human language. Fellow could carry out nearly 100 acts at a verbal command, such as "Go out to the elevator and wait for me," "Go put your feet on the radiator," and the like. He could also select one named object among three placed before him, even when the person giving the order was hidden behind a screen to eliminate the possibility of giving the dog gestural cues. After I had worked with Fellow for a while, he learned to recognize me by name and would pick me out of a large audience and come to me on command of his master. Of course, dogs live in a world in which human language plays an important role, but the ability to learn as many associations as Fellow did seems remarkable indeed.

The dog can be trained to great expertness in specific situations. The "Seeing Eye" dog, after a long and rigorous training, can be trusted to lead a blind man through heavy city traffic. It learns to stop the blind man from blundering into an obstruction, even when the latter is so high that the dog itself can pass under it without harm. As everyone knows, thousands of dogs performed skillful services in the last war. They were trained to protect soldiers and military supplies, tackle enemies, carry messages and do various other jobs.

AMONG the grazing animals the horse, probably in part because of its grace and beauty, is commonly thought to be the most intelligent. Actually the evidence at hand seems to indicate that the horse ranks below the elephant and the pig. I believe the elephant belongs at the top of this list, and I doubt that any comparative psychologist would disagree with this rating. Although the elephant has not been tested in the laboratory because of its size, we know that it is a docile and skillful beast of burden throughout the Orient, that it can be trained to do fairly complex circus tricks and that it has a proverbially long memory for friends and enemies. In comparing the pig and the horse we are on less sure ground. On one complicated test of intelligence level the pig stands relatively high. On the quadruple-choice test the horse, the only grazing animal tested, scored well below dogs and cats. On the whole, however, I think we must wait for further experimental evidence before assigning comparative ratings to the horse and the pig. I suppose the fact that the pig stands high at all will come as a surprise to most people. Perhaps we have thought of the pig too much in terms of ham and bacon!

It is clear that we can rank animals on the intelligence scale only by rough general levels. The evolution of intelligence did not proceed in a straight continuous line, from the stupidest to the smartest animals. Each species developed its own type of intelligence, within the limits of its specific instinctive equipment and in response to the more or less specific demands of its environment.

THE human level of intelligence is far higher than that of the anthropoids from which man evolved in the distant past or that of his present next-of-kin, the great apes. Man evolved a larger and more elaborate brain, the ability to walk upright and the capacity for superior manual skills. Furthermore, he also acquired the ability to develop culture and to transmit it from one generation to another by means of language symbols. The culture process was slow in starting, but once under way it operated at an increasingly rapid pace, without the need for further biological evolution. Man is the only animal that evolved the capacity and mechanism of culture. It is this fact more than anything else that sets him apart from all the other animals.

Carl J. Warden is director of the Animal Laboratory at Columbia University.

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What GENERAL ELECTRIC People Are Saying

L. K. BUSTAD

Nucleonics Department

ATOMIC BOMBING: In the planning for eventual damage in case of atomic bombing, one must realize the difficult and numerous problems. But one must realize they are not insurmountable.

In the bombing of a large city in the United States there is a good possibility of 120,000 casualties, of which 60,000 will probably be deaths. Approximately two-thirds of all these deaths will occur the first day. The other third will occur later, probably the number being halved every week.

Approximately 80 to 85 per cent of the casualties will result from burns or mechanical injuries, if the bomb is of the type used at Hiroshima and if the city is something of the type of Hiroshima. Burned cases will predominate the first week, but mechanical injury may predominate the first day. Probably about the end of the first day 50,000 people would need to be hospitalized, although a great many of the hospitals will be destroyed.

The need must also be realized for a mass of material, especially medicines, which must be stored to adequately take care of such eventualities. The need for plasma alone would be tremendous. For burn cases alone probably about 80,000 pints per week would be needed the first three weeks. Probably after that, to treat these cases would required up to 300,000 pints. One must realize that food, clothing, and water must also be supplied, together with drugs and bandages.

Emphasis must be made of the fact that the evacuation personnel and the medical doctors may also be stricken. The need then arises for adequately trained personnel who may administer some of these drugs.

It is recommended in disaster relief that definite locations be established outside the city limits, at the edge of them, or further away, where supplies of all types will be stored—not at one location but at numerous locations. They will coincide with locations also utilized for evacuation centers and for locations where personnel will meet for instruction.

Persons should be immediately given duties to perform in case of emergency, so that one person may know just the exact location of reporting and the exact location of the route of evacuation. Training for this type of personnel must then be inaugurated and mock attacks used for training. . . .

Panic must be avoided. An informed and working public is the best guarantee against panic. Everyone must be educated and informed of what is expected of them and made to feel important—because they are important.

Pasco, Washington
March 7, 1951

★

R. L. WANAMAKER

Apparatus Department

ELECTRONIC NAVIGATION: Although electronic tubes have been used in the past in ship steering systems, Navy specifications today forbid the use of any tubes in such equipment. Here the component parts must be placed on board ship and operated almost continuously for several years without attention or servicing or any failures. This cannot be done with electronic tubes in their present form. As a result, the navigation control engineer has been forced to relinquish electronic tubes . . . with a resulting loss of flexibility and increase in weight and space requirements.

What we need is a totally new concept of tube . . . It must be made as rugged and as long-lived as a heavy duty induction motor or power transformer. It must be unaffected by severe shock or vibration. Its life must be long—not 1000 hours or even 10,000 hours, but for all practical purposes indefinite.

Institute of Radio Engineers
Pittsfield, Massachusetts
October 19, 1950

J. C. FISHER
J. H. HOLLOMON

Research Laboratory

CANCER CELLS: It is suggested that a single cancer cell surrounded by normal tissues cannot initiate malignant growth, and that tumors appear at locations where for one reason or another a critical number of cancer cells are bunched together. The idea behind the critical-size concept is that individual cancer cells in normal tissue are bathed in normal chemistry, whereas a cancer cell surrounded by others of its kind is bathed in abnormal chemistry where malignant growth no longer is inhibited.

National Academy of Sciences
Schenectady, New York
October 10, 1950

★

B. R. PRENTICE

Nucleonics Department

ATOMIC REACTORS: A recent A.E.C. paper states the average cost of presently planned experimental reactors as something over $10,000 per equivalent electrical kilowatt output. Not exactly cheap! But that does not discourage me. Fifty years ago the theory of the gas turbine was known, just as the theory of the reactor is today. But suppose building a power-producing gas turbine at that time had been a command performance, like the development of the atomic bomb. I imagine the buckets and combustion chambers might have been made of platinum. What do you think the cost per kilowatt of such a unit would have been at that time? And that's about where we are today in the atomic power field.

Southeastern Electric Exchange
Atlanta, Georgia
October 28, 1950

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BOOKS

A fine popularization of the subject of lightning by one of its students

by James R. Newman

THE FLIGHT OF THUNDERBOLTS, by B. F. J. Schonland. Oxford University Press ($3.00).

LIGHTNING inspires in us a kind of negative respect. It is magnificent, terrible and erratic; it is the classical portent of evil deeds or great events, the favorite retributive instrument of jealous and capricious gods; from the earliest times it has entered strongly into religion and folklore. The Norsemen, as we learn from this excellent book, ascribed thunderbolts to their red-headed god Thor; the Bantu tribes of South Africa to the thunderbird Umpundulo; the Egyptians to the god Typhon; the Chinese and other Asiatics to Buddha. (It was presumably one of his sidelines.) The Romans had a College of Augurs whose members were experts on lightning. An augur "always looked south while carrying out his duties, and if a lightning flash was seen to pass from left to right it indicated a favorable omen for State affairs." If he thought the omen unfavorable, he might direct that public meetings be postponed or the results of elections canceled. In time the augurs thus came to exercise a powerful veto over political action, somewhat like the House Rules Committee.

Schonland recounts a few of the more celebrated examples of damage caused by lightning. The campanile of St. Mark's in Venice was struck a dozen times and on several occasions reduced to ashes; the Old St. Paul's in London that preceded Christopher Wren's cathedral was twice heavily damaged; other famous church steeples had similar unfortunate histories. The widespread practice of praying and tolling the church bells when a storm was approaching produced only one measurable result: many of the ringers were electrocuted while pulling the ropes. As civilization advanced churches came to be used as arsenals for gunpowder and artillery, and the combination of steeple and powder magazine had disastrous consequences. A flash which in 1769 set off the vaults under the church of St. Nazaire in Brescia caused the destruction of a sixth of the city and the death of 3,000 persons; in 1856 an explosion following a lightning-hit on the church of St. Jean on the island of Rhodes killed at least 4,000. The mast of a ship is of course an ideal lightning target, and for centuries vessels were damaged or destroyed by thunderbolts. In a single 15-year period (1799-1815) no fewer than 150 ships of the British Navy were struck, and many of them were badly disabled or entirely consumed by fire.

The lightning rod, the pleasingly simple device for controlling this force of nature, was the brain child of the inventor of the harmonica and founder of *The Saturday Evening Post,* to cite some of his trivial accomplishments. I refer of course to the inestimable Benjamin Franklin. In 1750, while discharging duties that would have taxed 10 ordinary men, he found time to conduct experiments on his frictional electric machine; these led him to the conclusion that the short sparks generated by it closely resembled lightning discharges. More important, he arrived at the opinion that "the electric fluid is attracted by points." It remained to find out "whether this property is in lightning." If so, "upright rods of iron, made sharp as a needle," fixed to the highest part of a house or ship and properly grounded, would "probably draw the electrical fire silently out of a cloud before it came nigh enough to strike and thereby secure us from that most sudden and terrible mischief." Unfortunately the experiment he proposed to test the nature of lightning could not, for lack of a high steeple, be carried out in Philadelphia, but it was successfully performed in France in 1752 and fully confirmed his theory. A month later, without knowing that this had been done, Franklin sent up his famous kite. He described the event to the chemist Joseph Priestley, who wrote: "Struck with this promising appearance, he immediately presented his knuckle to the key [hung on the kite string] and, let the reader judge of the exquisite pleasure he must have felt at that moment, the discovery was complete. He perceived a very evident electric spark. . . ." The pleasure was not always exquisite; on one occasion Franklin almost electrocuted himself. Other beautifully planned and executed experiments led to the conclusion that "clouds of a thundergust are most commonly in a negative state of electricity"—a statement substantially confirmed by "modern discussion and elaborate experiment."

In 1753 the suggestion Franklin had made three years earlier bore fruit: the first lightning rod was installed in Philadelphia. The "Franklin rod" soon became a familiar sight throughout the American colonies and within two or three decades found wide adoption in Europe. A controversy developed almost at once over the merits of "knobs" versus "points." This spread even into politics, being most vehemently debated among disputants who knew least about the subject. When the powder magazine at Purfleet, which was equipped with pointed conductors, was struck and slightly damaged, George III had the points removed from both Purfleet and his palace at St. James. He also attempted to have the Royal Society rescind resolutions it had adopted favoring the use of points. Since Franklin was an outstanding patriot of the insurgent American colonists, those who favored pointed rods were identified with the rebels. In time the wrangle subsided without a clear-cut victory for either side. The fact is that blunt conductors are perfectly satisfactory; on the other hand the contention that a pointed lightning rod is dangerous because it attracts lightning is the exact reverse of the truth. It is by this very influence, as Schonland shows, that the rod affords the desired protection within a certain radius.

It has been estimated that there are about 16 million thunderstorms a year, an average of 44,000 a day. Further arithmetic discloses that about 100 lightning flashes are emitted by these storms every second. Thus lightning is not a rare phenomenon, but it is difficult to record for scientific purposes. Ingenious optical devices such as the rotating camera invented by Sir C. V. Boys, in the hands of men of great patience and skill, have finally made it possible to trap the thunderbolt. Schonland, a distinguished South African geophysicist who has made major contributions to modern knowledge of lightning, presents in this book a clear, authoritative, often fascinating account of the nature of the lightning flash and of the luminous and electrical processes that take place in it. The sequence is somewhat as follows:

Thunderclouds, made up of enormous numbers of water drops and ice particles continually agitated by wind currents, upward drafts and the pull of gravitational forces, are in effect "great elec-

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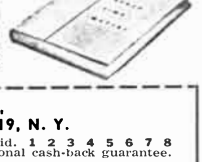

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trical machines, capable of developing potentials of thousands of millions of volts and of producing sparks many miles long." (An average thundercloud holds 100,000 tons of water, that is, about six trillion drops.) The usual electrical arrangement is for the cloud to carry a massive negative charge at its base, the upper portion being positively charged. In addition to the electricity produced by the busy commerce of raindrops and ice pellets, the cloud also draws current from the earth itself. "Each projecting point, bush or tree, or building is silently discharging electricity upwards in the form of ions. . . . " No single point produces much current but the total effect is considerable. Even so, the devastating energy of the flash arises from a small quantity of electricity: the 200 coulombs carried by an average cloud would not keep a 100-watt bulb lit for 10 minutes.

From time to time the great electrical stresses set up by the cloud are relieved by massive discharges of lightning. The flash itself is a composite event consisting of separate strokes, most frequently three. The theory is that the base of the cloud is divided into regions or cells and that the separate strokes represent successive discharges by adjacent cells. From one of the cells of the negatively-charged base, a faintly luminous "pilot leader" forces a channel a few inches in diameter through the air to the ground; but before this avalanche of jostling electrons reaches its destination a brilliant "return streamer," positively charged, rushes up to meet it. Unless there are projecting trees or buildings under the leader, the junction point is usually about 15 feet above the ground. The return streamer carries the main portion of the current (peak values as high as 200,000 amperes have been recorded) and is mainly responsible for the luminosity of the stroke. What causes this streamer is the "strong electrical field between the leader and the earth produced by the lowering of the cloud-charge by the first stroke."

Pictures taken with the Boys camera have revealed many of the luminous processes in a lightning flash. It has been shown, for example, that the leader in the first stroke does not plunge to earth in a single shaft but meanders downward in a series of steps, each about 50 yards long. After each step it pauses for about 50 microseconds, "as if it were exhausted and needed time to recuperate." Indeed, although it is the "pioneer" of the lightning flash, the pilot is too feeble to travel to the ground unless "step streamers" catch up and help it on its way. Moreover, "each step is made in a different direction from the previous one, and it is at the start of a new step that the streamer sometimes forms forks or branches, whereupon the leader continually divides along different paths, each itself involving a series of steps." The familiar principle involved is that of economy of work, the streamer evidently selecting the path through the air, however tortuous, that offers the least resistance. Once the channel has been formed, leaders of subsequent strokes, as well as the return streamer, follow, without pauses and without branching, the track already laid.

Without venturing further into many complex processes involved in lightning, we are now in a position to answer certain basic and highly interesting questions. What, for example, is the effect of the lightning rod? Since rods have been in use for more than a century and a half, it might be supposed that their operation has long been completely understood; but this is not the case. It was known that a properly installed rod would lead an otherwise destructive stroke safely to the ground; Franklin went further in conjecturing that lightning was actually "*attracted* by the points." But this question could not be settled until there was evidence of affirmative electrical action by the rod itself. What happens is this: The discharge of the cloud provokes numerous upwardly directed positive streamers from the earth. The rod being higher than the neighboring structures, its streamer reaches higher and is therefore the first to snag the descending streamer. Immediately a circuit is formed whereby the cloud discharge travels to the point of the rod, down through the conductor into the ground without damage to the building. Obviously a knob will serve as well as a point in this process; the more knobs or points the better, but one of either affords considerable protection. Complete protection is almost impossible, lightning being a freakish affair.

What about thunder? As the lightning flash cuts its narrow path through the air "the temperature rises in a few ten-millionths of a second to about 15,000 degrees Centigrade, causing the air in the channel to expand explosively and so create very powerful sound waves." Such factors as the number of separate strokes, echoes and the like produce the rumbling noises that can be heard miles away. Crackling sounds are produced by smaller, flickering streamers; the click often heard immediately before the loud crash is caused by the upward surge of St. Elmo's fire toward the descending discharge.

What are ball, ribbon and forked lightning? Are there bolts from the blue and does lightning strike in the same place twice? Why is an oak tree 62 times as likely as a beech to be damaged by lightning? How does the Empire State Building release its own lightning discharges? Is it dangerous to use the telephone during an electrical storm? What is the science of "sferics"? How does a cloud function as a wireless transmitter? What is the principle of

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artificial rain-making? Since the electrical attraction between the upper and lower charges on a cloud is sufficient to hold up its heavy base, how does rain ever escape from a cloud? For the often surprising answers to these and many other questions I refer you to Schonland's engrossing book.

THE NATURE OF THE UNIVERSE, by Fred Hoyle. Harper and Brothers ($2.50). On the appearance in England of this book based on his BBC lectures, Mr. Hoyle, a Cambridge astronomer, was proclaimed by several reviewers a worthy successor in popularization to A. S. Eddington and James Jeans. The accolade is deserved. An able scientific thinker, Hoyle is also gifted in making understandable the details of various theories about the origin, the machinery, the future and fate of the physical universe. Unlike Eddington and Jeans, he does not find it necessary either to invoke fanciful analogies or to take ultimate refuge from the inexplicableness of this "wholly fantastic universe" in religious explanations. Of particular interest is his account of the theory of the tunneling process whereby a star fattens on the interstellar gas through which it drifts on its majestic circuit around a galaxy.

PSYCHOANALYSIS AND RELIGION, by Erich Fromm. Yale University Press ($2.50). The thesis of this volume of Terry lectures is that there is no conflict between humanistic religion and psychoanalysis, because both are concerned with freeing man for the accomplishment of "the fundamental aims of human existence, independence and the ability to be productive, to love, to think." There is conflict, however, when religion, as so often is the case, means fearful submission to authority, the performance of meaningless rituals and idolatry. And it is only when the psychoanalyst serves as "the physician of the soul" that his goals are those of Christ, Buddha, Socrates or Spinoza. When he conceives his task to be the adjustment of his patient to the prevailing social milieu, he is, perhaps, achieving no more than would a Calvinist. The reader will recognize these themes as being applications to religion of the principles outlined in Dr. Fromm's earlier books.

GEOGRAPHY OF THE U.S.S.R., by Theodor Shabad. Columbia University Press ($8.50). A reliable, up-to-date treatise by a recognized authority offering both a general and regional survey of the geography of the U.S.S.R. The inherent problems of preparing a study of this kind are formidable. They have of course been many times magnified by the obstacles in the way of obtaining sound information, especially as to the latest Russian political, economic and

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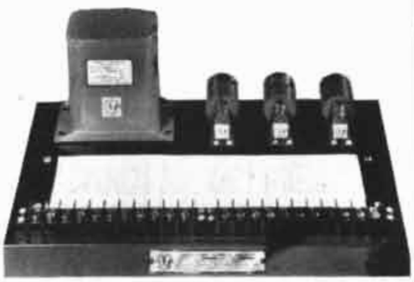

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industrial developments. Despite these hindrances Mr. Shabad has succeeded admirably in his task.

THE PAPERS OF THOMAS JEFFERSON: VOLUMES II AND III, edited by Julian P. Boyd. Princeton University Press ($10.00 each). The great enterprise goes forward. These two volumes, carrying past the mid-point of Jefferson's service as Governor of Virginia, include the report on the formidable Revisal of the Laws undertaken by Jefferson, Edmund Pendleton and George Wythe; the beginnings of Jefferson's correspondence with Madison and Monroe; letters on military matters (the defense of Virginia, the drafting of men for the Continental army and the like) and on a variety of state problems to and from George Washington, John Jay, Richard Henry Lee, Edmund Randolph, Benjamin Harrison and others; proclamations, orders, requisitions and other documents mainly relating to the conduct of the war. A historical feast made even more appetizing by the care taken to prepare it.

PATTERNS OF SEXUAL BEHAVIOR, by Clellan S. Ford and Frank A. Beach. Harper and Brothers ($4.50). Men, moles, shrews, cats, dogs, weasels, beavers, porcupines, rabbits, hares, whales, armadillos, monkeys, apes, bears and elephants are among the mammals with whose sexual behavior this report is concerned. In their sexual appetites, proclivities and practices, the members of this motley assembly differ remarkably and are yet remarkably alike. That the human animal is closely related to the ape is here persuasively confirmed. The authors, a psychologist and an anthropologist, have set their comparative survey in a much larger frame of reference than that adopted by Dr. Kinsey and his associates. The statistical detail is scant; on the other hand Ford and Beach have dealt at length with the social, biological and psychological factors affecting sexual habits, with no less than 190 separate societies distributed over the globe, and with the evolution of sexual mores since an epoch somewhat predating that assigned by the orthodox to "original sin." An engrossing study illuminating a vast but never tiresome subject.

THE LIFE OF VERTEBRATES, by J. Z. Young. Oxford University Press ($8.50). Professor Young represents this text as an "attempt to give a combined account of the embryology, anatomy, physiology, biochemistry, palaeontology, and ecology of all vertebrates . . . to define the organization of the whole life and its evolution in all its aspects." He has performed the task brilliantly. His book is fresh, literate, authoritative and beautifully illustrated; it offers a balanced description of the vertebrate sys-

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tem of life, its changes, adaptations, hazards; "the varieties of truce that accommodate the chronic enmity of the environment and everything else that is entailed by the act of living." Mammalian structure, function and development, as well as a survey of comparative embryology, are to be dealt with in a succeeding volume.

Also Noteworthy

ON THE ORIGIN OF SPECIES, by Charles Darwin. Philosophical Library ($3.75). A pocket-sized reprint of the original issue of this famous work, published November 24, 1859, in an edition of 1,250 copies. In the concluding passage of his interesting foreword, C. D. Darlington writes: "And it is an essay in scientific enquiry, applied freely, unrelentingly, and without fear of any master, that will remain to refresh and inspire succeeding generations of men."

HOW THE FIRST MEN LIVED and THE FIRST GREAT INVENTIONS, by Marie Neurath and J. A. Lauwerys. Lothrop-Chanticleer Press ($1.50 each). Colorful, well-written primers for 7-11-year-olds. Lancelot Hogben's name on the jacket and title page as "editor" is presumably intended as the equivalent of a Good Housekeeping seal of approval on a potato masher.

DATING THE PAST, by Friedrich E. Zeuner. Longmans Green & Company ($5.50). A revised edition of an authoritative work on geochronology, a young branch of science which by the use of a number of methods from tree-ring analysis to the measurement of radioactivity attempts to develop time scales for the epochs of prehistory.

THEORY AND APPLICATION OF INFINITE SERIES, by Konrad Knopp. Hafner Publishing Co. ($7.50). The second English edition of one of the best-known works in the field.

A HISTORY OF PHILOSOPHICAL SYSTEMS, edited by Vergilius Ferm. Philosophical Library ($6.00). Forty-one professional philosophers contribute to a cooperative survey, mainly intended for advanced students, of the major theories of philosophy, ancient and modern.

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VERSATILITY is the chief characteristic of the telescope shown in Roger Hayward's drawings on the opposite page. Planned and built by Garland S. Whitney of 4231 University Way, Seattle, Wash., it may be used in any of four ways: as a high-magnification Gregorian telescope for observing planets either visually or photographically; and as a low-magnification Newtonian for either visual or photographic observation of faint objects such as nebulae and the "star dust" of the Milky Way.

The telescope is shown as a visual Gregorian in the drawing. The eyepiece is at the lower end of the tube. At the opposite end a small concave secondary mirror reflects to the eyepiece the rays it receives from the large primary at the bottom. (This is shown more clearly at the upper left of the drawing on page 78.) The effect of these reflections, made at angles determined by the calculated curvature of the paraboloidal primary mirror and the ellipsoidal secondary, together with the effect of the added double folding, is to shorten the telescope greatly. The tube of this one is 56 inches long, with an effective focal length of 205 inches; a simple telescope with the same magnification would be about 17 feet long.

The gains of the Gregorian, however, are not obtained without certain losses; this is nearly always the case in optical design, which is by nature a compromise. Shaping the curve on the small secondary mirror is a fussy, delicate task. Lining up the mirrors of a compound telescope is another delicate job. The observer may pay with a wry neck and sagging knees for the whim of looking in the direction of the object. The image is erect, but astronomers are accustomed to inverted images and find erect ones abnormal. (This feature nonetheless makes the instrument useful as a terrestrial telescope.) The Gregorian's virtues include a higher magnification than the Cassegrainian, another type of compound telescope. In any case, the beginner should make two or three sim-

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ple telescopes before tackling a compound such as this.

In the second of the four uses of the Whitney telescope, a film carrier is substituted for the eyepiece at the bottom of the tube, and photographs are made. In the third use, as a visual Newtonian, the Gregorian secondary mirror remains in the tube but is nonfunctional, and the Newtonian secondary and eyepiece carrier unit is inserted and quickly latched to the side. Its secondary mirror, a flat diagonal, intercepts the rays from the primary and reflects them to a position outside the tube where they can enter the eye, as shown at the upper right in the drawing on the next page. The *f*/3.45 low-magnification Newtonian, best adapted for viewing faint objects, may also be used on the planets when the earth's atmosphere is so unsteady that high magnification causes greater loss in sharpness than gain in size.

Finally the Newtonian focus may be used photographically, not by substituting a film holder for the eyepiece, but by inserting it directly at the center of the tube and taking the photograph at the prime focus. This eliminates one reflection.

The Whitney telescope has many fine mechanical and optical features. The mirror cell at the lower end of the tube is made from an automobile brake drum; its central opening is covered with a metal plate to which the eyepiece and assembly are attached. When a photograph is to be taken, the eyepiece is taken out without removing the assembly, and a metal box with a 4-by-5 cut-film holder is attached by side clamps. A Packard-type shutter inside the cell is operated by a rubber air bulb.

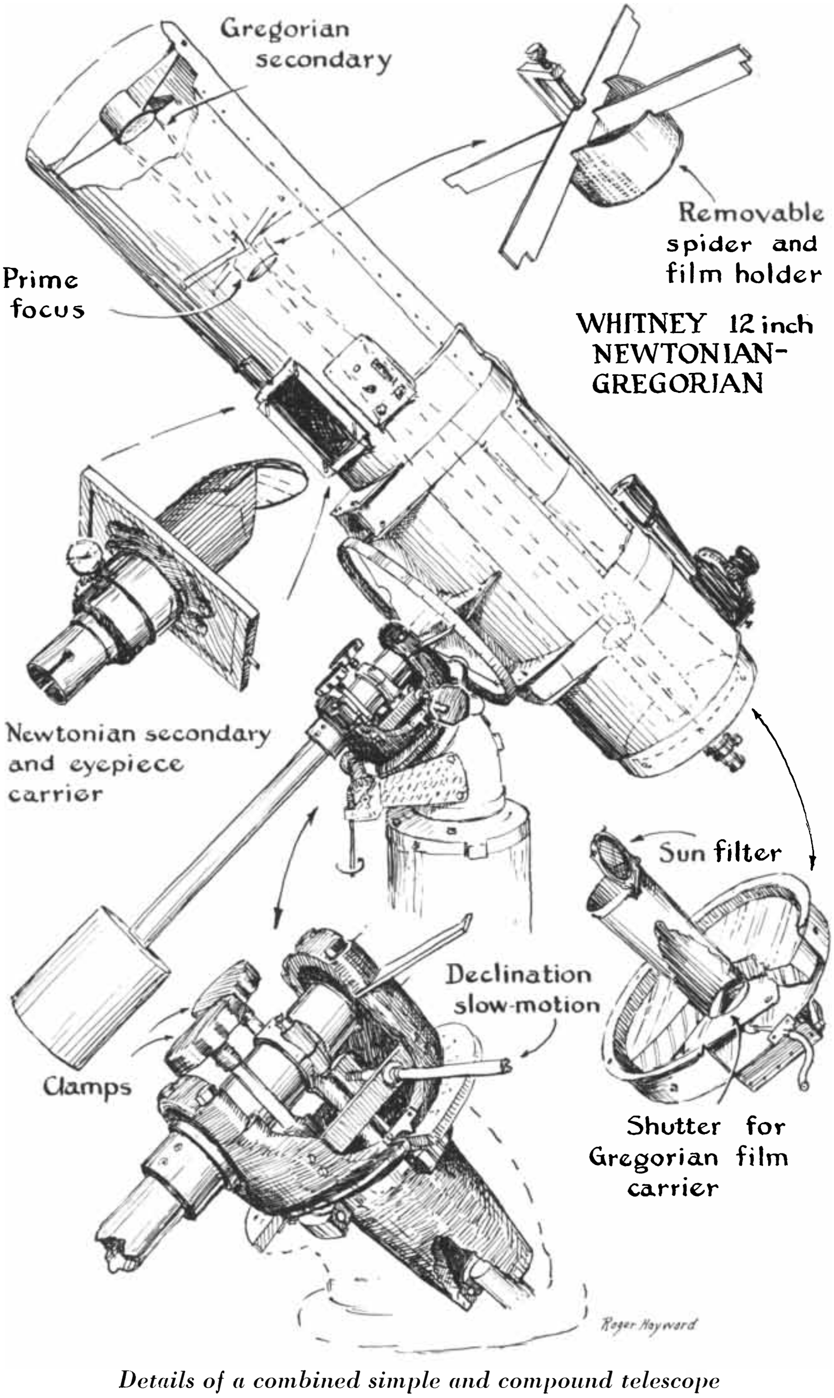
A photograph of the moon taken by Whitney looked so fine that it was sent by this department to Dr. Henry Paul, an advanced amateur who specializes in astronomical photography. He commented, "This is the best moon picture by an amateur I have ever seen." (He modestly omitted his own.)

When the sun is to be photographed, a tube with a Polaroid filter hinged at its top is inserted through the hole in the primary mirror and screwed into the backplate, the Polaroid filter is flipped into the path of the light rays, and the primary mirror is stopped down to one-eighth area. This tube is long enough to serve another function: it shields the eyepiece from the direct light of the sky. Otherwise this sky-flooding glare would render the Gregorian virtually useless as a daytime terrestrial telescope.

The instrument is mounted on a deep, broad concrete pier by means of a five-inch 45-degree pipe elbow. Inside this elbow, running on a propeller-pitch-type bearing, is the combined polar-axis and declination-axis unit. This was machined from a 1928 Chevrolet differential housing. Fine adjustment is imparted to the two-inch declination shaft by hand screws on either side of the mounting. These work through a linkage to a sawed-off connecting rod bolted to the shaft.

The guide mechanism, rebuilt from a war-surplus bomb-train intervalometer, has a knob that affords manual control of the driving rate for guiding the telescope during photography. Guiding is done with a 3½-inch elbow refractor of 40-inch focal length attached to the tube but not shown in the drawing. The rectangular object shown near the center of the tube contains a battery for illuminating the reticle of the guide telescope. The drive motor is a synchronous General Electric phonograph turntable motor, and the gear train is built up of spur gears.

The 12-inch primary mirror was made from a very ancient disk of green porthole glass two inches thick, obtained from a ship chandler. Today plate glass is not made thicker than 1½ inches.



Details of a combined simple and compound telescope

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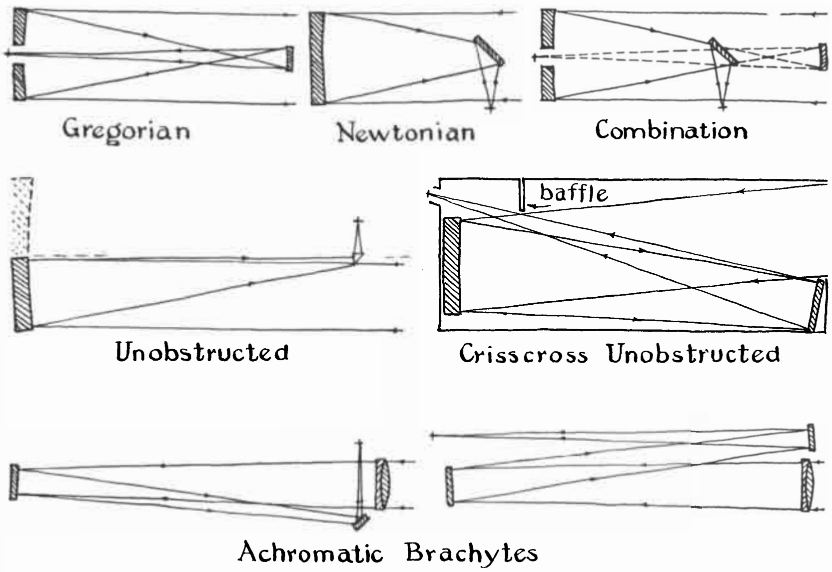

Illustrations for three subjects discussed in the text

Theoretically Pyrex is three times as good a mirror material as plate, since its expansion coefficient is only one third as great, but arguments could be adduced that in practice might narrow this difference considerably in most cases. During the excavation of the concavity, which is almost a quarter of an inch deep, the loss of glass thickness by grinding was held to a minimum by the use of sub-diameter tools. The mirror curve was excavated to about two-thirds the ultimate depth on top of an 8-inch tool. The hole was then bored from the face to within 1/2-inch of the back. Next, the same tool was used on top until the curve was nearly excavated. Then the hole was deepened to within 3/16-inch of the back and the slot was packed with wicking and paraffined over. Polishing and figuring were done face up, by hand, with the mirror on a turntable driven at six revolutions per minute. A lap having two-thirds diameter was used for smoothing, and laps of 3½-, 1½- and 3/4-inch diameter were used for treating zones and figuring. Finally the central plug was knocked out.

The telescope is housed in a circular dome of sheet aluminum bolted to shallow U-channel ribs of iron. The 10-foot dome diameter proved to be none too big and, while the 34-inch dome slot is wide enough, it is none too wide. The dome rotates rather rapidly at the rate of two revolutions per minute, driven by a 28-volt electric-clutch-operated reversible war-surplus motor, reduced in speed by a system of V-belts controlled from the pier.

THIS DEPARTMENT is now illustrated with drawings instead of photographs. As Russell Porter often pointed out with a chuckle of satisfaction, the camera cannot be inserted in the places where an artist can put his imaginary point of view, nor can it make all-revealing combination cut-away illustrations. The composite drawing on the preceding page was made by Roger Hayward from 21 photographs, only two of which could have been reproduced in the same space. The 21 photographs, mainly of disassembled parts of the telescope, together show only a few minor details not combined in the single drawing; yet only one part of the drawing, the mechanism immediately on top of the pier, approaches a direct copy of any single photograph.

The recombining is done after the photographs or rough sketches and the written description have been assimilated. With the understanding thus gained, the artist can safely alter the point of view or manner of presentation as much as he wishes, especially if he is himself an amateur telescope maker and mechanic, as Hayward is. For example, the single drawing at the bottom alone contains the elements of four photographs, plus a little that even these did not reveal. The reader need have no fear of loss of integrity in transmission.

A NEW WAY OF FOLDING the optics of a telescope into zigzag form to keep the length within reason, as in the Gregorian and Cassegrainian, has been suggested by Daniel E. McGuire, a Pittsburgh professional optician. McGuire began as an amateur, and retains the keen interest in amateur optics of all who add professional to amateur status. (This combination, impossible in athletics, is harmless in optics.) He writes:

"I had the lucky opportunity to look through the most perfect telescope that I have ever used. It was one of the off-axis reflectors of Norbert J. Schell of Beaver Falls, Pa. For the first time in my life I have seen in great detail the belts of Jupiter, yet the aperture of the telescope was only six inches. I couldn't get

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away from the impression that I was looking through a much larger telescope. The high power that goes with its $f/21$ ratio probably contributes to that impression."

Schell has promised this department a description of this new telescope, called the "oblique Cassegrainian." Two of his off-axis telescopes were described in this department in April, 1939, and May, 1940. The principle of the first is shown at the left side of the second row in the drawing on the opposite page. The mirror is a section from one side of the imaginary paraboloid shown by dotted lines. The object of the design is to eliminate the evil diffraction effects due to a secondary mirror or a diagonal. Schell emphasizes this fact by calling the telescope not an off-axis but "the unobstructed"; the off-axis mirror used in it is merely a means to avoid obstruction. The value of eliminating obstruction had been borne in on Schell after he repeated W. H. Pickering's experiment, described in *Amateur Telescope Making—Advanced,* page 613, in which Pickering gained refractor performance from a reflector by temporarily avoiding obstruction.

Schell also conceived and—with T. G. Beede, who made the off-axis mirror—constructed the "crisscross unobstructed" instrument shown in the next drawing. Here the optics are folded triply into a short tube, and light baffles prevent direct sky-flooding at the eyepiece.

McGuire's present proposal was inspired by the fact that Schell recommends, as others have, a closed tube as an added refinement for his unobstructed telescopes. McGuire writes: "If one goes so far as to use a window to close the tube, why not make the window in the form of an achromatic lens of very long focus? Then the 'off-axis' mirrors could be plane mirrors, which are much easier to make. The length of tube usual for a refractor having a ratio of $f/15$ would accommodate a ratio of $f/45$. For any given magnification color fringes would be reduced to a third of what they are in the typical refractor."

McGuire continues: "The idea of making a refractor with an unusually long focus to reduce the effect of the secondary spectrum came to my mind when considering the difficulty of making off-axis mirrors. The refractor is much easier to make, although the greater focal length brings about mounting problems. In *Telescopes and Accessories,* by Dimitroff and Baker, page 27, it is stated that the focal length of an achromatic objective with unobjectionable color aberration is given with sufficient accuracy by the formula $f = 5D^2$. By this standard a 3-inch objective having a focal ratio of $f/15$ has unobjectionable color. A 6-inch at $f/30$ and a 9-inch at $f/45$ would have the same amount of color at a given magnification per inch of aperture, but the telescope would be much too long in the conventional straight-line design.

"At the expense of using a wider tube and including auxiliary plane mirrors, the tube length can still be kept within convenient proportions. Two types of 'achromatic brachytes' are shown in the drawing. Mounting possibilities would include the Springfield arrangement with the eyepiece on the polar axis and the coudé Cassegrainian (*Amateur Telescope Making,* page 452) with eyepiece near the declination axis."

IN a frequently quoted article in the February, 1938, issue of *The Journal of the British Astronomical Association,* H. E. Dall of England described experiments on "diffraction effects due to axial obstructions in telescopes." Using various sizes of central obstruction, Dall made photographs of artificial planets consisting of a uniformly illuminated aperture overlaid with wires corresponding to lines 42, 84 and 168 miles wide on the Martian disk. Under these controlled laboratory conditions, which he described in a private communication as an attempt "to find out how much effect was due to the central obstruction and how much to air-current trouble in open tubes," he demonstrated that the effect of diffraction is to reduce contrast as well as definition but that "if the central obstruction does not exceed one fifth of the diameter of the aperture no *serious* loss of detail contrast occurs. Above this proportion of obstruction a noticeable falling off of crispness of detail results, accompanied by a growth of spurious detail and diffraction haloes." To avoid losses even less than serious, Dall still recommends the method of minimizing obstruction that he described on page 584 of *Amateur Telescope Making—Advanced:* a tiny prism just a little inside primary focus feeding the rays to a good erecting system. "By this means," he says, "I brought the secondary obstruction down to less than 6 per cent of diameter or .36 per cent of area, and got an erect image too."

"Of course," Dall adds, "for real simplicity and merit the oldest of the lot, the Herschelian, takes a lot of beating, as I am always trying to drive home. The decentering error can be reduced in several ways to less than the Rayleigh tolerance, provided the focus is not made too short, say, less than $f/8$. Off-axis cylinders or lens tilts will do it."

"All telescopes are compromises," he continues, commenting on the long tube of the Herschelian. "A Herschelian has six advantages: no primary figuring; spherical mirror; no flat; no obstruction; maximum light grasp; comfortable high powers because of long focus. All these to offset the disadvantage of an awkwardly long tube with $f/15$ or $f/16$. The coma of the eyepiece can be compensated for by eyepiece tilt or an off-center cylinder. A Lancashire telescope maker has made primaries of $f/10$ in this way."

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BIBLIOGRAPHY

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

AN ANALYSIS OF TELEVISION PROGRAMS

RADIO, TELEVISION AND SOCIETY. Charles A. Siepmann. Oxford University Press, 1950.

PUBLIC SERVICE RESPONSIBILITY OF BROADCAST LICENSEES. Report by Federal Communications Commission. March 7, 1946.

ZIRCONIUM

ZIRCONIUM METAL, AS OF 1949. R. I. Jaffee in *Journal of Metals,* Vol. 1, No. 7, pages 6-9; July, 1949.

PRODUCTION OF MALLEABLE ZIRCONIUM ON A PILOT-PLANT SCALE. W. J. Kroll, W. W. Stephens and H. P. Holmes in *Journal of Metals,* Vol. 188, No. 12, pages 1,445-1,453; December, 1950.

MELTING AND CASTING ZIRCONIUM METAL. W. J. Kroll and H. L. Gilbert in *Journal of the Electrochemical Society,* Vol. 96, No. 3, pages 158-169; September, 1949.

METEORS

BETWEEN THE PLANETS. Fletcher G. Watson. The Blakiston Company, 1941.

THE ULTRACENTRIFUGE

THE ULTRACENTRIFUGE. Thé Svedberg and Kai O. Pedersen. Oxford University Press, 1940.

HIGH CENTRIFUGAL FIELDS. Jesse W. Beams in *Journal of the Washington Academy of Sciences,* Vol. 37, No. 7, pages 221-241; July 15, 1947.

THE FERTILIZATION OF FLOWERS

HANDBOOK OF FLOWER POLLINATION, Vols. I, II and III. Paul Knuth. Oxford University Press, 1906-1909.

THE FLOWER CONSTANCY OF BEES. Verne Grant in *Botanical Review,* Vol. 16, pages 379-398; 1950.

MOVING THE OBELISK

MOVING THE OBELISKS. Bern Dibner. Burndy Library, 1950.

CALCIUM AND LIFE

AN OUTLINE OF GENERAL PHYSIOLOGY, Second Edition Revised. L. V. Heilbrunn. W. B. Saunders Company, 1943.

PROTOPLASM AND COLLOIDS. L. V. Heilbrunn in *The Cell and Protoplasm.* American Association for the Advancement of Science; Science Press, 1940.

ANIMAL INTELLIGENCE

INTRODUCTION TO COMPARATIVE PSYCHOLOGY. C. J. Warden, T. N. Jenkins and L. H. Warner. The Ronald Press Company, 1934.

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