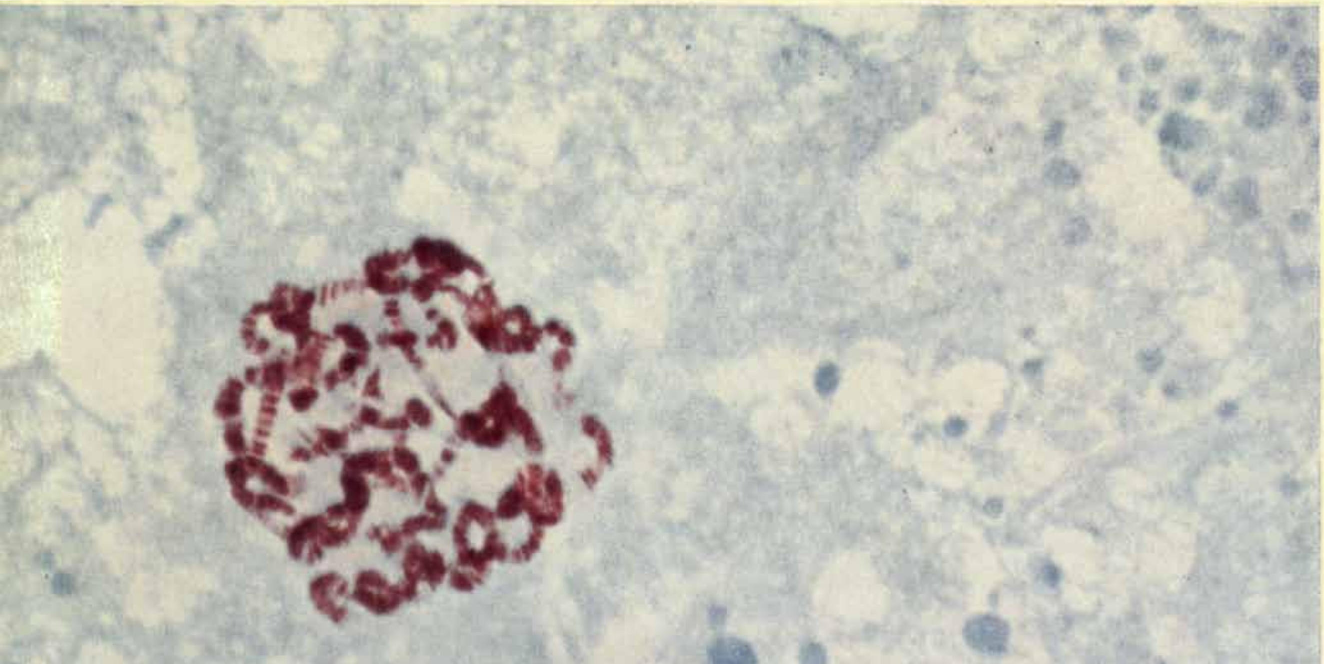
SCIENTIFIC AMERICAN



CHROMOSOMES

FIFTY CENTS
75 CENTS OUTSIDE THE AMERICAS

February 1952

Seeing things? It can be profitable!

Seeing the connection between the food freezer and the refrigerator car may put you on the track of a profitable idea.

Although the freezer is normally a stay-at-home, and the "reefer" pounds the rails all over the country, both have the job of keeping things cold. To do it economically and efficiently, both use the same kind of insulation. Specifically, Fiberglas* Insulation.

Why? . . . because it's the most effective barrier to heat and cold. And, beyond that, because it virtually refuses to wear out.

Made of glass in fiber form, it's immune to age, rot and corrosion. It is also resilient—won't shake or slump down to leave uninsulated gaps. It fabricates easily, or can be supplied in pre-cut pieces ready for your assembly line. No wonder it's used by alert industries in more diversified applications every year.

If you have temperatures to control, anywhere—from subzero to 1,000°F.—learn why widely different industries have turned to Fiberglas Insulations. These materials come in a range of forms and densities from a soft, feather-weight blanket to a structural board on which you can pour a gypsum roof. They weigh less than comparable materials, handle easily, won't burn. And in most cases, save money.

Check the list below. Then write for samples and specifications to Owens-Corning Fiberglas Corporation, 1602 Nicholas Building, Toledo 1, Ohio.

WHERE CAN YOU GO WITH THIS TRAIN OF THOUGHT?

With Fiberglas materials, either alone or in combination with other materials, you can have almost any combination of the following properties that your imagination can see a profit in: **CONTROL OF Heat or Cold . . Sound . . Dirt . . Electricity RESISTANCE TO Moisture . . Corrosion . . Aging • LIGHT WEIGHT NONCOMBUSTIBILITY • DIMENSIONAL STABILITY • RESILIENCY IMPACT STRENGTH • TENSILE STRENGTH • EASE OF APPLICATION**

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

FIBERGLAS

IS IN YOUR LIFE ...FOR GOOD!

U. S. PRODUCTION DRIVE TURNS SPOTLIGHT ON TRAINED MEN

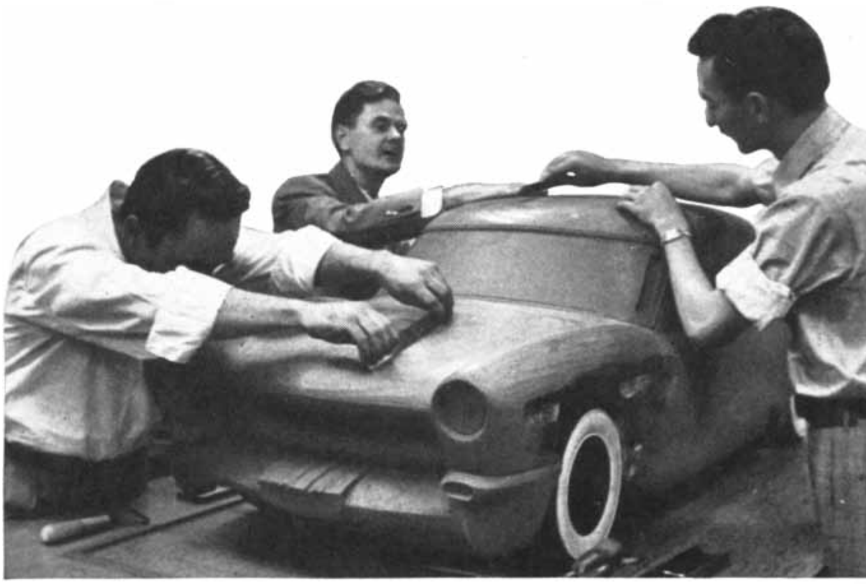
Chrysler Corporation's program helps people build better products and better careers for themselves

George Heyer, noted magazine photographer, turns his camera for this picture story on a program of importance to American production—how people learn to build military vehicles, defense weapons, and the cars and trucks that play a vital part in American life.

Heyer's pictures were made in Chrysler Corporation factories, classrooms and training shops. He shows a few of the thousands of men and boys who are now taking part in Chrysler's widespread training and technical education program.

TOMORROW'S CRAFTSMAN. Heyer snapped intent young Robert Chura—son of a Chrysler Corporation employee—during one of his first lessons in how to use tools and make useful things. In special workshops set aside by Chrysler, Robert and other boys work in wood, leather and metal under the guidance of veteran Chrysler artisans. Then they borrow from a "Library of Tools" and finish projects at home.

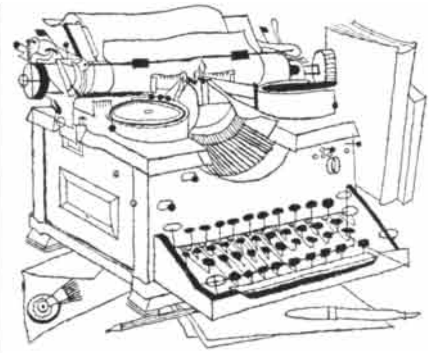
"A GOOD MACHINE DESERVES A GOOD MAN, SON." Albert Bazner learns about grinders from veteran machinist H. A. Nelson. For the past year Albert has been in an Apprentice Group in Chrysler's Industrial Education program, learning the machinist trade—at good pay. Chrysler helps ambitious employees move up to better jobs. Even high school and college students can learn jobs before graduation, earning both classroom credits and pay. Good training for good men pays off in better cars and trucks—and in such defense work as jet engines, too.



THEY THINK IN CLAY. In this clay model room at Chrysler Institute of Engineering, employee students D. M. Holiday, *left*, and Paul R. Diehl study body design with Engineer Carl Hood. The Institute is the most advanced part of Chrysler's education and training program. Courses compare with those in leading engineering colleges. At Chrysler, employees find training to improve themselves . . . become more valuable to America now when production need is great.

CHRYSLER CORPORATION engineers and builds **PLYMOUTH, DODGE, DE SOTO, CHRYSLER CARS & DODGE TRUCKS**

Chrysler Marine & Industrial Engines • **Oilite** Powdered Metal Products • **Mopar** Parts & Accessories • **Airtemp** Heating, Cooling, Refrigeration • **Cycleweld** Adhesives & Building Panels



LETTERS

Sirs:

I found the article on electrophoresis in your December issue extremely interesting and informative.

It should, however, be pointed out that *p*H is not the concentration of hydrogen ions, but the negative logarithm (to the base 10) of this concentration. This will clarify the statement that increasing the *p*H makes a solution more alkaline.

R. W. COTTINGHAM

Seattle, Wash.

Sirs:

I was very happy to see reported in your department "Science and the Citizen" for November a study of jazz musicians by one of my former students, now my colleague, Dr. Howard S. Becker.

You say, however, that Dr. Becker "passed himself off" as a pianist. It should be called to your attention that he was, and still is, a jazz pianist in good standing, in spite of his association with such squares as his teachers. I note that this error has been copied in other publications. *The Milwaukee Journal,* in fact, goes so far as to say that he "disguised himself as a pianist," which would have been a very good trick.

EVERETT C. HUGHES

The University of Chicago
Chicago, Ill.

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Sirs:

I found the item about Martha Wolfenstein's study of children's humor in your department "Science and the Citizen" for November most engaging. It seems to me, however, that her hypothesis about the riddle of the moron and the sleeping pill is a little far-fetched. The riddle, as you will remember, goes: "Why did the moron tiptoe past the medicine cabinet? Because he didn't want to wake the sleeping pills."

Miss Wolfenstein states that the popularity of this riddle among children from 6 to 10 is an expression of repressed sex curiosity because "the tiptoeing and reference to sleeping suggest that this has something to do with nocturnal investigations." Is it not just as likely that a child's concept of tiptoeing is the result of being shushed by one parent while the other is sleeping?

ADELE KAUFMANN

New York, N. Y.

Sirs:

Concerning the item about children's humor in your November issue, I believe Martha Wolfenstein has reached an erroneous conclusion.

We have recently been through the "moron and the sleeping pills" episode in our family and I was impressed at the time with the obvious basis for the hold this joke has on children.

Between the ages of 6 to 10 a child's vocabulary is growing very fast and his appreciation of the pun possibilities of our glorious and ridiculous language gives him great pleasure and feelings of superiority over the uninitiated. I have heard my children explain this and other puns to smaller children with a great show of tolerance and ill-concealed glee at the younger's ignorance. . . .

MRS. JOHN URBAN

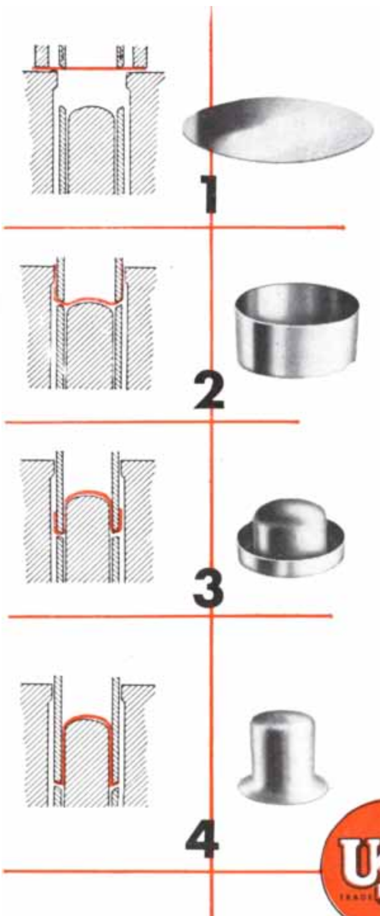
North Hollywood, Calif.

Sirs:

The thought-provoking articles in your September issue entitled "Human

Neatest steel trick of the year

. . . turning a high strength steel cup **inside out,** cold



Offhand, anyone familiar with high strength steels would say it couldn't be done. But one of our customers, the Scaife Company of Oakmont (Pittsburgh District) Pa., does it every day.

Employing a unique reverse-drawing method and using a U·S·S High Strength Steel especially adapted for this process they turn out cylindrical containers of various kinds that are not only stronger than those made from carbon steel but weigh substantially less.

To accomplish this, the steel has to meet two entirely opposite requirements. It has to be so strong that it can be used in thinner gages to reduce weight, and yet must have enough ductility to satisfy the drastic fabrication method that would be considered severe even for carbon steel.

Scaife was the first to use this method to draw cups for large, low-pressure cylinders. These cups, 14½ in. in diameter and 24½ in. deep, are drawn cold, from 12-gage steel blanks in one continuous stroke in a reverse draw press. The diagrams at left show how it is done.

Starting with a 38 in. diameter steel blank (Fig. 1) the press first draws the steel into a shallow cup (Fig. 2). As the stroke continues, the cup is literally *turned inside out* (Fig. 3) to form the finished cup (Fig. 4) which has very uniform wall thickness. Two of these cups are then welded together to make a cylinder.

Made with high strength steel, cylinders weigh about 20 lbs. less. The maker gets 26% more cylinders from each ton of steel used. Lighter weight makes cylinders easier to handle, and also pays off in lower freight costs—both on the steel from our mills and on cylinders shipped. (A customer 500 miles away saves as much as $100 per carload.)

No matter what your product or your fabricating procedure, United States Steel can supply you with the right steel to fit your needs. Our metallurgists, with their tremendous background of practical experience, are ready at all times to work with you on any problem that involves the more efficient use of steel. Simply write United States Steel, Room 4343, 525 William Penn Place, Pittsburgh 30, Pa.

UNITED STATES STEEL

Resources of the U. S." make one wonder whether the suggested means for alleviating the acute and growing shortage of technical personnel will be sufficient to fill the gap between the demand and supply. The following three auxiliary means should also be considered:

Many attentive students of the problem realize now that duplication of research is often due to the inability of the average research worker to cope with the problem of finding, studying and assimilating the published information relating to his problem. There are now 40,000 technical journals received by the Library of Congress which carry an estimated 2,900,000 articles on science and technology per year. Even though we have some excellent abstracting journals, one cannot limit the study of the literature to the reading of abstracting journals; one must study the details and furthermore one must think in terms of application of the outcome of scientific research in one field to other fields. Excellent examples of possibilities in this respect were cited by G. M. Findlay in *Chemistry and Industry* for November 26, 1949, including a speculation of what would have been the results for science and the world if Tyndall's discovery of penicillin, published in 1876 in the *Philosophical Transactions of the Royal Society,* had been adequately known to scientists of the world. There is obviously a need for scientists trained in the basic sciences involved and in the best bibliographical methods so that they could continually follow an important research project by an interpretive study of the literature related to it, from the moment of its planning to the completing of a process design.

A further subdivision of the duties of a scientist and engineer which could save some of his time would be effected by training assistants on a level above the present-day laboratory technician. Perhaps the type of German engineer as distinguished from the "diplomierter ingenieur" and from "doctor-ingenieur" or the training of engineering assistants afforded by the curriculum of the Russian "technikum" could be considered. It is interesting to note that the Russian plans for technical training, as far as we know, provided as early as the late 1930s for training a larger number of "technikum" graduates than engineers, with a ratio of two or three to one.

The status of the scientist reaching his retirement age should be reconsidered. Today it is very difficult to find employment for a technically trained individual aged 50 or above, unless he possesses some unusual qualifications. Retaining retiring scientists on part-time basis as consultants is definitely indicated as a desirable measure.

J. G. TOLPIN

Chicago, Ill.

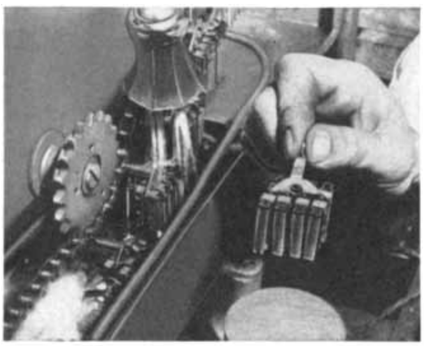
DEVELOPMENT BRIEFS

From Special Instrument Headquarters

Announcement by AEC of available fission products has accelerated the use of radioisotopes by industrial firms. Radioactive cobalt is a prime example. Proper instrumentation for specialized procedures is available from General Electric. See descriptive bulletin GEA-5735.*

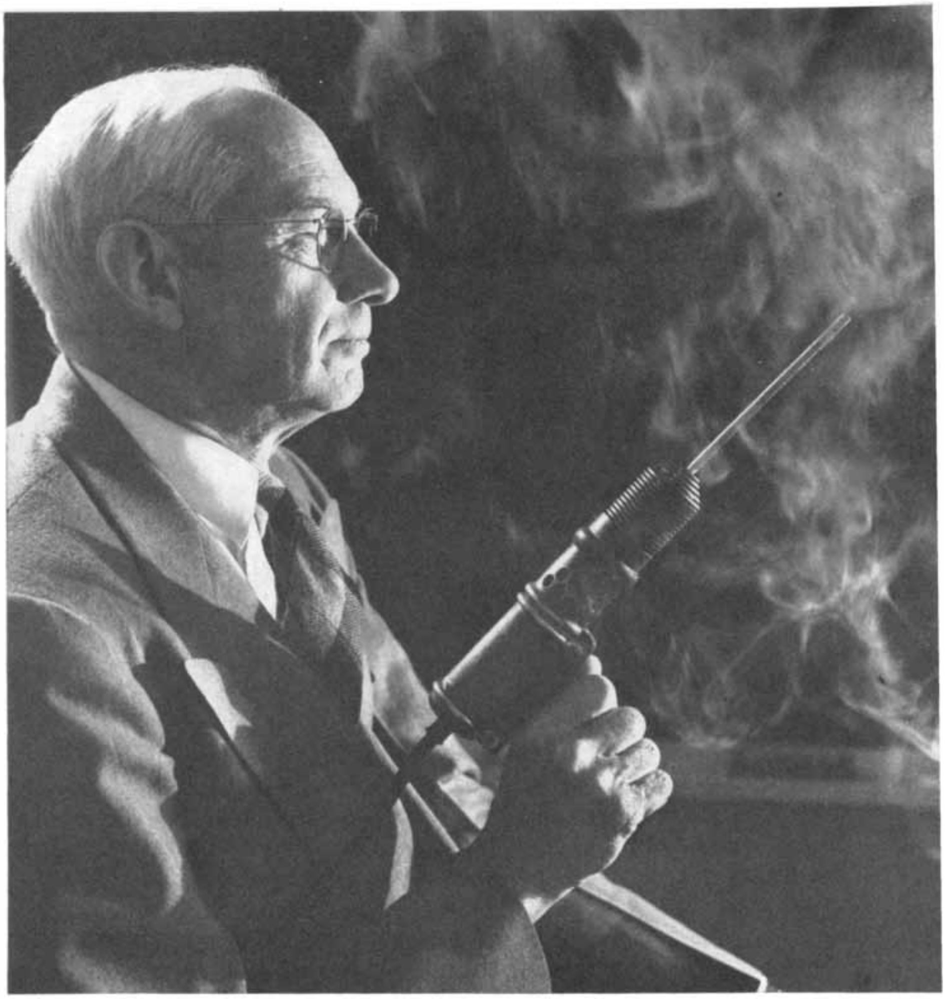
The new G-E Width Gage now being field tested provides accurate measure of hot strip steel. Mounted 15 feet above the moving strip, this non-contacting electronic device is actuated by the light of the strip itself. Increased production of critical steel and savings of hundreds of thousands of dollars annually are predicted by the steel industry. See bulletin GEC-783*.

Chemical analysis by x-ray absorption is now successful on a commercial scale with the G-E X-Ray Photometer, saving hours of valuable laboratory time, and freeing the chemist from routine work. Petroleum refiners slash time and cost determining tetraethyl lead in gasoline, and sulphur in oils. Many other industrial uses are possible since it measures the absorption coefficient of matter. See GEC-412A*.



Electric shaver heads sparkle . . .
when cleaned with 500-kc vibration in trichlorethylene. G-E Ultrasonic Generator beams high-frequency sound through any liquid solvent greatly accelerating the cleaning action. Small metal parts are quickly cleaned of oil, grease, lapping compound and metal chips. See bulletin GEA-5669* describing how an electric shaver manufacturer cut cleaning costs 58%.

**Write for bulletins to: General Electric Co., Sect. 687-84, Schenectady 5, N. Y.*



W. C. White, co-inventor of . . .

Leak Detector: New Tool for Fast Production Testing

Basic research at General Electric produced the Leak Detector—so sensitive it finds leaks of one ounce per century in tanks, pipes, valves, and even footballs.

It works like this: A halogen tracer is introduced in the closed system and air pressure applied. The detector nozzle "sniffs" for leaks in suspected areas.

Air drawn in the nozzle passes hot, electrically charged platinum surfaces. Vapors containing compounds of chlorine, fluorine, bromine, and iodine dissociate on the hot surfaces releasing positive ions. Resulting current registers on meter, light, or buzzer.

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

You can put this basic research to work on your special testing and measuring problems. Write, stating details, to: General Electric Company, Sect. 687-84, Schenectady 5, N. Y.

Locating minute leaks in 1000-gallon milk tank with G-E Leak Detector.

GENERAL ELECTRIC

687-84

50 AND 100 YEARS AGO

FEBRUARY 1902. "Mr. Wilbur Wright, of Dayton, Ohio, recently read a most interesting paper before the Western Society of Engineers, entitled 'Some Aeronautical Experiments,' and this paper was afterward published in the Journal of the Society. The experiments of Pilcher and Chanute stimulated Mr. Wilbur Wright and Mr. Orville Wright to try some experiments in 1900, which were conducted on the seashore of North Carolina. These gentlemen have been bold enough to attempt some things which neither Lilienthal, Pilcher nor Chanute dared to do. They have used surfaces very much greater in extent than those which hitherto have been deemed safe, and have accomplished very remarkable results. It was the plan of Messrs. Wright to glide from the tops of sand hills. It seemed reasonable that if the body of the operator could be placed in a horizontal position, instead of the upright, as in the machines of Lilienthal, Pilcher and Chanute, the wind resistance could be very materially reduced, since only one square foot, instead of five, would be exposed. The first machine had an area of only 165 square feet. A dozen glides were made with the wind blowing at 14 miles an hour. The operator placed himself in a horizontal position, and two assistants started the machine. Neither machine nor operator suffered any injury. The control of the apparatus proved even better than they had dared to expect, responding to the slightest motion of the rudder. The new machine for 1901 was exactly like the previous machine in theory and method of operation, but its lifting power was increased from 165 square feet to 308 square feet, although so large a machine had never before been deemed controllable. Quite a party went South to view the experiments, which were begun with the wind blowing at 13 miles an hour. The machine sailed off and made an undulating flight of a little more than 300 feet. The experiments also showed that one of the greatest dangers in machines with horizontal tails had been overcome by the use of a front rudder, and the operators escaped from positions which had proved very dangerous to preceding experimenters."

"Recently a locomotive has been devised for the use of the individual, which is no less interesting than the railway locomotive. It combines the peculiarities of the bicycle and the locomotive, and forms a new species of machine known as the motor cycle."

"In an address delivered before the American Chemical Society, April 12, 1901, on the occasion of the celebration of the 25th anniversary of the founding of the Society, H. W. Wiley of the U. S. Department of Agriculture predicted that on April 12, 1976, our country will have about 225,000,000 inhabitants. The revenues and expenditures of our government will each reach annually the sum of $4,000,000,000. New sources of energy will take the place of coal and gas, and this energy will come from the winds and the rains. The sun directly and indirectly will monopolize the power of the country."

"Dr. Hrdlicka has started on his fourth expedition into the country of the cliff-dwellers and Pueblos in the southwestern part of the United States and northern Mexico."

"The main points which Darwin and Wallace had so much difficulty to prove are now established truths. But the naturalist is no longer satisfied with these statements. He wants to know (as Darwin himself wanted) the cause of the variations which we call 'accidental.' An immense amount of work is being done now in this domain; and it is a growing conviction among biologists that, at least as regards plants, there is not one single organ which could not be modified in a permanent way by merely altering the conditions of temperature, light, moisture, and especially nutrition, under which the plant is reared at certain early periods of its development. The Dutch botanist De Vries, one of the greatest botanists living, for the last 15 years has cultivated a great number of so-called monstrosities, or rather aberrant types. The conditions under which these new varieties have been obtained were carefully studied by De Vries, and his conclusion is that it entirely depends upon heavy manuring or not, upon the keeping of seedlings wide apart or crowded, and upon the supply of temperature and light—upon *nutrition*, in a word. Now—and this is the main point—De Vries, like most botanists, does not doubt a moment that these 'acquired characters' are transmitted by inheritance from the mother plant to its progeny. Without such a transmission, of which the bota-

What's inside a *Radio-Relay* station?

Because microwaves travel in straight lines and the earth is round, there are 123 stations on the transcontinental television route between Boston and Los Angeles. This view of a typical unattended station shows the arrangement of the apparatus which amplifies the signal and sends it on.

ON THE ROOF are the lens antennas, each with its horn tapering into a waveguide which leads down to equipment

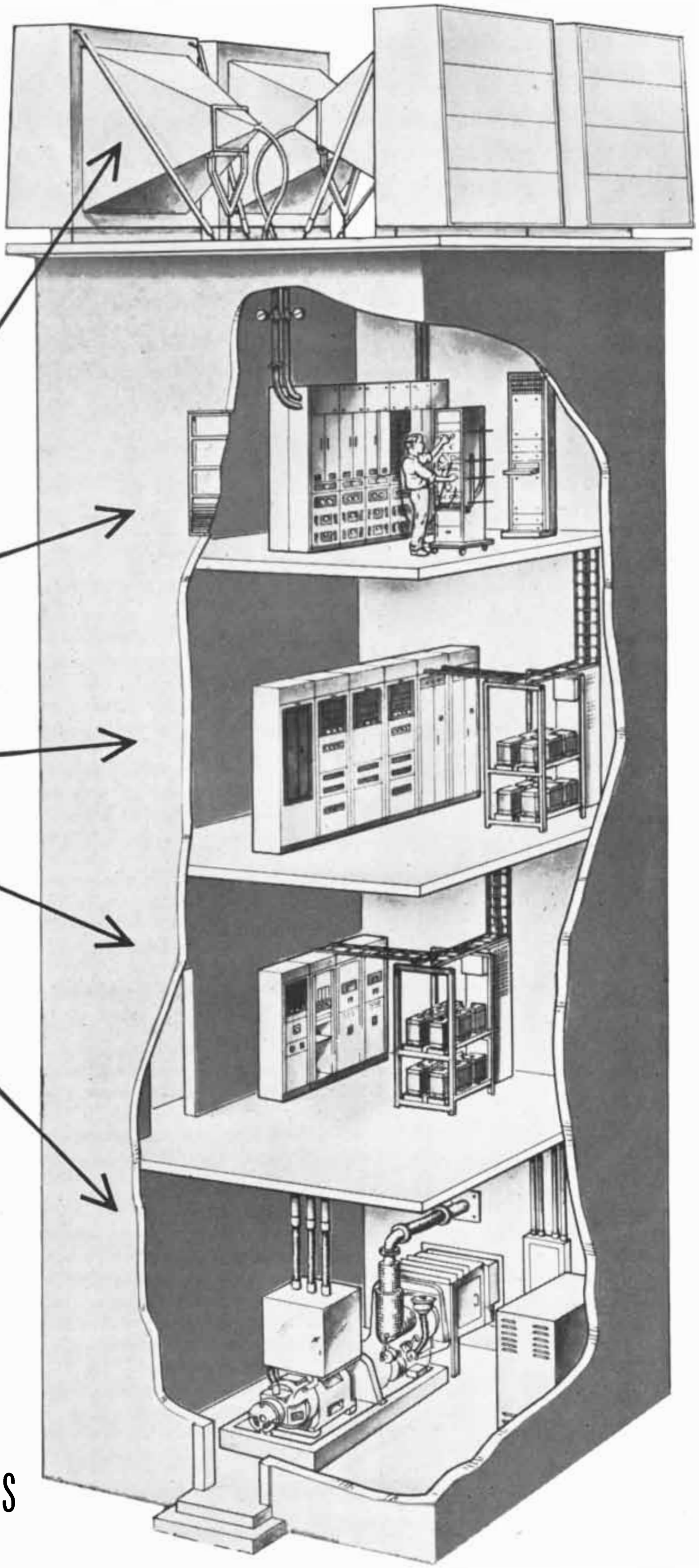
ON THE TOP FLOOR, where the signal is amplified, changed to a different carrier-channel and sent back to another antenna on the roof. Here are testing and switching facilities. Normally unattended, the station is visited periodically for maintenance.

ON THE THIRD FLOOR are the plate voltage power supplies for several score electron tubes.

ON THE SECOND FLOOR are filament power supplies. Storage batteries on both floors will operate the station in an emergency for several hours, but

ON THE GROUND FLOOR is an engine-driven generator which starts on anything more than a brief power failure.

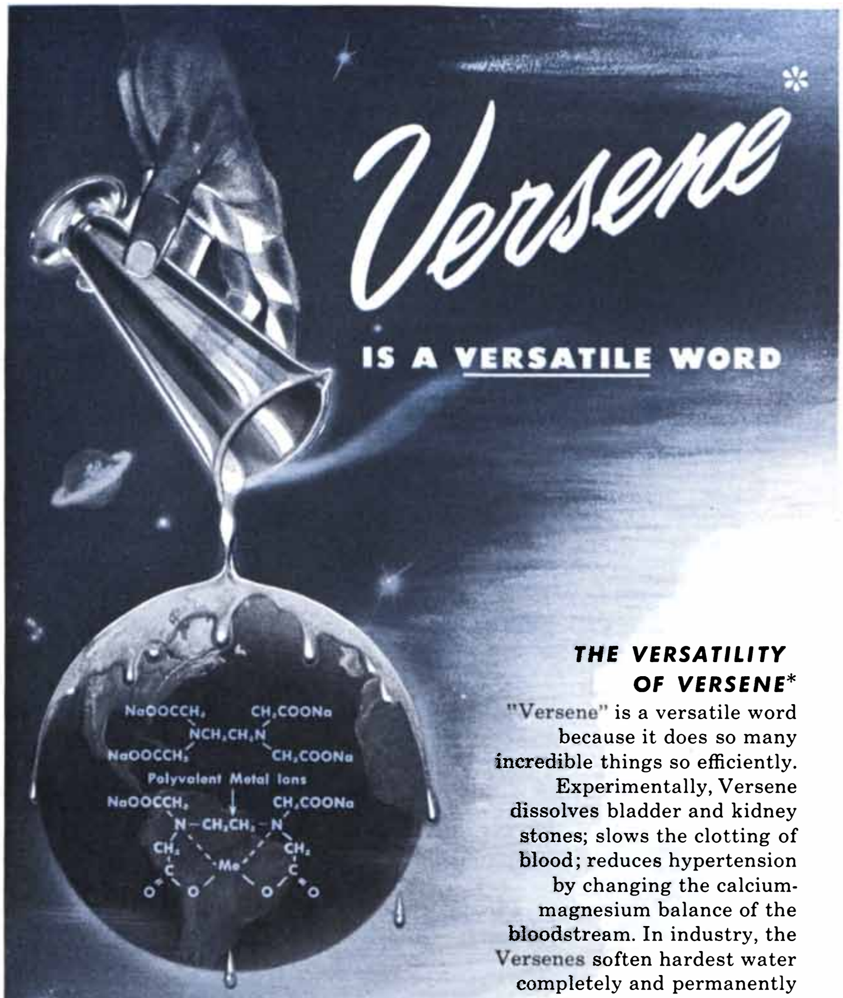
Anything that happens—even an opened door — is reported to the nearest attended station instantly.



Coast-to-coast *Radio-Relay* shows again how scientists at Bell Telephone Laboratories help your telephone service to grow steadily in value to you and to the nation.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields.



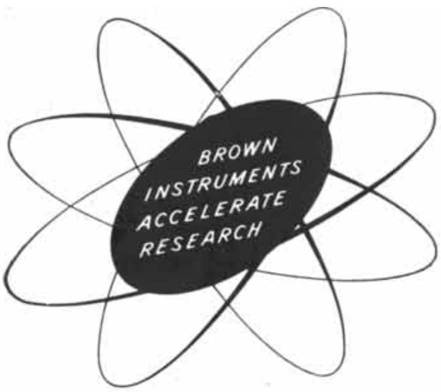
nist sees such an abundance of illustrations, no cumulative selection would even be possible."

FEBRUARY 1852. "Prof. Faraday delivered a lecture before the Royal Institution, London, on the 23rd ult., on a method of measuring the force of magnetic powers with precision and certainty."

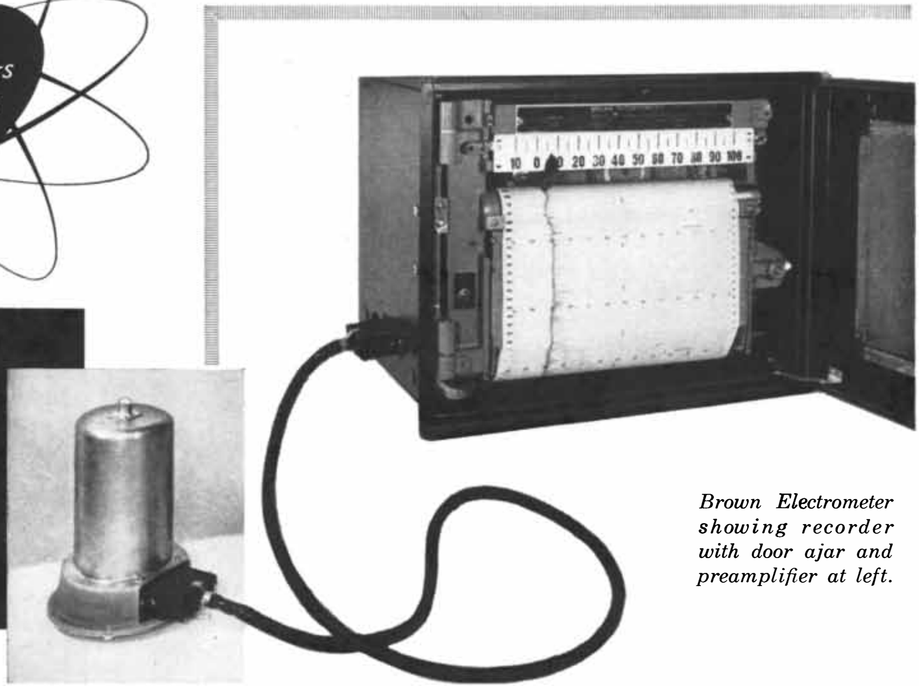
"At the last meeting of the London Geographical Society, Lieut. Osborne, a member of one of the British Arctic expeditions, argued, at some length, in support of the existence of a great Polar Ocean. He said that in Wellington Channel he had observed immense numbers of whales running out from under the ice, a proof that they had been to water and come to water, for every one knew they must have room to blow. He further said that there were almost constant flights of ducks and geese from the northward, another proof of water in that direction, since these birds found their food only in such water. Moreover, while in Baffin's Bay the tide made for the southward, coming from the Atlantic, in Barrow's Straits it made for the northward, which could only be explained on the hypothesis of a sea in that direction."

"There are two classes of geologists—one class believes in the deity of matter; the other in the Infinite Great Deity and Intelligent Creator of all matter. Prof. Oken, and others, have taught the doctrine that all life is progressive—that it commenced at a point, and, through a long series of ages, step by step, arose from the lowest conceivable points of life. It is even asserted that the primary man was a dolphin—and all such nonsense. This class of geologists, as a fundamental proof of the correctness of their theory, stated that no animals of a high class of intelligence had ever been found in the Old Red Sandstone formations. Two courses of lectures have been delivered in this city on geology: the one by Dr. Antisel and the other by Prof. Guyot, of Cambridge, Mass. It had been said that Dr. Antisel inculcated the doctrine that geology contradicted the Mosaic account of the Creation; and that Prof. Guyot was brought here to prove that geology harmonized with the Scriptures—that it agreed literally with the first chapter of *Genesis*."

"Encke's comet, which has recently made its reappearance, has the striking peculiarity that its orbit and periodic times are gradually decreasing. This comet, it is said, 'is certainly falling towards the central luminary,' actually drawing nearer at every revolution. Sir John Herschel believes 'that it will ultimately fall into the sun.'"



THE BROWN ELECTROMETER



Brown Electrometer showing recorder with door ajar and preamplifier at left.

for measuring and recording currents as low as 10^{-15} amperes

Electrical Characteristics

- Full Scale Current Ranges Available: 10^{-13} amperes with 10^{11} ohm resistor, and selector switch adjustment for full scale of 10^{-12} or 10^{-11} amperes. Using other resistors, full scale current ranges up to 10^{-7} amperes can be supplied with selector switch adjustment up to 10^{-5} amperes.
- Input Resistor: 10^{11} ohms for most sensitive current measurement. (Also supplied in values down to 10^{5} ohms.)
- System Accuracy: Approximately 1 per cent of scale.
- Zero Drift: Should not exceed 0.3 millivolt per day.
- System Noise: Approximately 5 microvolts.
- Instrument Speed of Response: Available for either 24, 12, or 4½ seconds full scale.
- Maximum Speed of Response Using 4½ Second Instrument Speed: 5 seconds for 90 per cent of change, with preamplifier located at source.
- Power Supply: 115 volts, 60 cycles. Also dry cell supplied in instrument.
- Power Requirements: 65 watts.

ACCURATE measurement of extremely small currents is accomplished in this instrument through the use of a null balance servo system and a-c amplifiers that prevent drift and consequent instability. It is the only such system that incorporates a recorder as an integral part of the circuit. Designed to measure and record minute currents in ionization chambers, the Brown Electrometer may be used in any application where currents as low as a billionth of a microampere are encountered.

Features of the instrument include a special power supply to prevent false measurements from stray signals which might originate in an a-c power source . . . vibration frequency carefully selected to prevent phase shift . . . and automatic standardization of voltage across the slide-wire.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* 4580 Wayne Ave., Philadelphia 44, Pa.

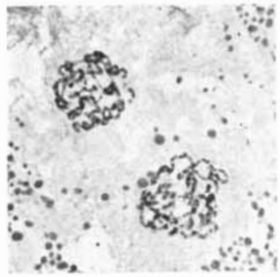
MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

H HONEYWELL

First in Controls

● *Important Reference Data*

Write for Data Sheet No. 10.0-4 . . . and for Bulletin No. 15-14. For valuable information on analytical and research instrumentation.



THE COVER

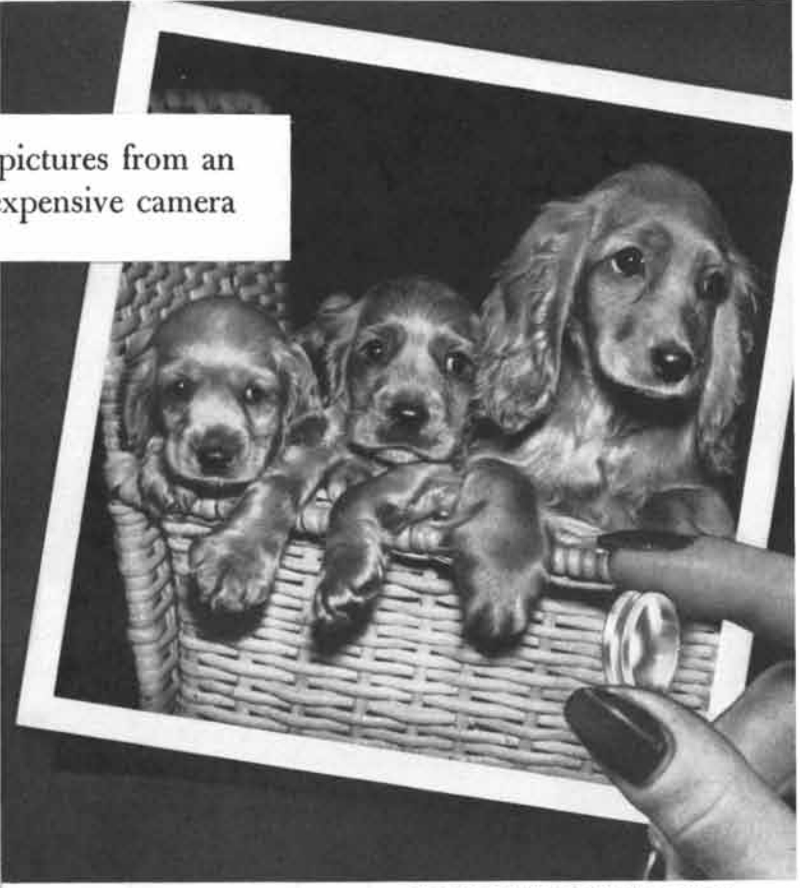
The two tangled red objects in the photomicrograph on the cover are sets of chromosomes from two cells of a fruit fly, the celebrated experimental animal of genetics. The chromosomes have been stained red to make them more visible under the microscope; for the same reason the protoplasm around them has been smeared and stained blue. Each set of chromosomes bears a complete assortment of the fruit fly's units of heredity. The hereditary units of man are similarly aligned on his chromosomes (*see page 68*). The slide from which the photograph was made was prepared by Helen Gay in the laboratory of Berwind P. Kaufmann at the Department of Genetics of the Carnegie Institution of Washington.

THE ILLUSTRATIONS

Cover photograph by Keturah Blakely

Page	Source
15	U. S. Bureau of Mines
16	Sara Love
17	U. S. Bureau of Mines
18	Sara Love
19	U. S. Bureau of Mines
20	The Glenn L. Martin Company
21	Douglas Aircraft Company, Inc.
22	Eric Mose
23	Official U. S. Navy Photograph
24-25	David E. Scherman
27	Dwinell Grant
28	David E. Scherman
44	Mount Wilson and Palomar Observatories
45	Sara Love
46	Mount Wilson and Palomar Observatories
47	Sara Love
48-50	Mount Wilson and Palomar Observatories
53-56	C. N. Jones, Jr.
58-59	National Bureau of Standards
60	Sara Love
61-64	Courtesy Theodore H. Ingalls
69-70	Donald Moss
85-87	Roger Hayward

PROBLEM: Sharp pictures from an inexpensive camera



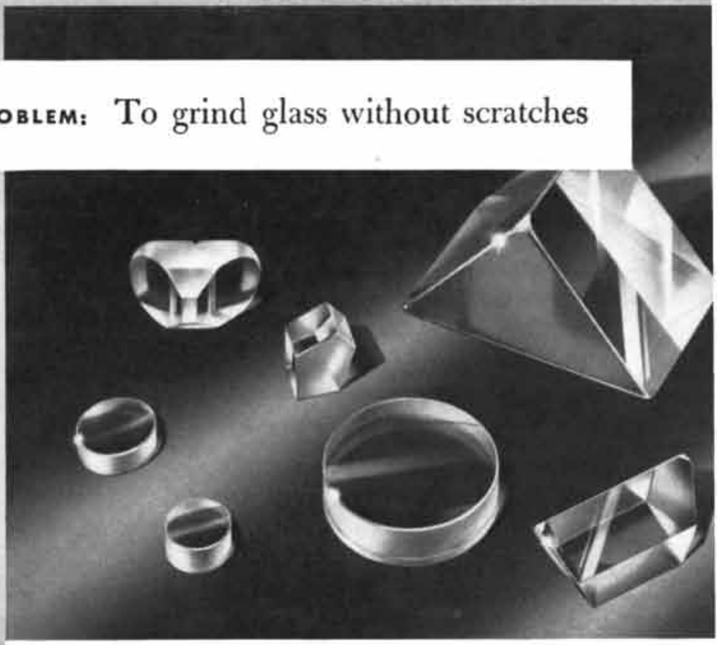
PHOTOGRAPHED WITH A BEACON 225 CAMERA

ANSWER: On request, American Optical recently designed, and is now producing, a new exclusive doublet lens which is being used in the inexpensive Beacon Camera. Enlargements from 2¼″ x 2¼″ are pleasantly sharp. A half million Beacon Cameras have been sold. Write us about your development problems. Address American Optical Company, 211 Vision Park, Southbridge, Massachusetts.

PROBLEM: To stare at a welder's torch and not go blind

ANSWER: Research indicates that ultraviolet and infrared are the villains that cause welder's keratitis or "flash eye," a painful condition brought about by looking at a welder's torch. To keep welders' eyes cool and safe, American Optical scientists developed Novi-weld glass, which absorbs 98 per cent of the ultraviolet and infrared rays.

PROBLEM: To grind glass without scratches



ANSWER: Poorly graded abrasives cause scratches on glass, hard to polish out. The abrasives we use are made from natural crystals, generally hexagonal in shape—not splinters that dig and scratch. Our centrifugal grading process guarantees uniformity of particle size to 1/5000 of an inch.

American Optical

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR FEBRUARY 1952 VOL. 186, NO. 2

ARTICLES

DEPARTMENTS

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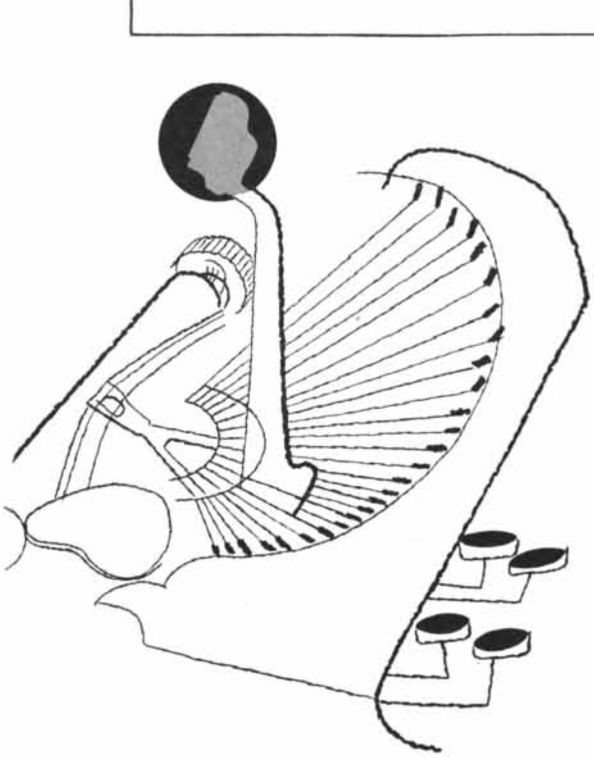
What's Happening at CRUCIBLE

about special shape type steel

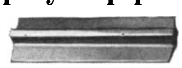


Crucible special purpose steel for type character application

The development of cold rolled special shape type steel is one of Crucible's important contributions to the business machine industry. A major part of the type characters used for the manufacture of typewriters are made from this special shape.

Here's the step-by-step process:

1. Cold rolled special shape produced by Crucible.



2. The type slug cut from the special shape material.

3. The wings of the type slug are bent down and taper formed toward the edges.

4. The type characters are cold swadged on the solid edge of the bent type slug.

5. The flash trimmed off after the swadging operation.

6. The finished type ready for hardening, plating and soldering to the type bar.

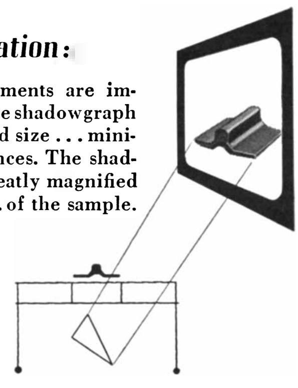
The production of Crucible steel for this job is the result of engineering and practical know-how combined with a special method of manufacture to assure a homogeneous microstructure for maximum forming properties, excellent surface characteristics for good die life, and close accuracy control for all dimensions of the shape.

The production of type steel requires the use of small precision rolling mills equipped with shaped rolls and operated by skilled workmen. During preliminary and final inspection, shadowgraph equipment is constantly used to check for size accuracy.

As a result of its outstanding quality, Crucible's special shape type steel is constantly in demand and used by leading typewriter manufacturers.

Shadowgraph Operation:

Since micrometer measurements are impractical due to the shape, the shadowgraph is used to measure shape and size . . . minimum and maximum tolerances. The shadowgraph is a projection, greatly magnified . . . on a calibrated screen . . . of the sample.



Schematic of shadowgraph

If you have a requirement for special steels—check with Crucible. Feel free to draw on the experience of our metallurgists and engineers. Crucible Steel Company of America, General Sales and Operating Offices, Oliver Building, Pittsburgh, Pa.

CRUCIBLE first name in special purpose steels

52 years of Fine steelmaking

Midland Works, Midland, Pa. • Spaulding Works, Harrison, N. J. • 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

SCIENTIFIC AMERICAN

FEBRUARY 1952 VOL. 186, NO. 2

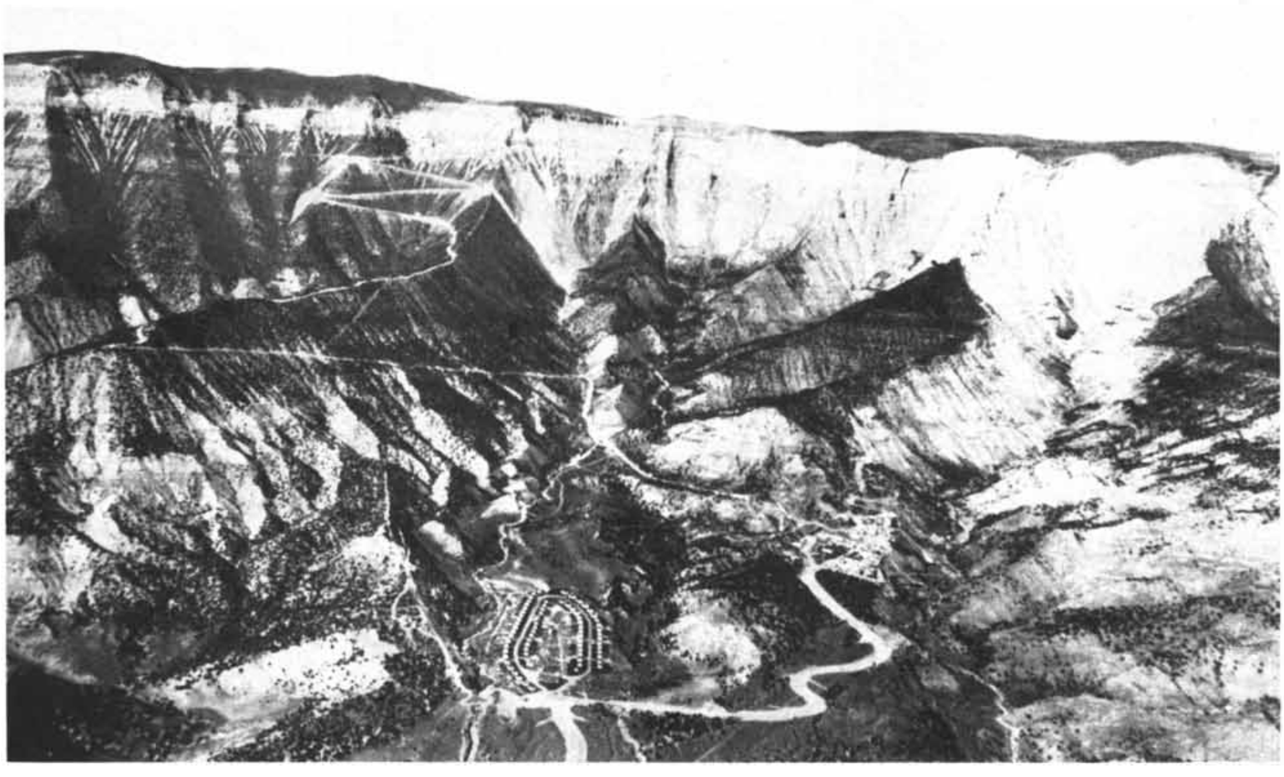
Oil from Shale

U. S. formations of the rock contain far more fuel and chemicals than our entire known reserve of petroleum. Some recent studies show that one such formation could be economically mined now

by H. M. Thorne

A HUNDRED years ago over 90 per cent of the fuel needs of the U. S. was supplied by wood. By 1920 coal had supplanted wood and furnished 78 per cent of our demand. Today petroleum and natural gas have surpassed coal and supply more than half of all our fuel energy, coal accounting for somewhat less than 40 per cent. As Eugene Ayres pointed out in his excellent article on "The Fuel Problem" in the December, 1949, issue of SCIENTIFIC AMERICAN, we must now begin to look for other sources of liquid fuel. In 1950 we used an average of 6.5 million barrels of oil per day, while we produced only 5.9 million barrels per day; we are already forced to import about a million barrels a day from foreign fields. The present Iranian situation underlines the precariousness of foreign sources of supply, and it is clear that in the event of war we would be very hard pressed to meet our military needs for oil.

As a result this nation is now giving intensive study to processes for manufacturing liquid fuels from resources such as oil-shale and coal, of which we have an abundant supply. This article will report the progress made in the investigation of oil-shale, which Howard G. Vesper, president of the California Research Corporation, recently described as "the most attractive of the synthetic alternates at present." Oil-shale could provide not only the various liquid fuels we need but also many of the chemicals now obtained as by-products from petroleum; indeed, oil-shale is a better source of some of these by-products than is petroleum. It could, for



DEMONSTRATION PLANT of the Bureau of Mines is beneath the oil-shale cliffs near Rifle, Col. The plant is at lower right center; its residential area, at lower left center. Shale is brought from a mine at upper left.

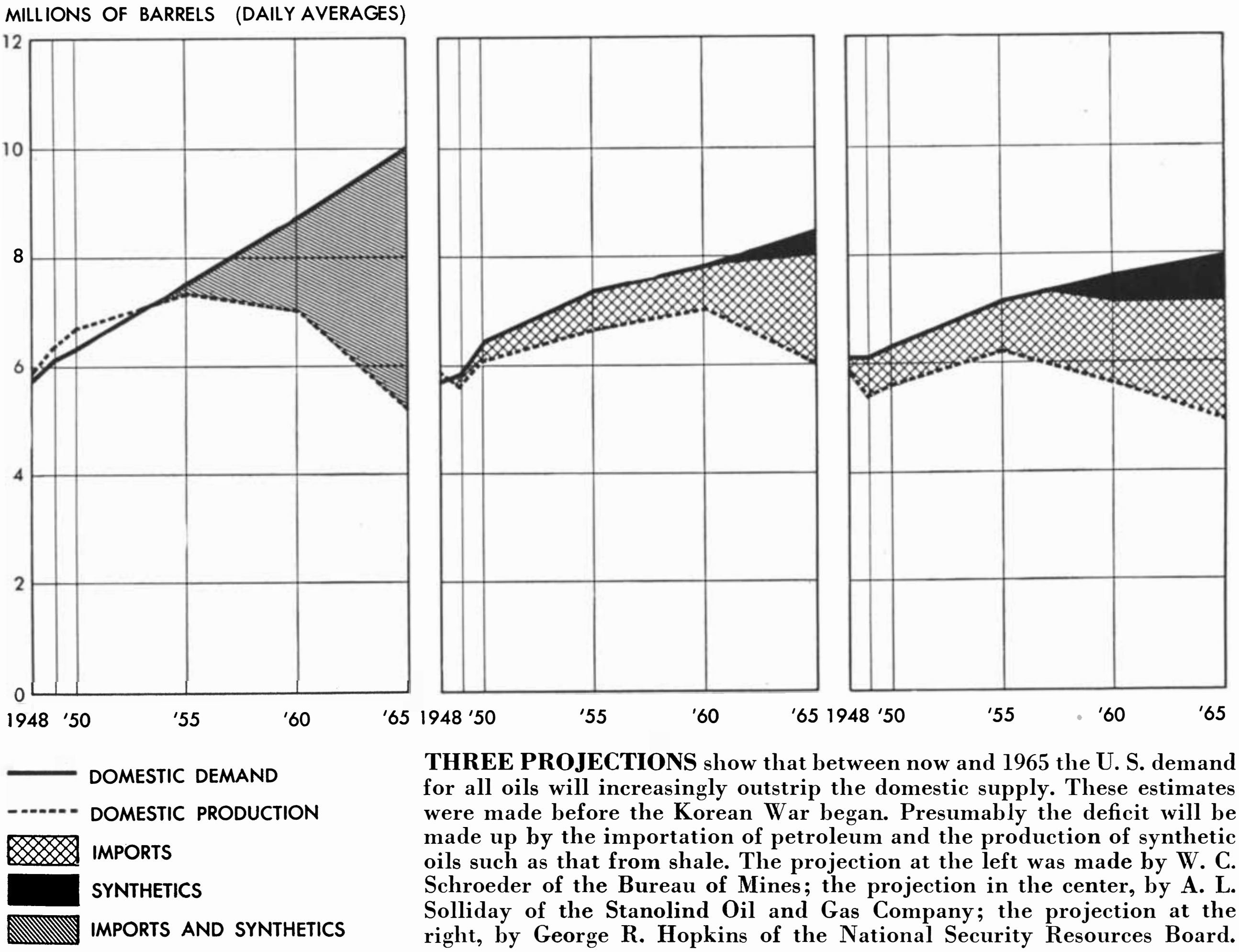
example, furnish large quantities of benzene, a chemical for which the demand is much greater than the supply and which is steadily growing in importance to our industrial economy.

Oil-shales are known to occur in some 25 states in this country. In an area of the Rocky Mountains that covers parts of Colorado, Utah and Wyoming lies the largest known oil-shale deposit in the world. The shales of the Green River formation, comprising 16,500 square miles of this area, are estimated to contain the equivalent of a trillion barrels of oil. In one area northwest of Rifle, Col., the most thoroughly investigated by core drilling and assaying, there is a continuous bed of shale 1,000 miles square and about 500 feet thick, with an average assay of 15 gallons of oil a ton—the equivalent of 500 billion barrels of shale-oil in place. This is 17 times our total known reserves of petroleum and 12 times as much oil as this nation has produced up to now. The lower part of this formation, known as the Mahogany ledge, alone contains 20 times as much recoverable oil as the East Texas field, by far the largest oil field in the U. S. The Mahogany ledge, whose shale is capable of yielding an average of better than 25 gallons of oil per ton, is considered to be the most likely oil-shale bed to be mined commercially in the near future.

About 50 million years ago the present Green River area was covered by two large fresh-water lakes, surrounded by high hills. Over a period of five to eight million years erosion from the hills deposited sediments in the lakes to a depth of 3,000 feet. The deposits contained a great deal of organic matter from plants and possibly from aquatic animals. They eventually hardened into the tough mudstone or marlstone known as oil-shale. Movements of the earth's crust later elevated portions of the beds to about 9,000 feet above sea level. Streams and rivers then cut deep into these formations, producing almost vertical cliffs and exposing cross-sections of the oil-shale strata.

An investigation of the oil-yielding possibilities of these shales began after Congress passed the Synthetic Liquid Fuels Act of 1944, which authorized the Secretary of the Interior through the Bureau of Mines to look into production of synthetic liquid fuels from oil-shales, among other sources. The Bureau assigned laboratory research and development work to its experiment station at Laramie, Wyo., and built an Oil Shale Demonstration Plant near Rifle, Col., for pilot-plant studies of mining, retorting and refining. Various industrial organizations and educational institutions also undertook research and processing work on oil-shale, both independently and in cooperation with the Bureau.

Oil-shales contain no oil as such: what they hold is an organic material called "kerogen," which can be decomposed into shale-oil and other products by heating. The first step in oil-shale operations is mining the shale. Since the rock yields only about 12 per cent of oil by weight, the mining must be done at low cost to make oil production practicable. Fortunately the Green River oil-shales are flat-lying, relatively thick and extensive, so it is possible to use machinery and mass-production mining methods. The Bureau mining engineers have developed highly efficient mechanized equipment and have been able to adapt many surface-mining practices to the underground operations; the operating mine is referred to as an "underground quarry." From tunnels driven into the top half of the Mahogany ledge drillers equipped with a specially designed multiple drill bore horizontal



THREE PROJECTIONS show that between now and 1965 the U. S. demand for all oils will increasingly outstrip the domestic supply. These estimates were made before the Korean War began. Presumably the deficit will be made up by the importation of petroleum and the production of synthetic oils such as that from shale. The projection at the left was made by W. C. Schroeder of the Bureau of Mines; the projection in the center, by A. L. Solliday of the Stanolind Oil and Gas Company; the projection at the right, by George R. Hopkins of the National Security Resources Board.

blast holes into the rock, and approximately 1,700 tons of shale is blasted loose from the heading at once. The shattered shale is loaded by a three-yard electric shovel into 15-ton Diesel trucks, which transport it to the crusher. The bottom half of the ledge is mined as a bench by drilling vertically and blasting from the floor of the top level. A portable, telescopic platform that can be elevated from floor level to a position 65 feet above the floor permits inspection and scaling of loose rock from the roof or pillar walls at any level of the mine. Pillars 60 feet square are left at intervals in the mine to support the roof. At an advanced stage of mining the Mahogany ledge would become a honeycomb of rooms 73 feet high and 60 feet wide, the roof stone and overlying beds being supported by the pillars of shale, representing 25 per cent of the original rock.

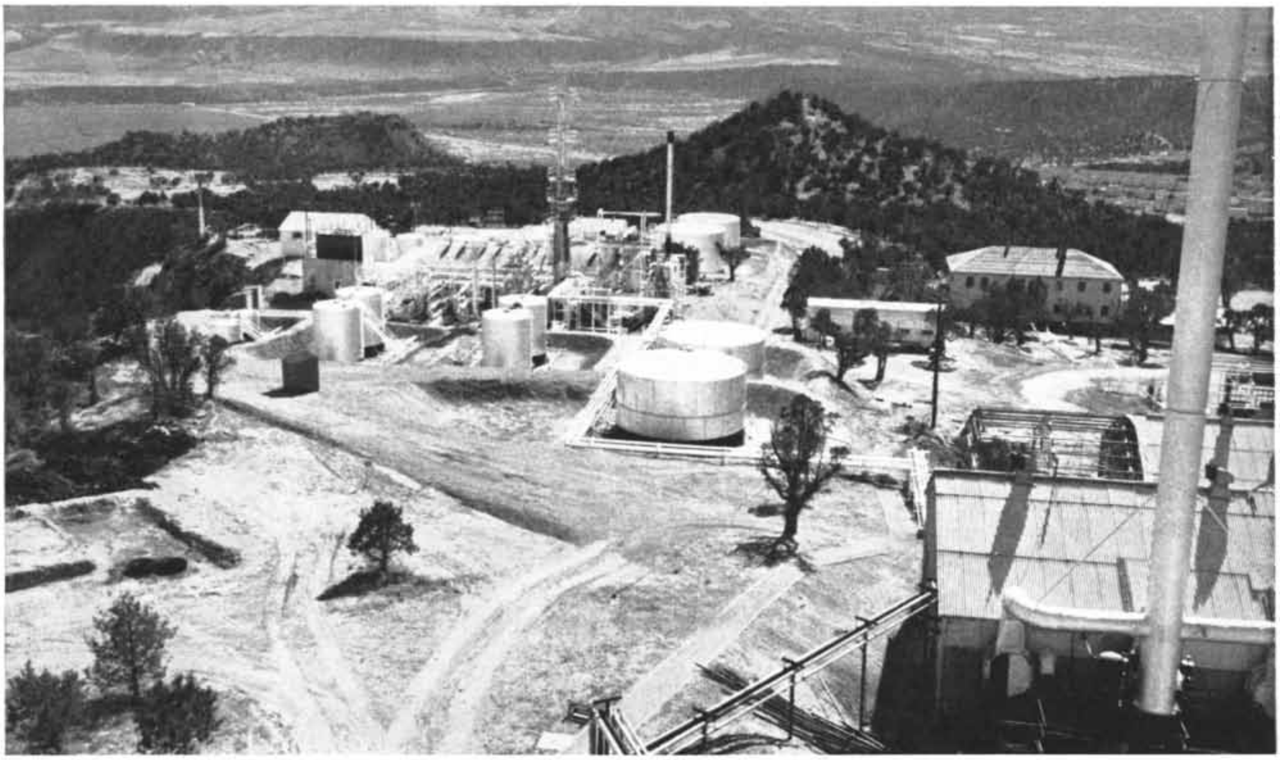
The goal of this project was to demonstrate that shale could be mined for 50 cents a ton. In spite of large increases in labor and equipment costs during the past few years, it has been shown that the Mahogany shale can be not only mined but crushed and conveyed to the retort stockpile for 48 cents a ton, not counting real-estate depletion, interest on investment, profit or expenditures for off-site facilities. The continuing research should further reduce the mining costs.

After mining, the next step is to extract the oil from the shale. For this it is only necessary to heat the shale to about 900 degrees Fahrenheit and separate and condense the oil vapors. Fortunately the procedure also yields combustible gases and a carbonaceous residue that can be burned to provide heat for the retorting operation. The Bureau of Mines and several companies are testing a number of different types of retorts for extracting oil from shale. The principles and objectives involved can best be illustrated by a brief description of a very promising retort now being operated as a pilot plant by the Bureau at Rifle, Col.

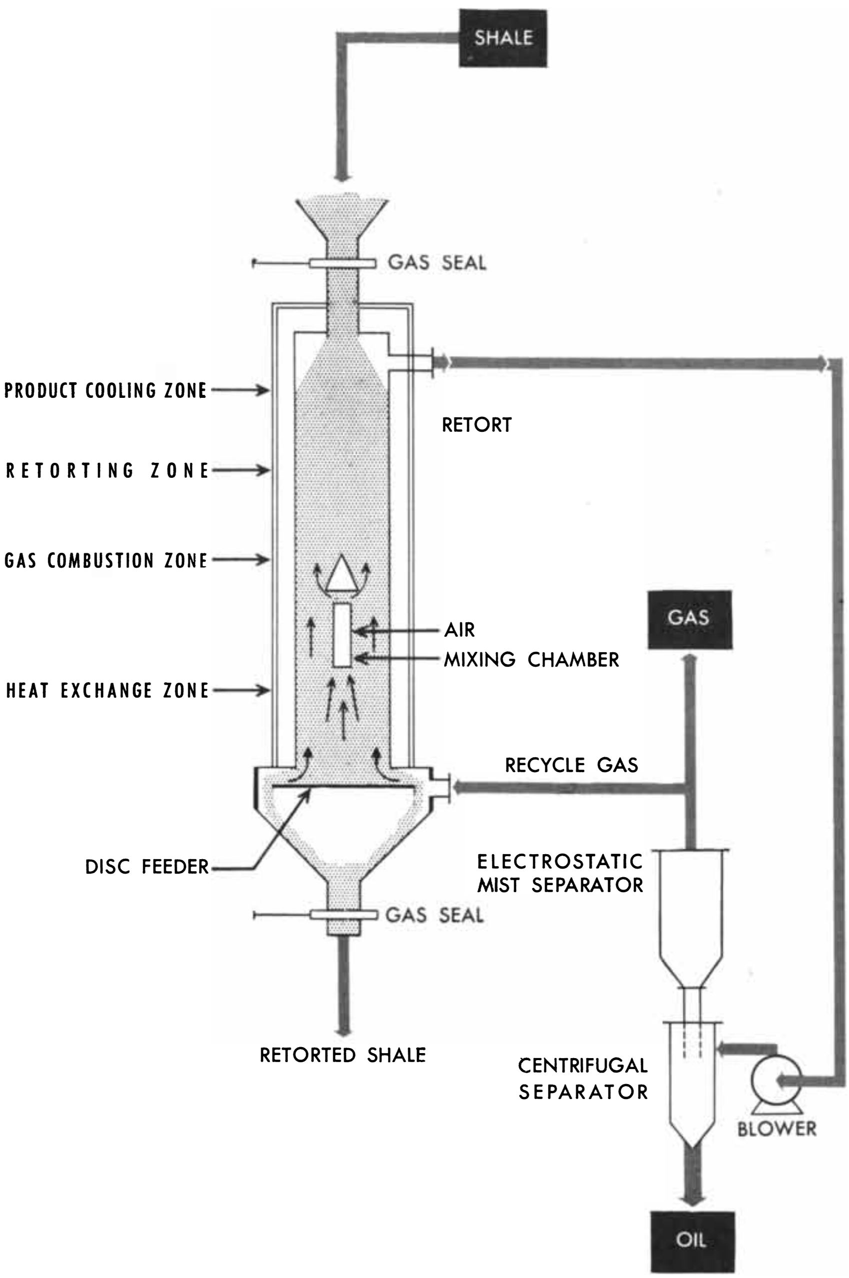
This unit is known as the "gas-combustion retort" (*see drawing on the next page*). It involves a two-way feed. From a hopper above crushed raw shale flows down into the retort. About halfway down the retort the shale is heated by hot combustion gases generated by burning recycled gas with air inside the retort. This recycled gas, a product recovered from heating of the shale, has been fed in at the bottom of the retort and preheated by flowing up through the hot spent shale. Some of the heat in the combustion chamber also is supplied by burning of part of the carbonaceous residue on the retorted shale.

The products from the heated shale—oil vapor and combustible gas—move up to the top of the retort, being cooled on the way by the cold shale flowing in. They pass out of the retort as a mist, which is picked up by a gas blower and blown into a centrifugal separator. There most of the oil is separated from the gas stream. Any oil remaining in the stream is recovered in an electrostatic mist separator. Part of the gas stream is then recycled to the retort; the rest is either vented or used as a source of heat or power.

The recovered oil is now ready for refining. In the main the refining of crude shale-oil is not too different from that of petroleum, but the processes must be adapted to the peculiar characteristics of the various shale-oils. A typical Colorado shale-oil produced by the gas-combustion retort meets the specifications for No. 6 heavy fuel oil without further processing, and a domestic distillate fuel can be obtained from it by simple distillation. But it contains 0.6



REFINERY at the Bureau of Mines Demonstration Plant fractionates the oil extracted from shale. In one refining procedure tested at the Demonstration Plant the crude oil obtained by retorting shale is distilled to yield 15 per cent gasoline, 25 per cent light gas oil, 55 per cent heavy gas oil and 5 per cent coke. The heavy gas oil is then cracked at 840 degrees Fahrenheit and 300 pounds per square inch to yield 23 per cent gasoline, 5 per cent light gas oil, 5 per cent residual fuel oil and 19 per cent heavy pitch. When the gasoline produced by these operations is passed over a catalyst with hydrogen at 900 degrees F. and 1,000 p.s.i., its octane number is increased and its content of sulfur and nitrogen reduced. The light gas oil from the coking process can be treated to make a satisfactory Diesel fuel; the light gas oil from the cracking process is a suitable domestic heating fuel.



GAS-COMBUSTION RETORT is one method of extracting oil from shale. The retort is heated by burning part of the gas generated by the process.

per cent sulfur and 2.1 per cent nitrogen, and it yields less than 2 per cent gasoline on distillation. To produce high-quality motor, jet or Diesel fuels from this material requires rather extensive refining. The research studies have provided much information on the necessary refining methods and have disclosed many of the idiosyncrasies of shale-oil. For example, the nitrogen in shale-oil inhibits the activity and usefulness of common cracking catalysts. On the other hand, hydrogenation of shale-oil at low pressures (1,000 to 1,500 pounds per square inch) has been found effective in reducing the nitrogen and sulfur content of its products.

About a year ago the Bureau of Mines made a cost analysis of the feasibility of operating a complete plant—mining, retorting and refining—and distributing the products in the Rocky Mountain area. The refining procedure was based on refining operations at the Demonstration Plant and Research Laboratories and the actual yields and quality of products obtained from these operations. By this method crude shale-oil produced by gas-combustion retorting is distilled continuously to coke by a delayed coking operation. It yields 15 per cent gasoline, 25 per cent light gas oil, 55 per cent heavy gas oil and 5 per cent coke. The heavy gas oil is thermally cracked by a recycle operation, and from it comes 23 per cent gasoline, 5 per cent light gas oil, 5 per cent residual fuel oil and 19 per cent heavy pitch. The gasoline from the coking and recycle-cracking operations is passed with hydrogen over a catalyst at 900 degrees F. and 1,000 p.s.i. pressure; this reduces its sulfur and nitrogen content and produces a good-quality motor fuel. The light gas oil from coking, treated with 12 pounds of sulfuric acid per barrel, yields a satisfactory Diesel fuel, and the light gas oil from cracking is a suitable domestic heating fuel. The residual oil from recycle cracking can be blended with the residue from gasoline redistillation to produce an industrial fuel oil. The pitch from the process may have a good market in the steel industry for manufacturing metallurgical coke.

Based upon these refining operations and the present prices of products in the Rocky Mountain area, a refinery using 11,700 barrels a day of crude shale-oil would produce 600 barrels of premium-grade gasoline valued at 15 cents a gallon, 3,200 barrels of regular-grade gasoline at 14 cents a gallon, 2,340 barrels of Diesel fuel at 10 cents a gallon, 530 barrels of heating oil at 10 cents a gallon, 850 barrels of residual fuel oil at $2.25 a barrel, 370 tons of pitch at $22.50 a ton and 95 tons of coke at $8.50 a ton. The total value of the daily product from this scale and type of operation would be $45,650, while the daily operating costs, including mining, retorting and refining, are estimated to be $29,410. A plant of this type would require an estimated capital investment of $32,300,000. It appears that such a plant, netting $16,000 a day on operations, could amortize its investment in a relatively few years.

The National Petroleum Council, an industrial advisory group to Secretary of the Interior Oscar L. Chapman, made an independent study of synthetic liquid-fuel costs at the Secretary's request. Its estimate of the cost of obtaining fuel from oil-shale was based on the Bureau's mining method and on retorting and refining methods proposed by the Union Oil Company of California. A special committee of the Council concluded, in a report published recently, that gasoline could be produced at the refinery at 14.7 cents a gallon. This compares not too unfavorably with gasoline from petroleum, for which the wholesale price at the refinery in California is now 12 to 13 cents a gallon.

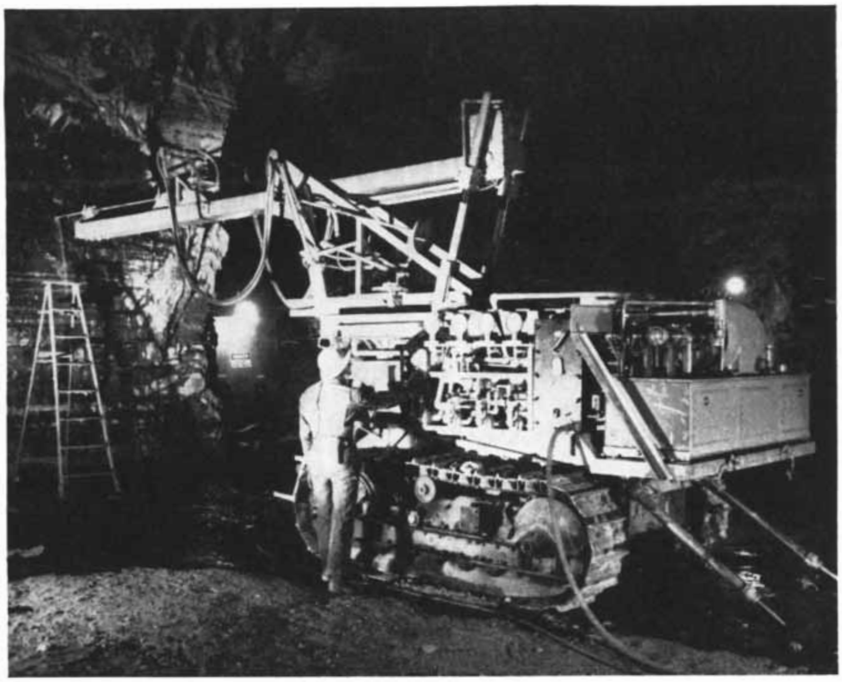
The Bureau of Mines has made an estimate of the cost of producing gasoline and other fuels from the same daily input of shale as that used by the Council. Based on somewhat different methods and conditions, this estimate of the cost of producing gasoline for sale in the Los Angeles area is a little lower than that arrived at by the Council.

As has been mentioned, oil-shale will be quite as important a source of chemicals as of fuels. For obtaining high yields of critical chemicals the Bureau's research laboratories at Laramie are developing an interesting new process for retorting shale. This process requires rapid heating of the raw shale to high temperatures, ranging from 1,200 to 1,800 degrees F. It is accomplished by using shale crushed into small particles; the process is particularly attractive because it can utilize the 5 to 10 per cent of shale fines usually discarded as waste in normal retorting operations.

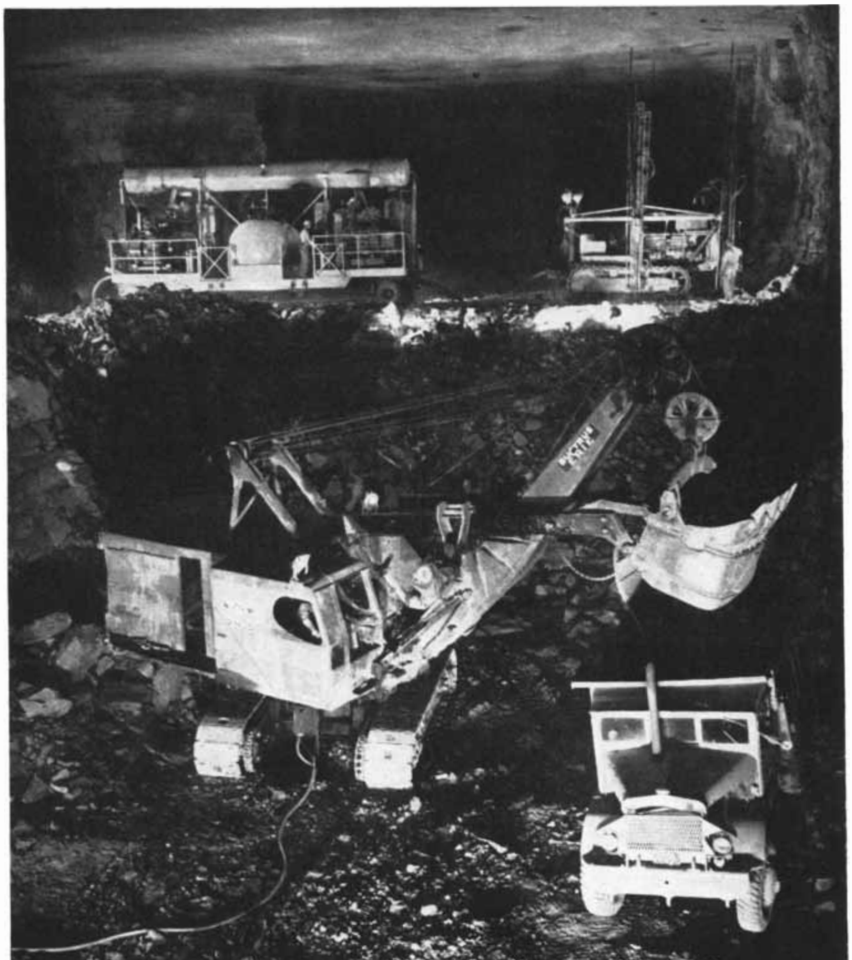
A high-temperature retorting unit, operating in conjunction with a normal retorting plant, would yield a crude oil containing about 40 per cent of a highly aromatic gasoline with an octane rating of 100, which would be valuable as a blending stock to upgrade the gasoline obtained from refining the crude oil from the normal-retorting part of the plant. But considering the present critical need and high market value of chemicals, it seems more desirable to recover and purify the individual chemicals. Based on the results of small pilot-plant experiments, it is estimated that a plant retorting 20,000 tons of average shale a day would produce annually 14 million tons of benzene, 5.3 million tons of toluene, 3.2 million tons of xylenes, 1.3 million tons of solvent naphtha, 39 million tons of ethyl alcohol, 2 million tons of ethyl ether, 800,000 tons of crude tar acids and 25 million pounds of naphthalene. All of these represent substantial percentages of our present annual consumption of these chemicals; the estimated benzene production, for example, would be some 8 per cent of our total supply of benzene in 1949, and the ethyl alcohol output would be 24 per cent of our 1949 consumption of that commodity. It is estimated that a commercial plant to manufacture these quantities of products, including the mine, retorts and facilities for purification and other processes, would cost about $55 million. Its total daily output would be worth $160,000 at present market prices, and its operating cost would be about $50,000, indicating a short payout time for such a plant.

Thus it would appear that a commercial oil-shale operation to produce fuels for a limited area or chemicals of which we have critical need is already feasible. Certainly additional research and development work should result in more economical processing methods and improvements in the quality of the products, narrowing further the differential between the costs of fuels from oil-shale and petroleum. It seems evident that we need not worry about our future source of fuels or chemicals.

H. M. Thorne is Chief of the Oil-Shale Research Branch of the Bureau of Mines in Laramie, Wyo.



EXPERIMENTAL DRILL is used to make holes for blasting in the mine of the Demonstration Plant. One blast can loosen some 1,700 tons of shale.



ELECTRIC SHOVEL loads a 15-ton truck in the Demonstration Plant mine. The mining operation cuts rooms 60 feet wide and 73 feet high in the shale.

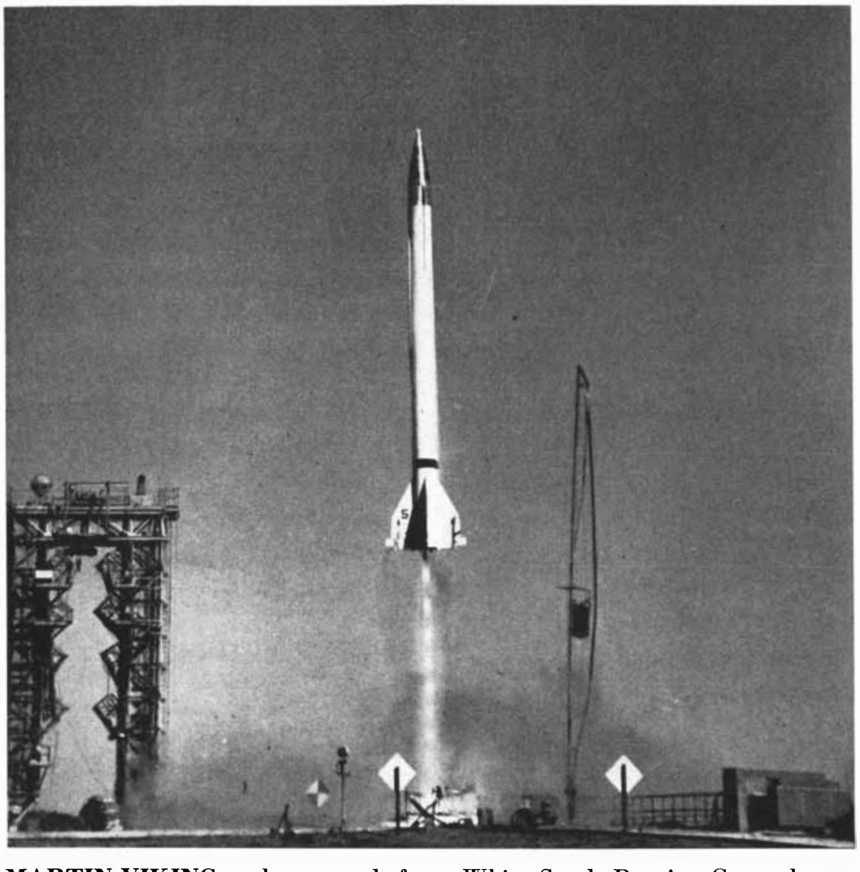
Flight at the Borders of Space

As aircraft and missiles attain higher and higher altitudes the question arises: Where, for practical purposes, does the atmosphere of the Earth end and interplanetary space begin?

by Heinz Haber

MAN'S CONQUEST of space will not be a single, crossing-the-Rubicon event. Long before the first Earth-dweller makes a landfall on the Moon, there will be other firsts. Many of these milestones have already been passed, and in a sense man is even now probing across the borders of space. In a recent experimental flight the Douglas Skyrocket, a pilot-carrying craft with a rocket motor, rose to an altitude where more than 96 per cent of the Earth's atmosphere lay below the pilot's feet. An unmanned two-stage rocket has climbed to 250 miles above the Earth's surface—at which height air molecules are rarer than in the best man-made vacuum.

To be sure, even at an altitude of 250 miles the missile had not yet passed entirely beyond the boundaries of this planet's atmosphere. At that height and even higher there are still enough air molecules to produce auroras. Moreover, no man-made rocket has yet achieved more than one third of the speed (about five miles per second) necessary to permit it to circle our planet permanently as an artificial satellite. Nevertheless, at an altitude of 250 miles the Earth's atmosphere for all practical purposes no longer exists, so far as effects on the rocket are concerned. For a few minutes at the top of its flight the unmanned 250-mile rocket was a true spaceship.



MARTIN VIKING rocket ascends from White Sands Proving Ground near Las Cruces, N. M. A rocket of this type has attained an altitude of 137 miles, a record for single-stage missiles. A two-stage rocket has risen 250 miles.

The boundary of the upper atmosphere is difficult to define. The frontier is commonly considered to be at about 600 miles, the limit at which the aurora borealis, the highest atmospheric phenomenon, is observed. But this definition has no significance for rocket flight or aviation. For fliers and rockets the critical boundaries are the levels at which the air becomes too thin for breathing, for filtering out cosmic radiations, for a balanced heat exchange or for affording a plane mechanical support. These borders come at different heights, and we have already passed several of them. In other words, our manned ships and guided missiles are already being exposed to some rigors that will not grow any worse no matter how much farther we go. Thus the conquest of space has truly begun.

Naturally most of the data on the performances of the newest rocket craft and planes must remain secret for reasons of national security. The problems of high-altitude flight are, however, accessible to public discussion.

THE U. S. Air Force requires crew members to use their oxygen equipment as soon as they reach an altitude of 8,000 to 10,000 feet. This furnishes a considerable safety margin, for nobody will collapse from lack of oxygen below 20,000 feet. At about 10,000 to 12,000 feet, however, people begin to show symptoms of altitude sickness. For example, a person who walks around or takes any mild exercise at the 13,000-foot-high saddle point of Independence Pass, near the town of Aspen on Colorado State Highway 82, soon finds himself short of breath and may even become dizzy. By gradual acclimatization over periods of months or years people may adapt themselves to live at altitudes as high as 25,000 to 28,000 feet, as explorers training to climb the Himalayas have done. But a pilot suddenly exposed to the rarefied air at 25,000 feet will lose consciousness within three or four minutes. This is the so-called "time of useful consciousness" that a flier has for taking action to save his life, by dropping to a lower altitude or restoring the oxygen pressure in some other way.

As we go higher, the time of useful consciousness becomes shorter and shorter. At 30,000 feet it is only one minute, and at 50,000 feet it dwindles to 11 to 18 seconds. Beyond that height, however, it apparently does not decrease further. In experiments in the low-pressure chamber the time of useful consciousness levels off and stays at an average of 15 seconds up to a simulated altitude of 55,000 feet. There is no reason to believe that the time span would be shorter at higher altitudes; indeed, a theoretical analysis shows that 50,000 feet should be the critical altitude. The reasoning is as follows: At any altitude the air in the lungs has a different composition from that of the atmosphere outside the body. In the atmospheric air at sea level, where the total pressure is 760 millimeters of mercury, nitrogen accounts for about 580 millimeters of the pressure, oxygen for 150 mm., water vapor for 23 mm. and argon for 7 mm., while the proportion of carbon dioxide is negligible. In the lungs, on the other hand, the proportions are: 570 mm. of nitrogen, 106 mm. of oxygen, 47 mm. of water vapor, 40 mm. of carbon dioxide and 7 mm. of argon. The extra carbon dioxide and water vapor in the lungs comes from the blood by evaporation. Now as we go up to higher altitudes, the partial pressures of the gases in the air drop off; in other words, we have less and less oxygen and nitrogen to breathe. But the water vapor and carbon dioxide in our lungs stays practically constant at about 80 to 87 mm. of pressure. Obviously when we reach an altitude where this pressure is greater than the total pressure of the outside air, the capacity of our lungs will be claimed exclusively by the water vapor and carbon dioxide streaming profusely from our blood, and the lungs will be unable to take in any oxygen at all. The body must then live on the oxygen previously stored in the

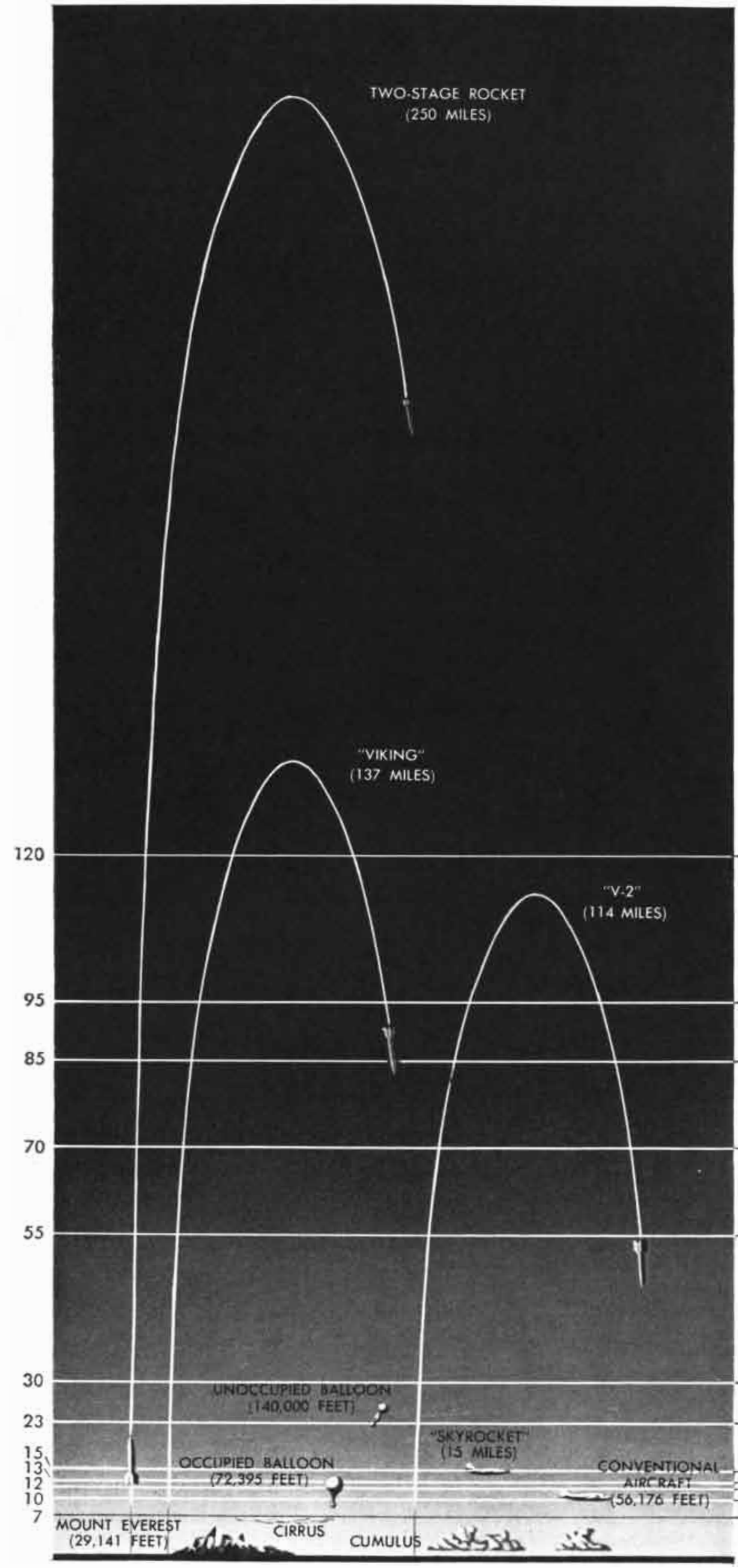
DOUGLAS SKYROCKET, a rocket-powered aircraft, has been reported to have reached an altitude of 15 miles. It was borne aloft from Edwards Air Force Base near Muroc, Calif., by a B-29 bomber and launched in the air.

blood and tissues. It takes only about 15 seconds for the oxygen stored in the brain tissues to fall to a level that produces loss of consciousness.

The critical altitude (where the total air pressure drops to 80 to 87 mm.) is roughly 50,000 feet. This is the boundary at which the atmosphere's ability to make any contribution to man's respiratory needs comes to an end. In other words, so far as his oxygen supply is concerned man crosses the borders of space at an altitude of about 10 miles. Above this level he is on his own. The pilot of the Douglas Skyrocket crossed this border. In order to do so he had to be encased in an airtight envelope inside his cabin—*i.e.*, he wore a spacesuit.

NOT FAR above this border we come to a boundary where the oxygen becomes too thin to support even combustion. Here we must abandon terrestrial power plants such as reciprocating or jet engines and turn to rocket motors that carry their own oxygen. This critical frontier is somewhere around 70,000 feet. It, too, has been pierced by our rocket craft.

Just a little higher we begin to approach the ceiling of our protection against the hazardous ultraviolet radiation and cosmic rays. The atmospheric



BORDERS OF SPACE differ for various problems of high-altitude flight, some of which are listed below. The scale at the left is in miles.

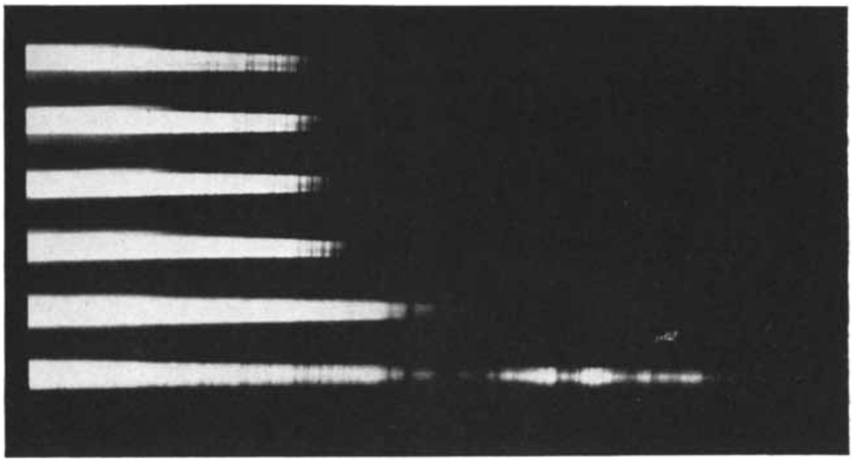
blanket that shelters us thins out fast, and above about 90,000 feet the damaging ultraviolet rays are about 10 times as strong as at sea level. This kind of radiation can easily be warded off by the walls of a spaceship, but the more energetic primary cosmic rays are another matter. At 120,000 feet and above we approach the region where only the shadow of our planet and the planet's deflecting magnetic field can shield us from the cosmic particles.

A good bit above this—say at 300,000 feet, or 60 miles—we start to run into peril from meteors. Of the vast number of meteors that hit the Earth's atmosphere every day, few reach the ground, as most of them are burned up in the atmospheric region between 60 and 90 miles up. Above 90 miles we would run the same risk of being hit by meteors as in interplanetary space, except for the protection afforded by the shielding bulk of the Earth.

At this altitude we shall also need artificial light in our spaceship, for the blue of the sky will have given way to the blackness of space. On the Earth the scattering of sunlight by the atmosphere gives us a soft, diffuse illumination. Above 90 miles the sky is as dark as the star-strewn heavens on a moonless night on Earth. Even at the altitudes already reached, pilots have trouble reading their instruments by day unless the panel is illuminated. The strong contrasts between the dark sky and a sunlit part of the airplane's structure are approaching the limit of discomfort.

The levels at which the atmosphere ceases to give mechanical support and heat exchange between the air and the ship ends will depend on the speed of the craft. Our high-speed aircraft already are becoming uncomfortably hot in flight. A fast-flying aircraft acts like a piston, compressing and heating the air in front of the nose and the leading edge of the wings. Friction of the air along the fuselage and the surface of the airfoil also produces heat, creating a thin film of hot air. A rocket pushed through the air at a speed four to five times faster than that of sound is enveloped in a film of air heated to more than 2,000 degrees Fahrenheit. Even at the supersonic speeds at which some of our jet aircraft fly today, cooling systems are needed.

The temperatures produced by compression and friction are independent of the density of the air. In the thin strata of the upper atmosphere a craft will still be enveloped in a film of hot air. But with increasing altitude the heat content of the envelope will decrease, and there will be less transfer of heat to the ship. Unfortunately we do not know precisely how fast a ship will be able to travel without becoming overheated, because the mechanism of heat transfer between hot envelope and craft is not well understood, especially in extremely rarefied air. We know that meteors are vaporized by air as thin as that found in the region between 60 and 90 miles of altitude. For a craft flying at five to six miles per second the thermal interaction between the atmosphere and the craft will become negligible only at an altitude of 110 to 120 miles. Above that height air compression and friction will cease to exist, and the temperature of the ship will be determined solely by the exchange of radiation between the outer hull, the Sun and the Earth.



SPECTRA OF THE SUN made from an ascending V-2 rocket demonstrate how the intensity of the shorter ultraviolet radiation increases with altitude. The spectra, from top to bottom, were made at altitudes of 1, 4, 10, 15, 20 and 35 miles. The longer wavelengths are at the left; the shorter, at right.

HOW FAR an aircraft will be able to get lifting support from the air will depend on the ship's speed. The aerodynamic forces of lift and drag fall off in proportion to the air's density but increase in proportion to the square of the craft's velocity. It appears, therefore, that an aircraft could make up by velocity what the air lacks in density. There is, however, a limit. At very high speeds the lift-drag ratio becomes increasingly unfavorable, and the heating of the ship imposes insurmountable difficulties. Eventually, when the craft runs out of atmosphere, it will have to be supported solely by the thrust of its rocket engine; yet this device can only operate for brief periods of time.

Where the mechanical support of the atmosphere fails, the craft must rely on centrifugal force arising from a curved trajectory. If the ship is to take up a permanent orbit, its speed must be such that it stays on a closed trajectory in the shape of a circle or ellipse. In the absence of air drag, the forces of inertia then exactly balance the gravitational pull of the Earth. The vessel must not be slowed down by air drag. Loss of velocity would decrease the centrifugal force, and the radius of the ship's orbit would shrink at an increasing rate. It has been estimated that a ship circling the Earth at a distance of 80 miles in unpropelled flight would lose about six miles of altitude per revolution and would soon spiral down toward the Earth. At a height of 110 miles the altitude loss per revolution due to air drag would be only three feet. A few miles farther up the ship's orbit would be permanent, according to human time standards. At an altitude of 120 miles the aerodynamic forces vanish completely. For all practical purposes this level can be considered the mechanical border of space. Several unmanned missiles have risen to heights twice as great.

The disappearance of the frictional forces at highest altitudes is a matter of interest not only to the aerodynamics engineer but also to the passengers. Beyond the mechanical borders of the atmosphere the balance between the forces of gravitation and inertia would leave the crew weightless. The problem of weightlessness is already present in certain flight maneuvers, even within the atmosphere. In power dives and in parabolic flight maneuvers in which the aircraft is accelerated vertically downward at the rate of free fall a pilot may experience the state of weightlessness for 30 to 50 seconds. Consequently the phenomenon of weightlessness has no defined border.

Aviation based on jet and rocket propulsion is emerging into space flight by gradual stages, as our vehicles cross the borders of space and probe briefly into the realm beyond the thin atmospheric skin of this planet. Actually space flight today differs from space travel in its commonly accepted meaning in only one respect: our flights into space at the present time last only a few minutes.

Heinz Haber is a research scientist in the Department of Space Medicine of the Air Force School of Aviation Medicine.

RADIOCARBON DATING

The exciting new method of measuring the age of organic materials is not entirely without difficulties, but the process of investigating them is enriching the whole study of human and geological history

by Edward S. Deevey, Jr.

NO BRANCH of learning is tame to its enthusiasts—not even grammar, as Browning reminded us. Some sciences, of course, have a more urgent appeal than others. The lure of nuclear physics, at least since 1945, is a force that feeds itself; like Cleopatra, physics "makes hungry where most she satisfies." The identification of fossil pollen grains in ancient lake beds is not commonly held fascinating to the same degree, nor would the study of Aztec calendric manuscripts get many votes as the most bewitching of occupations. Yet each has its allure. The most delightful fact about radiocarbon dating, a new research field that has captivated scientists of all descriptions, is that it combines the fascination of the immediate and the bizarre, of physics and history. While it was conceived in nuclear physics, much of its verve is contributed by such eccentrics as the students of fossil elephants and of the architecture of ancient Peru. Radiocarbon dating has brought science and the humanities together in the laboratory for the first time.

The credit for starting this union belongs to Willard F. Libby, of the University of Chicago's Institute for Nuclear Studies. His postwar discovery that radioactive carbon 14 in nature could be used for dating the past has already given birth to radiocarbon laboratories at the Universities of Chicago, Columbia, Michigan and Yale, and others are being constructed at the Universities of Cambridge, Copenhagen and Pennsylvania, by the U. S. Geological Survey and by the government of New Zealand. Compact assemblies for dating objects by radiocarbon analysis may soon be as easy to buy as dentists' chairs.

Why all the excitement? Is this new dating method as good as it looks? The Chicago laboratory has now published some 300 radiocarbon dates, and on the basis of cross-checks on these dates one can say that in general the method has fulfilled its original promise. In detail, however, there are puzzles, contradictions and weaknesses. It will be a long time before radiocarbon dating is as straightforward as an electric dishwasher.

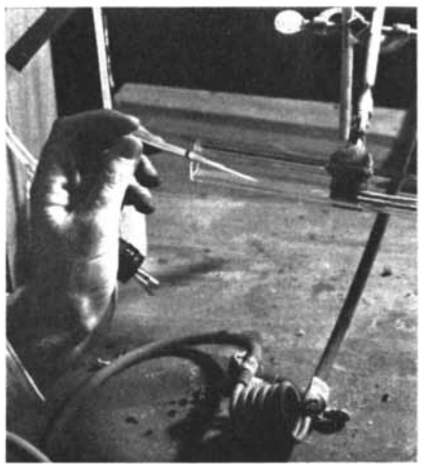
The basis of the method is magnificently simple. Carbon 14 is continuously produced in the upper atmosphere by the action of cosmic rays, which set free neutrons that transmute nitrogen in the air into the radioactive carbon. Incorporated in carbon dioxide, the radiocarbon moves through the atmosphere and is absorbed by plants. Animals in turn build radiocarbon into their tissues by eating the plants. As long as they are alive, plants and animals go on ingesting radiocarbon. When an organism dies, and ceases to take in fresh carbon, its built-in clock begins to run down. The disintegrations of its carbon-14 atoms tick away the seconds and the years: in 5,568 years (on the average) only half of its original store of radiocarbon atoms is left, and in another 5,568 years only half of those, or one quarter of the original number.

Long before that time, of course, most plants and animals have decayed into dust. But when the remains of an organism are fortuitously preserved, as a fossil or a house beam or a bit of charcoal, the age of the remains can be calculated. The amount of radiocarbon the organism possessed when it was alive is known, and so is the rate of its radioactive disintegration. It is easy to compute the relic's age from the amount of radioactivity it still retains.

The radiocarbon time-scale, to be sure, covers only the last few thousand years. The initial quantity of radiocar-

CARBON 14 METHOD requires that materials to be dated be sent to a specially equipped laboratory.

SAMPLE IS SPLIT from a block of wood being dated in Geochronometric Laboratory of Yale University.



SAMPLE IS PLACED in a heating tube at the beginning of the process of converting it into carbon dioxide.

bon, at the organism's death, is exceedingly small—about one atom of carbon 14 to a trillion atoms of ordinary carbon. Three half-lives (16,700 years) later only one eighth of that amount remains, and its detection is hardly possible. Hence radiocarbon cannot be used as a long-term clock like uranium, which decays to lead with a half-life of 7.6 billion years: it merely adds a second-hand to the cosmic clock.

As SOON as Libby and his collaborators conceived the idea of using radiocarbon for dating, they began to check the accuracy of their clock on old objects of known age. Heartwood from a giant sequoia tree, laid down nearly 3,000 years ago, gave a satisfactory check; this was especially gratifying because it showed that wood already formed in a tree is not contaminated with carbon from younger wood as the tree grows. From Egyptologists (of whom some of the best in the world live or have lived in Chicago) Libby obtained specimens of mummy cases and house beams, whose dates are among the best-established in all archaeology. Radiocarbon analysis gave accurate measurements of the age of these objects also.

All this was splendid as far as it went, but the oldest of these specimens was only about 4,600 years old. Back of that date the supply of organic matter of accurately known age ran out, and not even one half-life cf carbon 14 had yet been reached. Could radiocarbon dating be used with confidence on objects older than 5,000 years? What if the cosmic shower had varied in intensity in the past? Furthermore, the radiocarbon method was based on the assumption that the movement of carbon 14 from the upper to the lower atmosphere and its thorough mixing was a rapid process compared with the carbon's radioactive decay. What if this assumption was wrong? This could easily be the case, for great ice sheets stood over the Northern continents 20,000 years ago, and the world's weather must have been notably different from today.

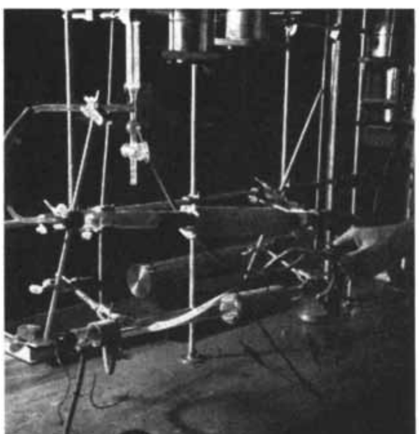
There was only one way to check the reliability of radiocarbon dating over a longer span, and that was to test it on the materials of geology and prehistoric archaeology. The age of such material is not "known" in the same sense as that of mummy cases or trees, but some of the geologic dates have a high probability of being correct. The results of this checking process, as far as it has gone, are exceedingly interesting.

GEOLOGIC chronology depends on the study of stratified deposits that represent elapsed time. One way to date the deposits is to examine their content of fossilized pollen from plants. The pollen proportions in one of these layers show what types of plants predominated when the deposit was laid down, and this in turn indicates the climate at that time and place. A predominance of spruce pollen, for instance, means that the climate was cold; if oak was dominant, the weather was warmer. The method involves stabbing with coring devices into the beds of old lakes or peat bogs, where pollen fell and was buried in successive layers of mud as time and stratification went on, and then counting the percentages of pollen in the successive strata. The chronology that is built up from the changing pollen percentages is a sequence of climatic changes—cold, cool and warmer, moister and drier.

This makes it possible to date, in terms of relative age, events which at first sight seem remote from bogs, or even from climate. The pollen remains can fix the time of a rise in sea level that covered fresh-water deposits with marine material. If the archaeologist is lucky enough to find human remains stratified in bog or salt-marsh peat, he can date the ancient culture directly; more indirectly, he may be able to date it by the stratigraphic relation between a village site or shell heap and a former sea level, or by its debris of animal bones, the time of whose prevalence in the region is known from the level at which remains of the same animals lie in bogs.

Useful as it is, the pollen chronology has limitations. It is helpful only during the time when pollen sequences were continuously forming. Mostly this means the time since the last ice age, for lakes and bogs are transitory features, and those in which we find the pollen sequences were formed in the youthful landscape left behind by the glaciers as they retreated northward. In the light of that movement we can see what an odd sort of chronology this is: it begins at different times in different latitudes, and the chronology itself shifts with the northward migration of climatic belts and of trees. The schoolboy, asked why the days are longer in summer than in winter, replied: "Because heat expands and cold contracts." So a unit of pollen time is not a constant but varies in a peculiar way with the temperature. In Connecticut spruce pollen time (when spruce prevailed) apparently means at least 8,000 years ago, but in much of Canada it marks "today." Fortunately the smearing of the time-scale is not so serious as this particular situation would imply, for the present prevalence of spruce in Canada reflects a recent return to cooler climate. Nonetheless a more typical marker such as pine pollen time, in its march northward from West Virginia to Maine, covers a spread of 3,000 years—from 9,000 to 6,000 years ago. There is, consequently, a certain fuzziness about pollen dates which suggests caution in using them to check radiocarbon dating.

BACK OF postglacial time the geologist gauges time by the advances and retreats of the glaciers. Here again



SAMPLE IS BURNED in the tube. The reaction is started by a torch and continued by an electric furnace.

CARBON DIOXIDE from the sample is dried by freezing (*center*) and stored in glass bottles (*upper right*).

GEIGER COUNTER finally measures the amount of radioactivity in the carbon prepared from the sample.

he runs into important difficulties, particularly in trying to correlate independent sequences. The succession of advances and retreats of the North American ice sheet in the Middle West is reasonably well understood. So is the similar sequence in northern Europe. But how can they be fitted together? True, both continents, and Asia as well, seem to have known four major glacial ages in the Pleistocene epoch, and the coastlines of all the continents show traces of the long, warm interglacial ages when the oceans were fuller. On the whole the evidence supports the idea that the stately alternation of glacial and interglacial climates was essentially synchronous everywhere. But for the short period of the past 20,000 years, which is only two per cent of the total estimated duration of the ice ages, one would hardly expect the climatic sequences in different places to agree in detail.

During the last glacial age the North American ice sheet was three times as large as its Scandinavian counterpart, and lay on the opposite side of an ocean and its moisture-bearing air masses. Enough can be deduced about the weather of those days to suggest that the waxing and waning of two such different glaciers should not have followed identical patterns. Yet radiocarbon dating of materials from the last ice age indicates that the ice sheets on both sides of the Atlantic did follow a similar pattern, at least in their retreat. If so surprising a result can be accepted, stratigraphers need have no further hesitation in relying on the radiocarbon method and using it to dispel the doubts and contradictions of the stratigraphic chronology. Has this happy time arrived?

It looks to most geologists as though it has, but it is really too early to say for certain. This much seems sure:

The melting of both ice sheets was intermittent. Before they dwindled away for good both paused in their retreat and readvanced in places. The readvance brought colder climate into regions that had been temperate enough for trees to grow. In Denmark a birch woodland grew up during a relatively warm spell and then was replaced by a treeless tundra. That is, the climate got as warm as that of Lappland and later became more like that of Spitsbergen; as the reindeer may have said to the musk ox, "It will get worse before it gets better." All this is told by evidence of pollen and other fossils in bogs. In Wisconsin, too, there was a mild phase when trees grew, only to be killed when the returning glacier plowed into them. Indeed, if we compress the last few chapters of the Pleistocene into parallel sequences, it is plain that Wisconsin and Denmark have more than cheese-making in common.

At each place the story has four chapters. In Wisconsin there was (1) an early glaciation; then (2) the mild, tree-growing time, named Two Creeks from a place where the waters of Lake Michigan cut back a cliff exposing the spruce forest stratum; then (3) a new ice sheet, called Mankato after a place in Minnesota where the glacier's moraines are especially well displayed, and finally (4) postglacial time. In Denmark there is an exactly parallel sequence: (1) an early glaciation; (2) the mild time of the birch woodland, named Alleröd after a Danish town; (3) a cold time when new glaciation called Fennoscandian reached southern Sweden, and (4) postglacial time.

Now radiocarbon analyses have been made of five separate specimens of wood and peat from the buried Two Creeks forest in Wisconsin, and the average age of these is computed to be 11,400 ± 700 years. The average radiocarbon age of four typical specimens of lake mud of the parallel Alleröd interlude in Europe is 10,800 ± 1,200 years. The agreement is essentially perfect, and it is especially impressive in view of the fact that three of the four Alleröd samples came from England and Ireland, where the glaciers had seceded from the Scandinavian parent body long before Alleröd time; radiocarbon dating carries chronologies across the North Sea as easily as it does across the Atlantic.

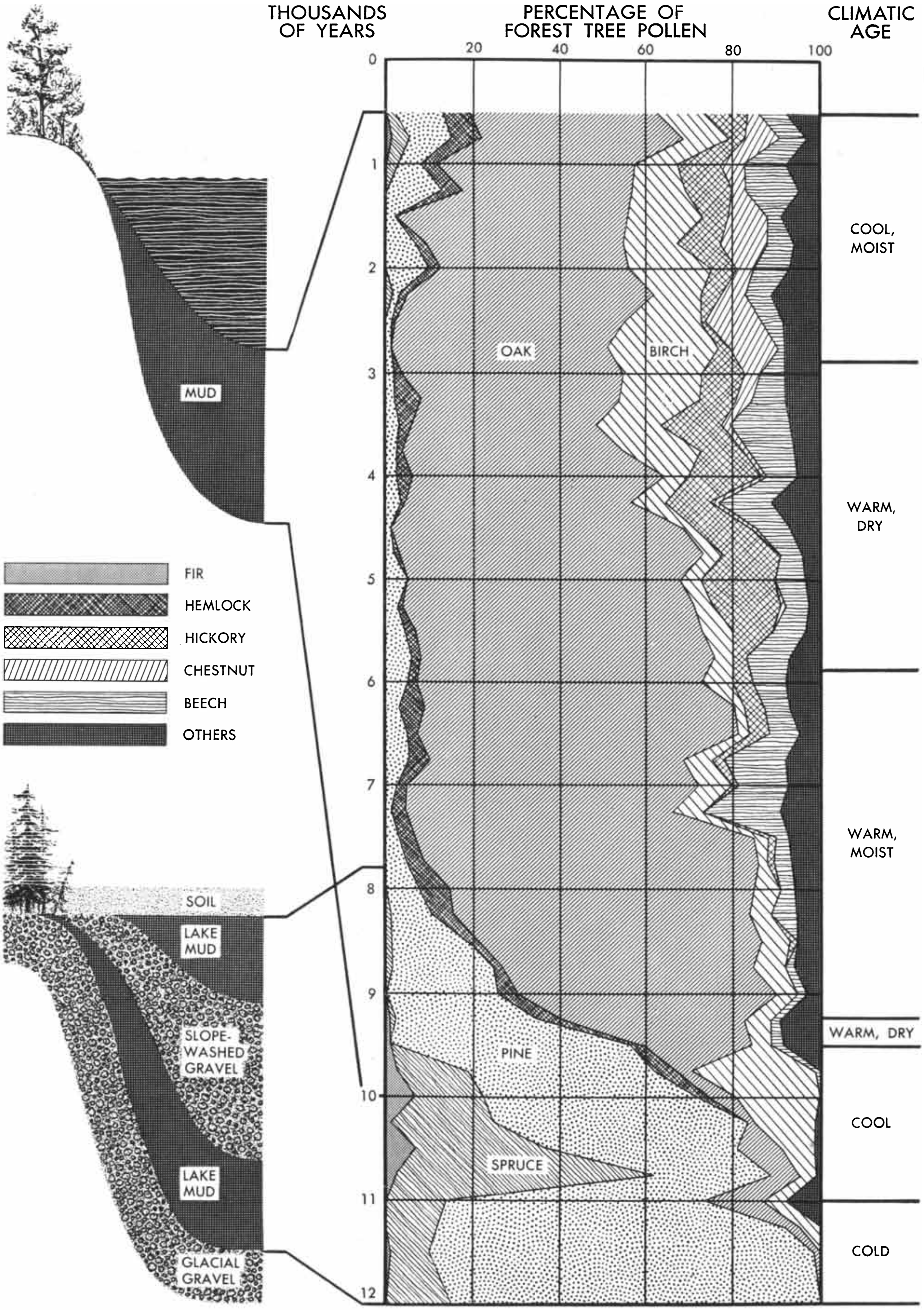
A TRAP may be concealed in these figures, because we are not sure that the Mankato ice sheet is the last glaciation that approached Wisconsin, the region to the north being an almost unexplored wilderness. It is possible there were post-Mankato cycles of readvance and retreat. So long as this suspicion remains, the skeptic of radiocarbon dating is free to doubt that the Two Creeks forest bed is in the same stratigraphic position as the Alleröd mud. But the radiocarbon age of 11,000 years for the latter agrees closely with previous geological estimates and provides a good check on the radiocarbon method.

It is conceivable that there may be a systematic error in "old" dates obtained by radiocarbon analysis, for a great number of them come out about 10,000 years. But if this is the case, it is hard to see how such an error could apply to the Two Creeks analysis, because radiocarbon determinations on at least nine samples of material known to be a little older than the Two Creeks forest came out "older than 16,000 years." The supposed error would not be systematic, in other words, but must affect the Two Creeks date independently. The skeptic may still argue that, since the Two Creeks forest was buried, the fossils might have become contaminated by younger carbon from subterranean waters. But the spruce wood and the peat were measured separately, and both gave the same age. This would not be expected if contamination had occurred. The wary geologist can still reserve judgment, but more and more evidence is relieving his doubt.

Several other events connected with the retreat of the last ice sheets in North America have been dated by radiocarbon in the neighborhood of 10,000 years ago. The connection is somewhat hazy, because what the dates actually refer to is the last stage of moist climate in the arid West. A charred bone of an extinct bison, left over from a picnic of Folsom man, gave 9,900 ± 700 years. Charcoal from hunting camps occupied by Scottsbluff Yuma people gave 10,500 ± 3,000 years, and excreta of ground sloths, in faraway Chile as well as in Nevada, also gave figures of about 10,000 years (see "The Early Americans," by Frank H. H. Roberts; SCIENTIFIC AMERICAN, February, 1951).

A number of radiocarbon dates therefore agree with each other in saying that the last ice advance occurred about 10,000 years ago, both in North America and in Europe. They also agree with the stratigraphic chronology, making due allowance for traps. Some popular articles have given the impression that this result caused consternation among geologists, who for many years had considered the Mankato glaciation to be about 25,000 years old. But that figure had already been questioned before the radiocarbon analysis. It had been based originally on estimates of the time it took the Niagara River to cut back 6½ miles to the present position of the Falls; more recently geologists had found that the river had not been biting its rocky lip throughout post-Mankato time but had been excavating an old gravel-filled valley—a more rapid process. To geologists the new idea that one might prove agreement between stages of retreat of

POLLEN ANALYSIS is a method of dating which, together with other methods, can be used to test the validity of radiocarbon dates; the principles of this method are outlined in the illustration on the opposite page. If mud is taken from the bottom of a lake (*upper left*), it will be found to contain the pollen of various plants. If a vertical sample is taken from several layers, however, the relative amount of pollen from each species at each level of the mud will vary (*diagram at the right*). From the kinds of pollen that predominate at any one level the pollen analyst can infer the vegetation, and hence the climate, when the pollen drifted down from the surface of the lake. To extend the usefulness of the method backward in time the same kind of analysis can be applied to the bed of an extinct lake (*lower left*).


THOUSANDS OF YEARS
PERCENTAGE OF FOREST TREE POLLEN
CLIMATIC AGE
20
40
60
80
100
0
1
2
3
4
5
6
7
8
9
10
11
12
OAK
BIRCH
PINE
SPRUCE
COOL, MOIST
WARM, DRY
WARM, MOIST
WARM, DRY
COOL
COLD
MUD
SOIL
LAKE MUD
SLOPE-WASHED GRAVEL
LAKE MUD
GLACIAL GRAVEL
FIR
HEMLOCK
HICKORY
CHESTNUT
BEECH
OTHERS

two major ice sheets was far more exciting than the loss of a few thousand years' antiquity that Folsom man wasn't entitled to in the first place.

CLEARLY the stratigraphic chronology is too full of pitfalls for an isolated date to tell us very much. A figure like 15,500 ± 1,800 years (the oldest radiocarbon date so far determined) for charcoal from the famous Lascaux Cave in France, the "Versailles of prehistoric man," is not especially informative, for it cannot even be proved that the charcoal belonged to the gifted people who decorated the walls of the cave. Clusters of radiocarbon dates are more enlightening. An example is a group of more than a dozen for archaeological objects found in Peru. Six of these were on samples from the same mound. Most of the dates agreed with the stratigraphic position—but not all. Of two samples that came from the same level, one gave 3,600 ± 440, the other 4,400 ± 540 years. The younger date was from shell, the older from plant remains. At another site there was a more remarkable discrepancy: the radiocarbon dates of wooden artifacts from two graves, which must have been made at about the same time because one contained broken pots whose missing pieces were found in the other, were 900 years apart. What is the archaeologist to say of such a finding? Offhand it seems that both dates cannot be right, but the archaeologic position is not certain enough to show which is correct, or whether both are wrong. In Denmark the radiocarbon dates for objects found in old houses stratified in a peat bog were so badly out that it seems certain that the bog sediments were stirred up by the ancient Danes. In fact, one writer, worrying about the dates of some hazel nuts from this site, and perhaps trying too hard to avoid quoting Hamlet's opinion about Denmark, suggested that the inhabitants had gone in for collecting thousand-year-old hazel nuts! No doubt, like the Chinese with their elderly eggs, they enjoyed the flavor.

The fact is, then, that radiocarbon dating has not been an unalloyed blessing to geologists. What did they expect: that proof of their wildest guesses would be handed over to them, tied in pink ribbon with Mother Nature's compliments? If science were as easy as that, most of us would be doing something really difficult, like playing poker.

Dating the past by radioactive carbon, as a matter of fact, is in some respects akin to poker. In both games there are two sorts of probability—one calculable and the other not. The geologist contributes to dating the kind of inspired guesswork that is involved in deciding when to bluff and when to call; the physicist's kind of probability corresponds to the chances of filling a four-card straight. That is to say, the physical measurement of the radiocarbon in a sample is subject to the laws of chance in the same way as the distribution of cards.

The reasons for this become clear when we look at the method by which a sample of material is analyzed. The carbon of the sample, both ordinary carbon 12 and radioactive carbon 14, is converted to carbon dioxide, purified and reduced to pure carbon by passing it over hot magnesium. After washing it is spread in a thin film around the inside of a Geiger counter, and carbon-14 disintegrations are counted electronically. The best counters made have a background radiation of their own, which is no lower than 2½ counts per minute even after cosmic rays and other sorts of stray radiation have been screened out. The net radioactivity of the carbon is obtained by subtracting the background from the total, but both measurements are averages, usually of 24 hours' observation for each.

Like other averages, these figures are subject to a probable error that can be estimated. The probability that the radiocarbon dates so far determined are off the true value by as much as one standard deviation is ⅓; in other words, of all the dates published by the Chicago laboratory, one in three is "wrong" by an amount exceeding the published errors—but one cannot tell which particular dates are wrong. The two discrepant dates from the Peruvian graves are not necessarily 900 years apart; they could easily differ by as little as three years.

There are at least two ways of improving the accuracy of radiocarbon dates. One is to count for longer periods; another is to enrich the carbon 14 of the sample. Both are costly and cumbersome, and neither has seemed worth while up to now. If the counting time is four times as long, four times as many physicist-hours have to be paid for by someone, but the accuracy is only doubled (on account of the rule that the standard deviation is approximately equal to the square root of the number of observations). And if one attempts to enrich the sample, new sources of error are introduced by the new instruments. There is still a third way of improving the present measurements, and that is to improve the efficiency of the Geiger counter; this offers hope of more immediate success.

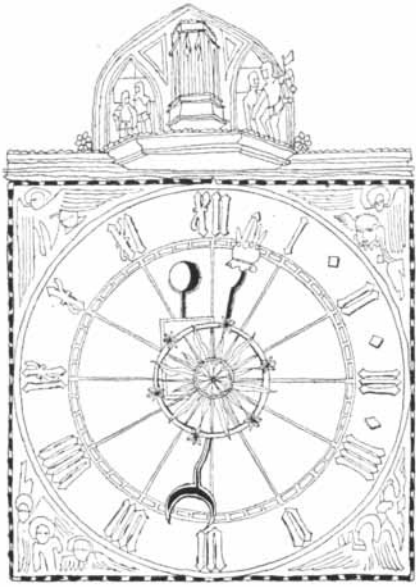
GEOLOGISTS and archaeologists can learn to live with a dating method that has only this moderately high probability. After all, a unit of radiocarbon time is constant, and does not vary with the latitude, as the pollen chronology does, and it gives absolute rather than relative dating. These are big advantages, and if it is necessary to measure all the dates several times in order to get accurate averages, historians can afford to be patient. There are other difficulties to be cleared up, however, before we are sure that nothing but chance is producing the errors. At present it is not certain that the physicist and the historian are playing with the same 52 cards.

Among these difficulties the most obvious is that the nature of the material, or the circumstances of its preservation during thousands of years, might affect the radiocarbon content of a specimen. A sample of fresh shell contains about 10 per cent more radiocarbon than fresh wood; no one knows why. Ancient shell and ancient wood or charcoal, buried in a geologic formation or an archaeologic site, may respond in different ways to the carbon dioxide in the ground water that has percolated over them since their burial. If they respond at all, we are in for trouble, and this is a problem of interest to chemists.

Aquatic plants, which of course make up most of the fossils in peat, present a different kind of theoretical difficulty: they do not restrict themselves to the carbon dioxide of the air in making their bodies, but take in bicarbonate from the water. Radiocarbon is incorporated in the bicarbonates in water as well as in the carbon dioxide in air. But some of the bicarbonate that plants get from water will have been derived from an ancient, and therefore radioactively dead, limestone rock. There is a long chain of chemical processes: from carbon dioxide in the air to carbonic acid in ground water percolating over limestone, to bicarbonate in stream or lake water, to protoplasm in an aquatic plant, to organic mud on a lake bottom. Each of these reactions is partly cyclical, and no one knows enough about the rates and quantities concerned to say what the carbon-14 content of peat should be.

The direct approach is to measure it, and let the results give guidance to the theory. Naturally, this is being done. When enough such measurements have been made, we shall not merely know more about the reliability of radiocarbon dating, which brings the physicist and the historian into the same friendly game; we shall know much more than we do about the chemical history of lakes, the atmosphere and the oceans. The main thing about radiocarbon dating, then, is not the dates themselves, exciting though they are. It is the dawning realization that a new field has come into being, one that is worthy of the best talent that natural science, social science and the humanities can collectively command.

Edward S. Deevey, Jr., is Director of the Geochronometric Laboratory at Yale University.



SCIENCE AND

New Direction for A.A.A.S.

THE 118th meeting of the American Association for the Advancement of Science in Philadelphia at the end of December was typical of the last 25 or 30 in the series. Always the largest and busiest gathering of scientists anywhere, the A.A.A.S. annual convention has traditionally served as a crossroads for American science. This year it brought to Philadelphia an estimated 9,000 scientists from all over the country and all the departments of modern science. They got together, according to their specialties, in 300 formally programmed conferences, symposia, colloquia, smokers, breakfasts, lunches and dinners in dozens of meeting places. The 352-page program listed a total of nearly 1,000 papers on work in nearly every field of science.

Large as the A.A.A.S. meetings are, however, many scientists have arrived at the conclusion that they are becoming less and less representative of the advancement of American science. Last September leaders of the A.A.A.S. met to consider the trend cf the meetings at an informal conference at Arden House, near Harriman, N. Y., called at the suggestion of Warren Weaver, director for the natural sciences of the Rockefeller Foundation. The conferees were concerned that the A.A.A.S. appears to be losing its value as a clearing house. Over the past century, as the work of science has increased in volume and in specialization, first one and then another of the 173 affiliated and associated professional societies has taken over from the parent body its function as the forum for the presentation of new work in each field of science. Today even the biologists, whose 485 papers took up nearly half the program at Philadelphia, are in process of transferring their allegiance to their own organizations. The conferees found the result of this historical trend clearly reflected in the quality and scope of the papers now presented at A.A.A.S. meetings.

The Arden House group drafted a resolution which was adopted at the Philadelphia convention by the 250-man governing Council of the A.A.A.S. as the organization's official policy. The resolution holds that the overwhelming preponderance of papers at A.A.A.S. conventions (and this year's were no exception) are concerned with minutiae of scientific work which "can more properly be presented before meetings sponsored and arranged by the appropriate professional groups." The Council concludes that the traditional pattern of A.A.A.S. meetings, though effective in the past, "is now outmoded."

It proposes that in the future the organization "devote less of its energies to the more detailed and more isolated technical aspects of science, and more and more of its energies to broad problems which involve the whole of science, the relations of science to government, and indeed the relations of science to our society as a whole." The scientific sessions at A.A.A.S. conventions are to be given to "central problems whose treatment requires the attack of several disciplines." As to "the relation of science to society," the A.A.A.S. must devote itself seriously to the objective "that science be better understood by government officials, by businessmen, and indeed by all the people."

To Kirtley F. Mather, this year's president, and to the 10 other members of the Executive Committee was delegated the task of organizing the necessary committees to study "the practical details of implementing these principles," with the injunction that "the studies themselves should be carried out in a scientific manner."

As president-elect, to succeed President Mather at the next annual meeting, the A.A.A.S. chose Edward U. Condon, physicist, who recently resigned as director of the National Bureau of Standards to become director of research and development at the Corning Glass Works. The A.A.A.S. thus brought in a final verdict on Dr. Condon's 1948-49 trial by newspaper (SCIENTIFIC AMERICAN, February, 1949).

Highlights of the Meeting

OF the many developments reported at the A.A.A.S. convention, the most widely discussed was the new synthetic soil conditioner produced by chemists of the Monsanto Chemical Company. The product, called Krilium, was explained in detail at a technical symposium. Charles A. Thomas, president of Monsanto, announced that a $50 million plant is under construction in Texas City, Tex., to produce acrylonitrile, the starting material for Krilium and other plastic substances.

The $1,000 A.A.A.S. prize for the meeting's most noteworthy scientific paper was awarded to geochemist J. Laurence Kulp of Columbia University. Kulp, who has worked out improvements in the radiocarbon dating method which make it possible to date objects as old as 30,000 years (*see page 24*), reported on studies of the circulation of ocean water. By measuring the radioactivity of samples of water taken from 10,000 feet below the surface in the Atlantic Ocean, he determined that this water had not been near the surface (where it could take radiocarbon from the air) for about 1,750 years.

John Lear of *Collier's* Magazine and Victor Cohn of the Minneapolis *Tribune* won the $1,000 annual A.A.A.S.-Westinghouse awards for science writing. Lear's article "Atomic Miracle," which described the use of nuclear reactions in medical research, was judged the best magazine article on science of 1951. Cohn won the prize in the newspaper field for a series on "the problems and opportunities of old age." Honorable mention went to Dick Pearce of the San Francisco *Examiner;* Claude Stanush and Kenneth MacLeish of *Life;* and Frederick G. Vosburgh of *National Geographic Magazine.*

Some other interesting papers:

John C. Lilly, Ruth Cherry and A. A. Lurie of the University of Pennsylvania described a new technique for studying the electrical activity of the brain. They built an apparatus of 25 electrodes, arranged in a square, which pick up voltage differences in the brain and transmit the record by means of an amplifier to a square board, where the activity is displayed through the brightening and dimming of glow lamps. The light patterns produced on the board are recorded by a motion-picture camera. Thus the experimenters get moving patterns of light, reflecting movements of electric charge in the brain, which they call "apparitions."

Experimenting on cats, they found that when the brain is at rest, it produces slow-moving block patterns, like "mesas," on the lamp board. When the brain is stimulated by a series of clicking sounds, it produces apparitions "like twin 'mountains,' which become a single 'peak' as they travel rapidly over a part of the brain." Lilly and his co-workers think that their approach may help attain the traditional goal of neurophysiology: correlation of brain activities with psychological events.

J. Lawrence Angel of the Jefferson Medical College presented an analysis of three human skeletons found in the Hotu cave in northern Iran last summer by the anthropologist Carleton S. Coon of the University of Pennsylvania. These 75,000-year-old bones are among the most ancient specimens of modern man. They look like men of today, not Neanderthal. One of the skeletons was of a woman whom Angel described as a real Amazon—stronger, taller, and slenderer than the average woman of ancient Greece or the modern U. S. and "comparable in build to the modern college girl." The second skeleton was that of "a small, stocky, overworked dame, about 37, with beginning arthritis" and about five feet two inches tall. The third skeleton was a male between 30 and 40 years old, massive, muscular and over five feet nine inches tall. Angel deduces from the bones that the women did much carrying and climbing and digging, but little rough-country running after game, and that "pregnancy was frequent and involved no rest period." Development of the hand bones suggests "hard manual work . . . plaiting baskets, net-making, or possibly midwifery. This gives a picture of a small band of gatherers, where every one worked at top capacity, where children were treated well, fed as regularly as possible, and valued, where strangers might be admitted, and where accident rather than disease might cause death."

H. D. Bruner and A. F. Rupp of Oak Ridge reported a number of new developments in the field of cancer treatment with radioisotopes. Cesium 137, a fission product, shows great promise as a source of gamma radiation comparable to the cobalt "bombs" now manufactured by irradiation in a nuclear reactor. Bruner described some new methods of using radioisotopes internally. In one method tried in Switzerland charcoal particles with radioactive gold fixed on their surfaces were injected into the veins. They acted like tiny blood clots and "plugged many of the arterioles and capillaries of the lung, with the result that the lungs were exposed to a more or less even field of radiation." Another new technique is a combination of the radioactive qualities of one isotope with the biological characteristics of another. The surfaces of a colloid of radiogold are coated with silver. The silver has the quality of being picked up by the lymph nodes, which then undergo radiation from the gold.

Pike Resigns

SUMNER PIKE, last of the five original members of the Atomic Energy Commission, has resigned from his post. He had been a Commissioner since 1946,

and served as the AEC's acting chairman for several months after David Lilienthal resigned as chairman two years ago. President Truman accepted the resignation with "utmost regret" and said Pike's loss would be "sorely felt." His replacement has not yet been announced.

Electricity from the Atom

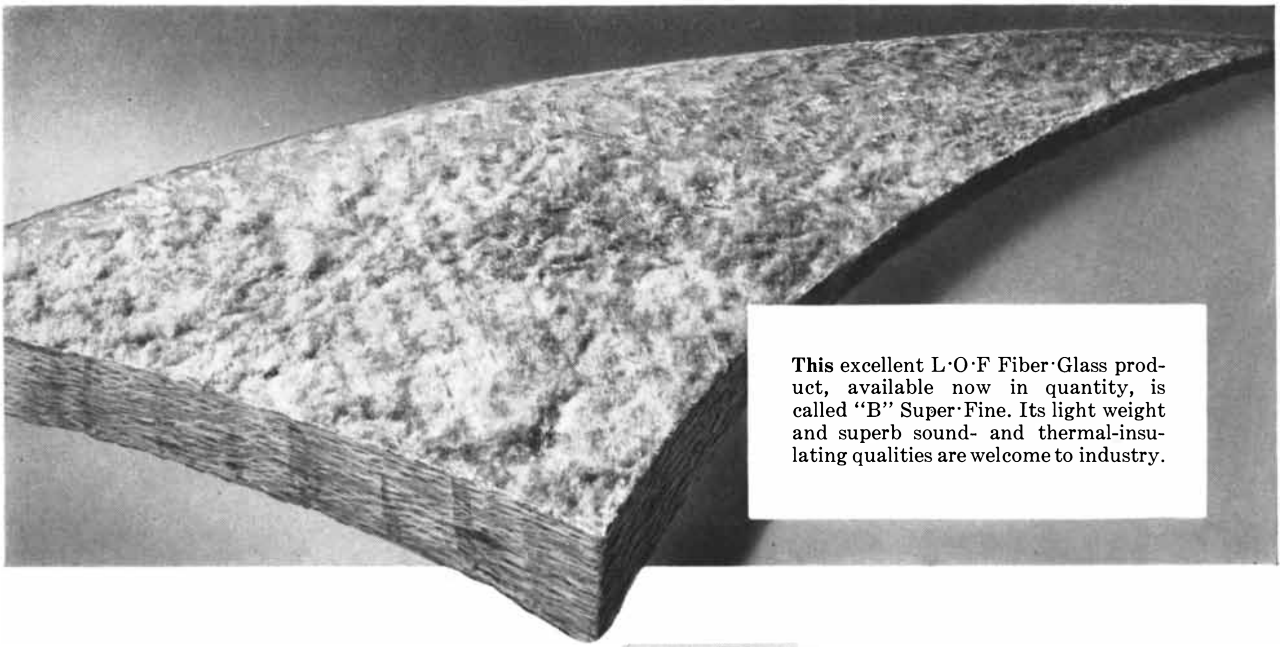
THE Atomic Energy Commission's experimental breeder reactor at Arco, Idaho, has gone into operation and is producing electric power—the first to be obtained in any substantial amount from a nuclear pile. The Commission announced last month that the reactor is generating 100 kilowatts, and that the power is being used to operate pumps and to light up the reactor building.

The plant employs liquid (molten) metal as the heat exchanger; it transfers the reactor's heat to a boiler where steam is generated to run turbines and produce electricity. The AEC pointed out that power production is not the primary purpose of this reactor; it was designed to test the possibility of breeding more fissionable fuel than is consumed in a reactor. No announcement was made as to what success has been achieved toward this objective.

International Nuclear Laboratory

PHYSICISTS from 12 countries of Western Europe have met in Paris and taken the first steps toward organizing an international "Institute for Advanced Studies in Nuclear Research." Among those at the meeting, held at the headquarters of UNESCO, were Niels Bohr of Denmark, Werner Heisenberg of Germany, Sir George Thomson of Britain and Francis Perrin of France. The main problem they hope to solve is that of keeping young physicists in Europe. Thomson said: "We feel that many are leaving Europe because there are not adequate facilities for research." Perrin added: "We must rapidly give the young scientist a means of work . . . on a scale similar to that in the United States."

To accomplish this task, which is beyond the individual resources of any of the Western European countries, planning will start this month on a cooperative research center to be built by 1957 or 1958 at a cost of $15 to $18 million. The site of the laboratory has not yet been selected. It will contain three powerful nuclear accelerators, including one of five-billion electron volts and a 400-million electron volt synchro-cyclotron which British workers will complete by next fall. These machines will be used, among other things, for research on mesons. The laboratory will publish all its results. Until the new center is ready, an international study group will be or-



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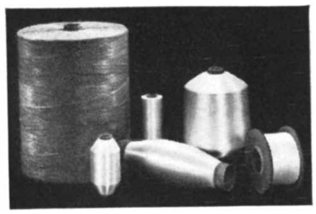

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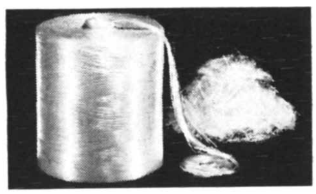

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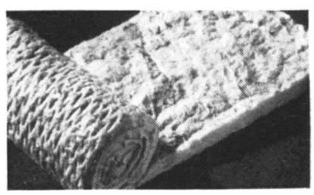

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ganized by the sponsoring governments at the Institute of Theoretical Physics in Copenhagen.

Return of the Ether

THE idea of the ether, which went out with the Michelson-Morley experiments and Einstein's formulation of the theory of relativity at the turn of the century, has been revived by P. A. M. Dirac, one of the outstanding creators of modern quantum mechanics. Dirac recently declared that "we are rather forced to have an ether" after all.

An ether medium used to be thought necessary to explain the propagation of light waves. But despite repeated attempts it proved impossible to detect any motion of the earth relative to the ether. When Einstein and Planck discovered that light consisted of discrete bundles of energy the logical need for an ether vanished. But Dirac now comes forward with an entirely new line of reasoning. The arguments against an ether are outdated, he says, because the ether must now be considered according to the principles of quantum mechanics. In the old conception, the ether at any point had to have a definite velocity in relation to the earth; this is what Einstein proved could not be the case. But according to Heisenberg's uncertainty principle, which Dirac says should apply to the ether, there would only be a certain probability for each possible velocity. If a velocity in any direction is equally probable, the ether can be fitted into the principles cf relativity, according to Dirac.

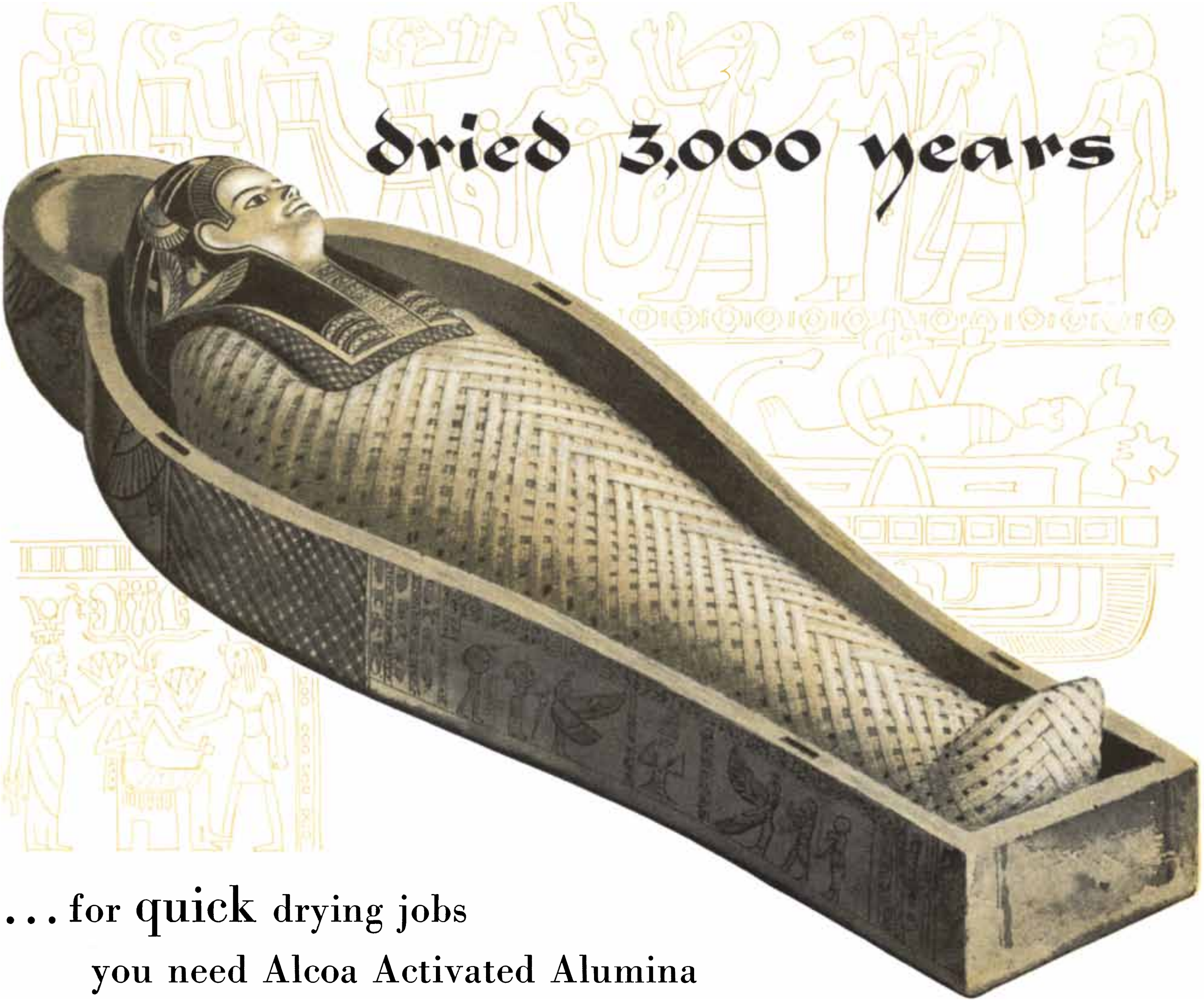
He says it is entirely possible to set up a wave function to fit these qualifications. This function turns out to be of the type that can be approached as a limit but never attained in practice. Dirac concludes: "We can now see that we may very well have an ether, subject to quantum mechanics and conforming to relativity, provided we are willing to consider the perfect vacuum as an idealized state, not attainable in practice. From the experimental point of view, there does not seem to be any objection to this. We must make some profound alterations in our theoretical ideas of the vacuum. It is no longer a trivial state, but needs elaborate mathematics for its description."

The new ether is a part of a theory of electrodynamics recently put forward by Dirac. In it the velocity of the ether appears as the velocity of a small electric charge introduced into a vacuum.

Counter-Explosion

CHEMISTS of Britain's Royal Air Force have suggested an ingenious scheme for suppressing explosions which they believe could prevent the blowing-up of a military airplane or fatal blasts

dried 3,000 years



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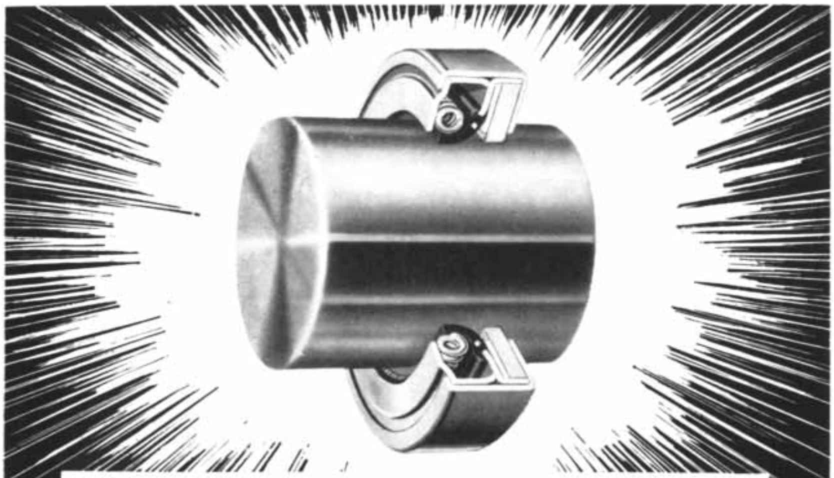

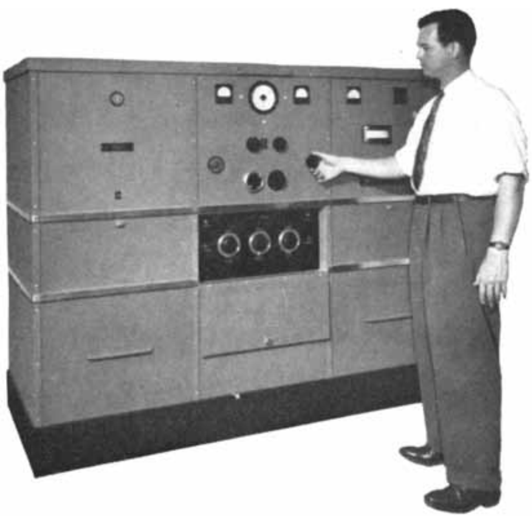

in a coal mine. They would simply stop the explosion by a back-explosion, as firemen fight fire with fire.

The idea is based on the fact that explosions take some time to get started. The British workers discovered that in the first five thousandths of a second of an explosion there is a pressure rise of only half a pound per square inch; even after 15 thousandths of a second the pressure is only five pounds per square inch. These figures suggested that it might be possible to prevent damage by suppressing explosions in the first few thousandths of a second. W. G. Glendinning and A. M. McLennan of the Royal Aircraft Establishment at Farnborough designed a "bomb" of inert carbon tetrachloride gas which is triggered by sensitive diaphragms. Within the first few milliseconds of an explosion, before the pressure passes three pounds per square inch, the increase in pressure sets off this counter-bomb and the carbon tetrachloride acts as a suppressor gas, scattering the explosion before it can reach a dangerous level.

The suppressor bombs, about the size of a half grapefruit, were tested in gasoline tanks. Tracer bullets were fired into the tanks, but instead of the normal violent explosion, the tanks just rocked a little as the bullets hit. The British workers think the suppressor bombs could nip explosions in the bud if they were placed at strategic points in a plane, coal mine or hazardous industrial plant.

A Boon for the Elms

THE most promising antagonist so far produced against Dutch elm disease, which has been threatening to wipe out the traditional shade tree of New England, has been announced by workers at the Connecticut Agricultural Experiment Station. They have produced a drug, called 2-methylcarboxymercaptobenzothiazole, which stops the fungus causing the disease.

The drug, applied as a preventive spray, is absorbed through the leaves and reduces the susceptibility of elms to the fungus. First tests showed that the drug protected all but five per cent of the trees sprayed. It seems to be considerably more effective than present protective measures. The drug will not be placed on the market, however, until several more seasons of testing.

The Right to be Ignorant

SCHOOL children in New York State may not be required to learn about the germ theory of disease. This fact came to light last month when the State Education Department omitted from Regents examinations in biology all questions relating to bacteria and infection. It developed that the State Legis-

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lature, at the request of the Christian Science Church, had quietly passed a law two years ago providing that "a pupil may be excused from such study of health and hygiene as conflicts with the religion of his parents or guardian."

Under this provision the State Commissioner of Education has ordered the exemption of Christian Science children from instruction in disease prevention and control. Among the excluded topics are the building up of resistance to disease; control of communicable disease; the importance of pure food and water; what bacteria are; first-aid treatment, and so on.

The disclosure that questions on these topics had been dropped from the statewide high-school examinations created a storm. The Christian Science Church itself objected that the authorities had gone too far; it said it had no wish "to interfere with the rights" of pupils who were not Christian Scientists. The New York Academy of Medicine and the State's biology teachers promptly set out to get the law repealed. The biology teachers, pointing out that curricula and textbooks are based on the Regents examinations, warned that "virtual elimination of these topics looms up for all children, Christian Science or not."

Largest Prime

PRIME numbers—numbers that cannot be divided evenly by any integer except themselves and 1—are one of the chief topics in the branch of mathematics known as the theory of numbers. The primality of any number can be proved only by elaborate trial, and the larger the number, the more difficult the trial. About 75 years ago a French mathematician named Edouard Lucas proved that $2^{127}-1$ is a prime number, and until now it has stood as the largest proved prime. But recently two Cambridge University mathematicians unlimbered an electronic calculator on the problem and discovered a dozen primes higher than Lucas'.

J. C. P. Miller and D. J. Wheeler wrote to *Nature* last June that their highest prime was $934(2^{127}-1)+1$. By the time their letter was in proof this value had become obsolete; in a postscript they reported a new one: $180(2^{127}-1)^2+1$. They also reported that a French mathematician named A. Ferrier, using a desk calculator, had proved the primality of $(2^{148}+1)/17$, which was, at last reports, the second largest known prime.

To print characters of this type size in the number represented by Miller and Wheeler's largest prime would take approximately 1,809,250,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 columns of SCIENTIFIC AMERICAN.

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THE UNIVERSE FROM PALOMAR

For more than two years the dome of the 200-inch telescope has been open every clear night. An account of how the astronomers on the mountain have used the instrument in their explorations

by George W. Gray

NEARLY four years have passed since Palomar Observatory was officially opened with the dedication of its 200-inch telescope in memory of the astronomer who conceived it, George Ellery Hale. Because of the need for additional polishing to perfect the curvature of the great mirror and for revision of the complicated supporting mechanisms, the Hale Telescope was not ready for work until the autumn of 1949. Since then it has been in use every clear night.

A recent visit to the Observatory provided an opportunity to watch the giant eye in operation and learn of the problems on which the astronomers are engaged. Director Ira S. Bowen, describing the research program during our three-and-a-half-hour drive to the mountain top from Observatory headquarters in Pasadena, was enthusiastic over the way in which the plan for the joint operation of Mount Wilson and Palomar Observatories is working out. Palomar and its equipment are owned by the California Institute of Technology, while the facilities on Mount Wilson are the property of the Carnegie Institution of Washington. Under the cooperative arrangement the scientific staff members from the two institutions—15 employed by Carnegie and three by Caltech—share all the facilities of the two observatories.

These include three solar telescopes and the 60-inch and 100-inch reflectors on Mount Wilson and two schmidt-type telescopes and the 200-inch giant on Palomar Mountain. Each type of instrument is uniquely adapted to a certain kind of investigation, and assignments of the instruments are determined by the problems on which the staff members are working. A man assigned a telescope customarily has exclusive use of it for about one week a month as long as his problem requires it. After spending five or six nights photographing his particular spot of the sky, the observer will usually have accumulated more than enough material to keep him busy the rest of the month analyzing and trying to interpret it.

Stuff and Structure

What the men of Palomar and Mount Wilson are studying is (1) the stuff and (2) the structure of the Universe. The stuff is not only the stars but also the clouds of cosmic gas and interstellar dust, from which stars are formed. The structure means the ways in which the stars are organized into clusters and other multiple systems, and how the systems in turn are regimented by the millions to form the gigantic rotating pinwheels known as spiral nebulae. The nebulae appear to be of different luminosities and sizes, and here and there in remote wildernesses of space groups of nebulae are found associated in clusters, with all the members of the group moving in the same general direction and at about the same speed. It would seem, therefore, that these spiral systems are not "island universes," as was once suggested, but are integrated parts of a still larger, all-inclusive structure which we may call the Whole, that is, the Universe.

According to the general theory of relativity, the size of the Universe is determined by the amount of matter it contains. The number of nebulae in a representative sample of space therefore is of critical importance to cosmologists. Mount Wilson's 100-inch telescope is able to photograph out to 500 million light-years. Practically all that mankind has found out so far about the remote nebulae we owe to this superb instrument. And yet its reach was not enough. A radius of 500 million light-years proved to be insufficient to stake out a representative sample of the Universe. It was the realization of this limitation that led George Ellery Hale and his associates to plan the 200-inch telescope. The giant on Palomar is able to photograph objects at a distance of 1,000 million light-years, thus doubling the space-penetrating power in every direction and enlarging the volume of the observable region eightfold. There are men at Palomar who hope that by studying this enlarged sample they will be able to draw sound conclusions as to the size, structure, composition and nature of the entire Universe.

One of these Palomar optimists is Edwin P. Hubble. "It may be wishful thinking on my part," he admitted, "and the answer will not be known for a few years, but I believe we shall find that the sample is significantly large and that from it the type of Universe we inhabit can be identified among the long array of possible universes."

Hubble, now in his 63rd year, is a veteran investigator of nebulae. Thirty years ago he began a study of the Great Nebula in Andromeda. Up to that time many had thought that the spiral systems, of which the Andromeda Nebula is one, were simply luminous whirlpools of gas. Turning the 100-inch telescope to an analysis of the Nebula's composition, Hubble found that he could resolve its spiral arms into individual stars. He also identified some of them as cepheid variable stars—a type which is found in our own Milky Way and whose absolute brightness is known. From the apparent brightness of the cepheid variables in the Andromeda Nebula, Hubble calculated that the great spiral was between 900,000 and 1,000,000 light-years away. Shortly after this determination other stellar systems, known as

GREAT NEBULA in Andromeda, the spiral galaxy closest to our own, is intensively studied from Palomar Mountain. This photograph of the galaxy and two satellite systems was made by the 48-inch schmidt telescope.

Messier 33 and N.G.C. (New General Catalogue) 6822, were plumbed and reported to be of the order of 1,000,000 light-years distant.

These dimensions were staggering to the imagination in 1925. James Jeans suggested that such distances probably approached the limits of the Universe. "We may suppose," he wrote in December of that year, "although it is little more than a guess, that the most remote objects of all in our Universe are at four times the distance of these two remote objects, and so at four million light-years from us."

This was only a quarter of a century ago—and how timid the speculation seems today! In the period between the two world wars man's concept of the cosmos expanded more than a thousand-fold, thanks largely to the continually accumulating evidence unveiled by the great American telescopes as they pushed deeper into the abyss of space.

POSITION OF NEBULAE	DISTANCE IN LIGHT-YEARS	VELOCITY IN MILES PER SECOND
VIRGO	6,000,000	700
PEGASUS	23,000,000	3,400
COMA BERENICES	45,000,000	4,200
URSA MAJOR	85,000,000	9,600
LEO	105,000,000	12,000
GEMINI	135,000,000	15,000
BOOTES	228,000,000	24,400
HYDRA	360,000,000	38,000

VELOCITY with which nebulae recede from one another increases with distance. This principle was confirmed for distant nebulae with the 200-inch.

The Red Shift

Before Hubble began his exploration of the Andromeda Nebula, V. M. Slipher at the Lowell Observatory in Arizona had started a different kind of survey. Instead of photographing the nebulae directly, Slipher passed their light through a prism and photographed the resulting spectra or patterns of rainbow colors. In such a photograph there are dark lines which here and there cross the bands of color like slender shadows. The lines identify chemical elements present in the system from which the light comes. When Slipher photographed the Andromeda Nebula in this way, he found that these shadows were shifted toward the violet end of the rainbow. This indicated that the Andromeda was moving toward our Earth, for the Doppler effect would crowd the wave-lengths of the light closer together and make all of them slightly shorter than they were when they left their source. But the very next nebula that Slipher spectrographed showed a shift toward the red end of the rainbow, indicating that the nebula was moving not toward but away from the Earth.

Slipher kept at these laborious studies, photographing and then measuring the displacement of spectral lines and calculating the indicated velocity. He accumulated data on 40 nebulae, and all but five showed shifts toward the red. The five exceptions were the Andromeda and four other nearby systems. For the remaining 35 there seemed to be but one objective—to get away from our part of the Universe.

In 1929, some years after Slipher ceased these studies, Hubble compared the velocities with his own newly-determined distances and found a striking correlation: The speed of the nebulae's flight away from us (*i.e.*, the amount of red-shift) increased directly with their distance from us.

At the time Hubble discovered this correlation, now known as the law of the red-shifts, only 46 nebulae had been spectrophotographed, and of these but a bare dozen were sufficiently remote to point up the relationship. In order to investigate the matter on a much larger scale, Milton L. Humason of Mount Wilson began a program of determining the velocities of fainter and more distant nebulae, using the 100-inch telescope. By 1948 the number of known nebular velocities had been increased to over 500. Even at distances of 200 million light-years or so, the limit of the 100-inch for spectra, Hubble's law of the red-shifts still held. With the more penetrating 200-inch telescope Humason last year photographed two nebulae estimated to be 360 million light-years away. The redward shift recorded by these plates was the largest ever measured, indicating a velocity of 38,000 miles a second. The steady increase of velocity with distance as fainter and more distant objects were observed is strikingly shown in the table above.

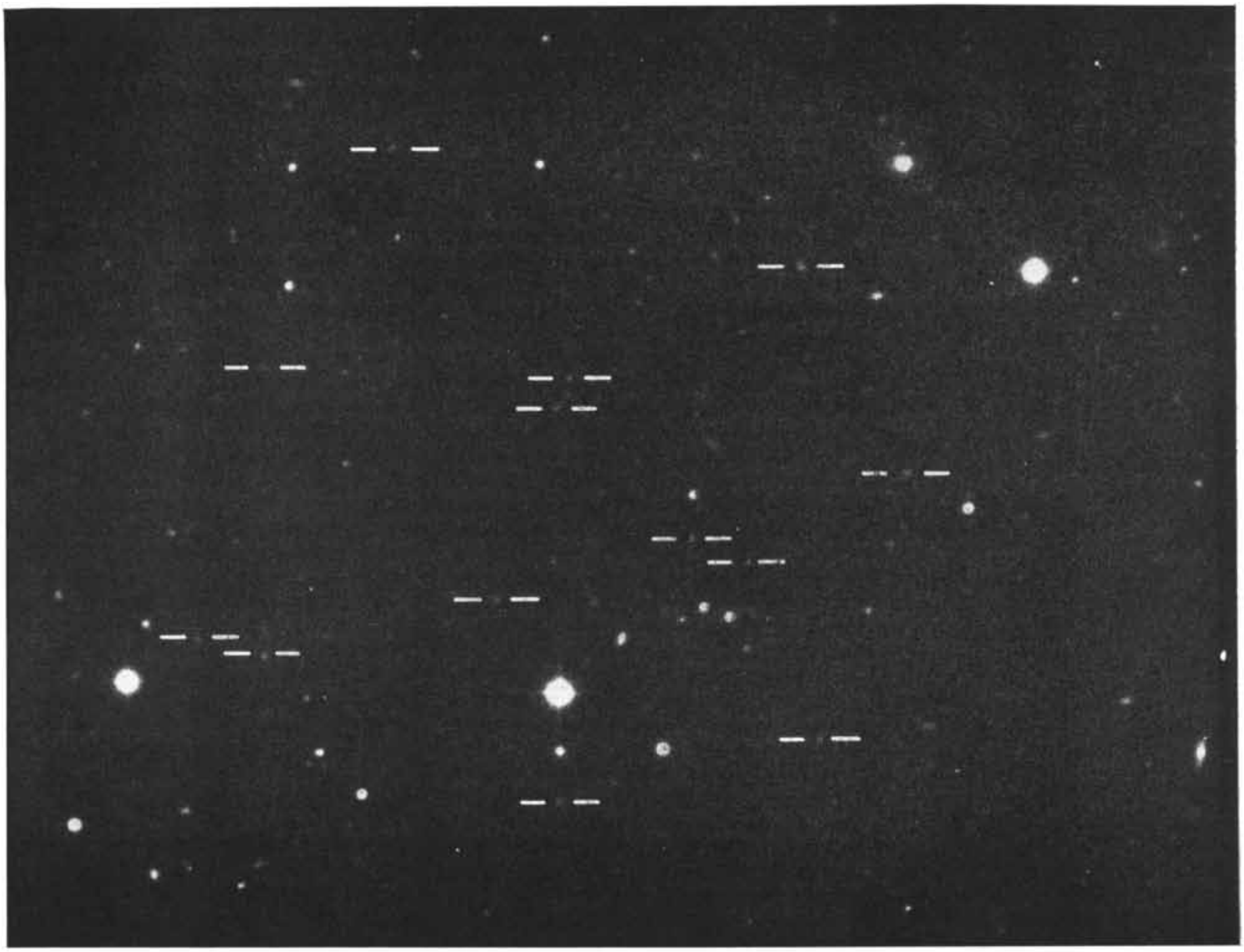
Humason was delighted with the performance of the 200-inch. "In three reasonably good nights of observation," he remarked, "I accomplished what may have taken three years to achieve with the 100-inch telescope." With the 100-inch, exposure times of 25 hours would be required, assuming that the instrument were able to resolve the spectra at all. With the 200-inch, four to six hours were sufficient.

Analyzing the Stars

The task of determining the physical properties of the Universe and arriving at a picture of the Whole obviously cannot be tackled as a single project; it must be broken down into specific problems. "One of the specific problems," explained Bowen, "is the study of individual stars to determine their temperatures, pressures, magnetic fields, internal motions and chemical components. The question of composition is becoming of increasing importance. We know that the energy radiated by the Sun and most of the other stars comes from the transformation of hydrogen to helium, a process which takes place in the super-hot stellar cores. But none of the mechanisms which we conceive as possible in stellar interiors provides a means for creating calcium, iron and the other metals that we know from spectrographic evidence are there. It is therefore important to learn whether all stars have the same relative abundance of the heavier atoms, and if not, to determine the patterns of variation."

Some stars are surrounded by halos of diffuse gases, which presumably were ejected from them in explosions. These rarefied envelopes of gas are called planetary nebulae, to distinguish them from the spiral nebulae and other extragalactic systems of stars. "We are studying a number of planetary nebulae with the Hale Telescope," said Bowen, "to determine their chemical composition and also to measure their internal motions. As we move out from the star through successive layers of its surrounding gas, we find that the stage of ionization of the atoms decreases. By measuring the displacement of the spectral lines representing the various ions, we measure the velocities at all points of the object. Velocities as high as 40 miles a second have been recorded in layers far from the star."

Another study is directed at determining the masses of the spiral nebulae. Hubble estimates that the Andromeda Nebula as a whole is 100,000 million



FAINT NEBULAE in Coma Berenices were photographed by the 200-inch. Each of the nebulae is marked by a white line to its left and right. If the luminosity of these systems is comparable to that of others, they are between 500 and 1,000 million light-years away. The brighter objects in the photograph are relatively nearby stars.

times as massive and 2,500 million times as luminous as the Sun. From this it would appear that the average star in Andromeda is less bright than our Sun, but obscuring clouds of dust that cut down the nebula's brightness may account for some of the difference.

Finally there are the two great cosmological problems: first, that of the distribution of nebulae, and second, the meaning of the red-shift.

There is no question of the reality of the red-shift. The experimental proof of its reality is shown by hundreds of photographic plates. But what does the shift mean?

Most investigators have assumed that the displacement of lines in the spectra of distant nebulae indicates motion, because motion is known to alter the wavelengths of the light emitted by the Sun and other nearby stars. Certainly a shift to the red means loss of energy. The red-shift of light from a remote star may well be due to the motion of recession, which snatches away some of the energy of the light. But there is another possible explanation. It is conceivable that light may simply lose energy in the course of traveling millions of years through space. If it did, all its wavelengths would systematically lengthen and all its spectral lines would shift toward the red or low-energy end of the spectrum, even though the source of the light was standing still or moving at random. It is a question, therefore, whether the red-shift means that the Universe is expanding or merely that light has grown tired. Hubble believes that the 200-inch telescope will help establish the true state of affairs.

The distribution of star systems in the Universe also is a key problem. For if the nebulae are unevenly scattered through space, the task of estimating the size and mass of the Universe is greater than would be the case for a homogeneous Universe. It is therefore important to map the positions of nebulae. This project already is under way at the Lick Observatory under the direction of Charles D. Shane. He expects his survey to include all nebulae down to those of the 18th apparent magnitude —an estimated total of more than a million stellar systems. The fainter nebulae, beyond the range of the Lick telescope, are so numerous, ranging into the billions, that it is impracticable to try to plot the entire sky. The Palomar group will select certain sample areas on the basis of the Lick results and count the nebulae in those areas out to the photographic limit of the 48-inch schmidt. Then the 200-inch will be used on sample regions uniformly scattered over these selected areas, and again the nebulae will be counted to the telescope's limit. In this way it is planned to determine the distribution of nebulae to different limits of brightness and distance.

The astronomer's chief yardsticks of distance are the cepheid variable stars, the blue supergiants and the novae, or exploding stars. The intrinsic brightness of these types of stars has been fairly well established by study of their spectra and by other means; they are accessible for study because they occur in our own galaxy, the Milky Way. When one of these beacons is spotted in a spiral nebula, it is possible to determine from the star's faintness the distance to the nebula. With the distance known, it is a simple problem in arithmetic to calculate the whole nebula's real brightness.

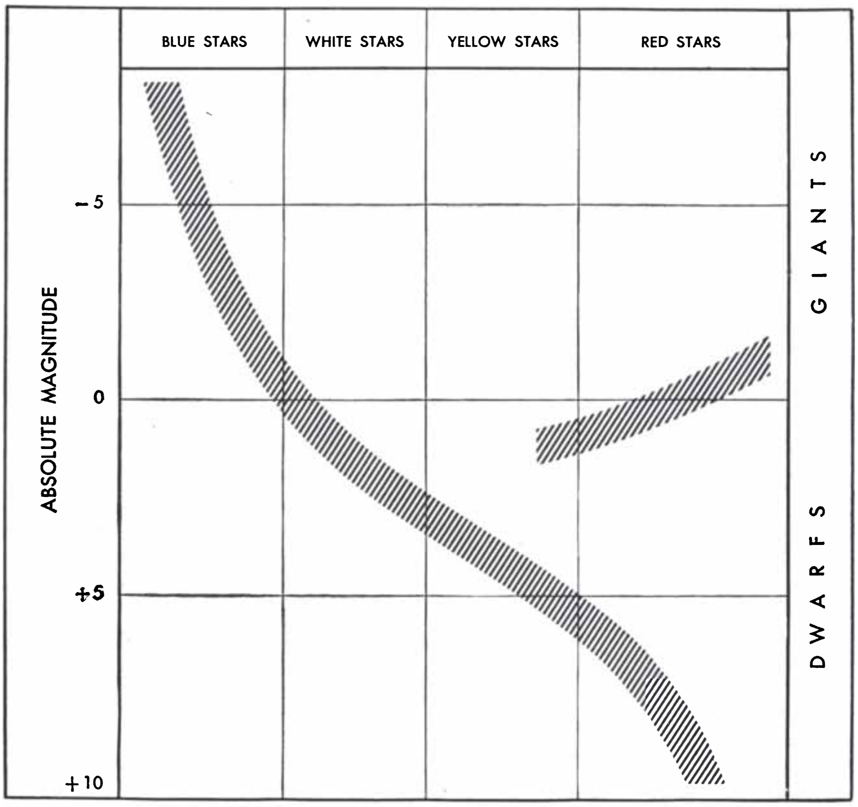
Such determinations have been made for several hundred nebulae within about 10 million light-years of the Earth. (Beyond that distance even the 200-inch telescope is unable to resolve individual stars.) Some of these are giant systems, some dwarfs. The calculated average luminosity of each group serves as a distance indicator with which to gauge more remote groups and collections, since it is assumed that the average for a large sample is typical of the average for other large samples of the same kind.

Now such a system is scientifically sound, provided the yardsticks are correct. But recently Joel C. Stebbins and Albert E. Whitford of the Washburn Observatory in Wisconsin, using photoelectric tubes to measure luminosities of very faint stars instead of the old method of measuring photographic images, discovered that many of the old measurements were in error by as much as a quarter-magnitude. And Walter Baade, of the Mount Wilson and Palomar staff, made another discovery that threw all the calculations off. He found that the stars of the Universe, which had all been supposed previously to run true to type, actually had to be divided into two general classes, which he calls Population I and Population II. "Baade's discovery," said Hubble, "is the most important contribution of the last decade to our knowledge of the components of the Universe. It is revolutionizing our thinking about the composition of nebulae, and I am confident it will prove to be a powerful tool in the study of cosmic structure."

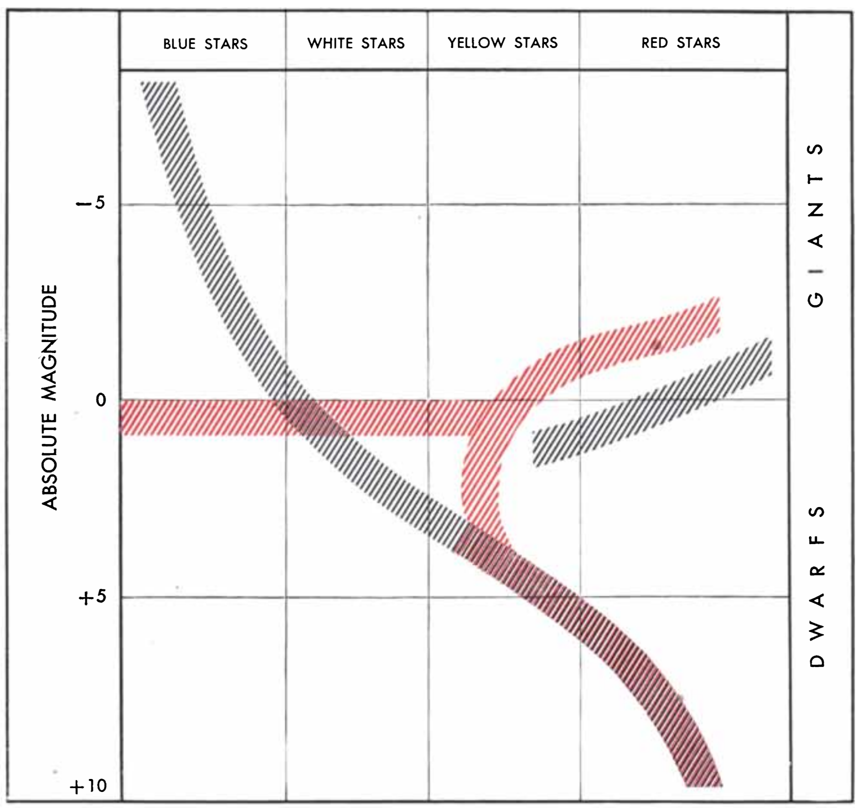
The Mountain

Baade was working with the 200-inch telescope when we arrived on the top of Palomar Mountain. A dozen buildings dot Palomar's peak—powerhouses that provide electricity, water and other utilities; cottages for the mechanics and other workers; the "Monastery," where the astronomers live; the domes of the 48-inch and 18-inch schmidts. But all these structures and their equipment are auxiliary to the master installation—the 200-inch reflector that rests under the gigantic Pantheon-like dome of 135-foot diameter and 137-foot height. Under this great silvery dome they were readying the 200-inch eye for its night's vigil on the Universe.

All day the dome had remained tightly closed to insulate the sensitive giant against solar heat and terrestrial weather. As the Sun sank behind a distant mountain, the roof shutters were rolled back, exposing the vast uptilted framework of the 60-foot tube. At the same time a bank of electric fans began to whir, directing their breezes against the undersurface of the great mirror. Or-



HERTZSPRUNG-RUSSELL DIAGRAM plots magnitude of stars against their color. Most stars in the Milky Way occupy a "main sequence" running from upper left to lower right. Red-giant stars occupy a separate branch.



TYPE I AND TYPE II DIAGRAM utilizes the same scheme. The stars of Type II are found to occupy a different sequence (*red*) from those of Type II. The brightest stars of Type I are blue; the brightest stars of Type II, red.

TYPE I STARS predominate in the open spiral Messier 33, which is about a million light-years away. This photograph was made with the 200-inch.

TYPE II STARS predominate in one of the two companions of the Great Nebula in Andromeda. This photograph was also made with the 200-inch.

dinarily the outside temperature on the mountain drops to its night minimum a few minutes after sunset, and the fans quickly cool the 15-ton slab of glass to the same level. By the time the last streak of crimson had faded from the West, the telescope was poised and waiting, ready to peer hundreds of millions of years into the past of the stars.

And the stars were waiting too, in dazzling pageantry. Although Palomar is 2,300 miles north of the Equator, from its elevation the 200-inch mirror can sweep over three quarters of the sky. Only the heavens above the Antarctic zone are beyond its gaze. Palomar's air is so clear and steady that the stars shine with a brilliance never seen down in valleys, prairies or city streets. This starlight is the principal concern of the astronomers, and they take great pains to keep it uncontaminated. Road lamps and headlights are strictly forbidden on the mountain top.

Bowen was driving the car that took us the half-mile from the Monastery to the 200-inch, and as the dark road wound through the heavy brush, it seemed that he must be feeling his way by a sort of sixth sense. He never faltered or took a wrong turn, and at length we drew up in front of the dome and entered by a door on the ground floor.

To pass from the star-studded vault without into the darkness within was blinding. There was nothing to do but to hang on to Bowen's arm and follow where he led. We finally risked a pocket flashlight, which disclosed that we were groping among a forest of steel piers—the underpinning of the telescope and its observing floor above. Eventually we reached the elevator. It, too, was pitch dark, but the director knew which button to push—and a few moments later we stepped out on the observing floor.

It was not so dark here. A soft radiance suffused the massive overshadowing structure of the telescope. Looking up, we saw its tubular frame silhouetted against the Milky Way. Starlight was pouring through the open shutter of the dome, touching the whole interior with its celestial magic.

Across the floor, under one of the supporting arms of the telescope yoke, a man sat at a table in the semi-darkness watching hands move around a series of illuminated dials. This was Byron Hill, superintendent of grounds, who was serving as instrument-tender for the night. Seventy feet up in the air, seated in a cage at the open end of the telescope tube, was Baade, observer for the night. In the floor of the cage is an aperture that admits the concentrated beam of starlight gathered by the more than 190 square feet of flawless mirror below. At the spot where the curvature of the mirror focuses this beam, Baade had exposed a photographic plate. He was watching through the eyepiece and guiding the steel-glass giant with his fingers on electric controls to keep the star image centered at the cross-hairs. Below, buried in the base of the telescope, a motor of one-twelfth horsepower was slowly turning the great tube toward the West, in step with the rotation of the Earth. The telescope weighs 500 tons, but it swung effortlessly and noiselessly on its oil-padded mounting.

"Thirty seconds to go," sang out Hill, his eye on the clock.

"Ready," answered Baade from his microphone in the cage.

"Twenty-five," droned Hill, "twenty—fifteen—ten—five—four—three—two—and close!"

Baade closed the plateholder, removed it and inserted another. Then he called down through the speaker: "After we've taken this one I'll come down for a cup of tea—at 12 o'clock."

Red Giants

Baade is 58, a native of Germany who left a private-docentship at Hamburg Observatory in 1931 to accept appointment to the Mount Wilson staff. Over tea, he discussed his work:

"During the war years the city lights of Los Angeles and Pasadena were blacked out, and that was an encouragement to intensified study of the nebulae. Dr. Hubble had found stars in the spiral arms but had been unable to resolve the bright central nucleus of the Andromeda Nebula into stars. Now, with the sky free of artificial light and with improved photographic plates available, I thought I would make a search for them with the 100-inch telescope. I tried blue-sensitive plates, because usually the brightest stars in galaxies had turned out to be blue giants. But these photographs got me nowhere; the central area remained a great unresolved luminous blob.

"Then I had a hunch. It occurred to me that the brightest stars of this region might be red. Red-sensitive photographic plates of high speed had just become available, and I began to use them. The results were immediate. The bright central nucleus broke up into a mass of individual star images, and as I photographed various regions of the nebula, on out to the tips of the outermost spiral arms, I found a change in the pattern. Every time I encountered a spiral arm the blue supergiants showed up, whereas in the center and in the spaces between the spiral arms I could find only red giants."

The Andromeda Nebula has two smaller companion nebulae which do not have the spiral structure; one is nearly circular in shape, the other shows a vague bar-and-disk pattern. No one had been able to resolve either nebula into individual stars. Baade photographed them with his red-sensitive plates and found them resolved into a vast number of red giants. But with the blue-sensitive plates he was not able to get any star images at all.

"From this study," Baade continued, "three results stood out: first, the brightest stars in the hitherto unresolved nebulosities were red; second, the moment one reached the brightest stars in these systems they appeared at once by the hundreds and thousands; third, as far as luminosity was concerned, these brightest red stars were about five magnitudes (that is, 100 times) fainter than the blue supergiants on the spiral arms of the Andromeda Nebula."

A New Population

Before discussing luminosity comparisons, let us get clearly in mind what is meant by the stellar magnitude scale. The numbers on this scale stand for increasing faintness. Thus Betelgeuse, a bright star, is rated as of the first magnitude, the North Star of the second, and so on down the line. The sixth magnitude is the faintest the naked eye can see; the 21st the faintest the 100-inch telescope can photograph, and the 23rd the limit of the 200-inch telescope. Stars that appear brighter than Betelgeuse are assigned zero and even negative magnitudes: the dog-star Sirius is rated as minus 1½ magnitude and the Sun as minus 26.

These magnitudes stand for the apparent brightness of the stars as we see them, with their light attenuated by distance and the cosmic haze; they do not, of course, measure the stars' real luminosities at the source. As a basis for comparing luminosities, astronomers compute what the brightness of each star would be if it were placed at a standard distance from the Earth. This is called the absolute magnitude. The standard distance is 10 parsecs (about 32½ light-years). If all the naked-eye stars were lined up around the Earth at this standard distance, how our firmament would change! Sirius, which now appears the brightest of the night array, would dim to a magnitude of about 2 and some of the seemingly faint blue stars would blaze into a magnitude of minus 7.

When Baade compared the blue and red supergiants in terms of absolute magnitude, he found that whereas the brightest blue stars, found in the spiral arms, were of the minus-7th magnitude, the brightest red stars, found in the central region and the two companions, were of only the minus-2nd magnitude.

Baade now turned to the famous Hertzsprung-Russell diagram of the classes of stars to see what light it could throw on the sudden emergence of hundreds and thousands of red giants in the nebulae. In this diagram all the stars are plotted according to absolute magnitude and spectral type. Most of the stars of our Milky Way system describe a curve known as the "main sequence." The main sequence begins with blue giants of about the minus-7th magnitude and ranges down through white stars of lesser magnitude, yellow stars, orange stars and finally red dwarfs of about the 19th magnitude. Entirely separate from this curve of the main sequence, the diagram shows a shorter sequence made up almost entirely of red stars; it is known as the "red-giant branch." Examining this group, Baade found that these red giants were a good deal fainter than his new-found red giants in Andromeda; most of those in the Hertzsprung-Russell diagram were around magnitude 0.

"At this point I was stumped," continued Baade, "for it seemed clear that the red giants of the newly resolved systems could not be members of the standard Hertzsprung-Russell diagram. Then I remembered the curious diagram of the globular clusters."

These globular star clusters are satellite systems which surround our Milky Way, apparently hedging it about in all directions. One hundred such clusters have been photographed. Their stars had been plotted by Harlow Shapley according to the Hertzsprung-Russell system, and their red giants had seemed different from the red giants of the main sequence—they were about two magnitudes brighter. In other words, their magnitudes were about minus 2—just like the red giants of the Andromeda Nebula and its two companions!

"Suddenly everything fell into line," related Baade. "There must be, I realized, two populations of stars—one characteristic of the globular clusters and the newly resolved Andromedan systems; the other characteristic of the spiral arms and of our own part of the Milky Way."

Populations I and II

Following the Hertzsprung-Russell scheme, Baade now plotted the stars anew, and his diagram shows at a glance how the magnitude factor separates the giants of Population I from those of Population II (*see diagram on page 47*). Both populations have blue stars, but those of Population I are the brightest giants known, while the blue stars of Population II are not far above the dwarf level. Similarly, both have red stars, but Population II has the top giants of this color. When we reach stars at about the Sun's luminosity, absolute magnitude 4, the two curves merge.

"This is exactly what we should expect if we are dealing with stars of two different age groups," explained Baade. "Inasmuch as we are certain that the conversion of hydrogen into helium is the process that keeps the stars going, we can make rough but reliable estimates of the time period in which a star of given luminosity exhausts its hydrogen supply. The result shows that the fastest spenders are the blue giants of Population I. Even if they were originally composed wholly of hydrogen (with a few impurities to get the transmutation cycle going), they would expend their last hydrogen in about 100 million years. In other words, none of the stars at the top of the diagram of Population I which we observe today can be older than 100 million years. If there were blue stars of this luminosity in our Milky Way 100 million years ago, they must have faded long since and now occupy places of much lower magnitude in the diagram.

"As we move down the scale from the blue giants, the rate at which hydrogen is converted into helium and radiation becomes less and less, until at about absolute magnitude 4 we come upon stars which can not have spent more than a few per cent of their hydrogen. Even if they were formed at the birth of the Universe, which we estimate to have occurred about 3,000 million years ago, they still have an enormous fuel reserve in the form of hydrogen. In other words, stars of absolute luminosity 4, such as our Sun, and all fainter stars which were formed at the begining of the Universe have changed neither their luminosity nor their chemical composition in the 3,000 million years that have elapsed. Even if the two populations represent stars of two different age groups—and there are strong indications that Population II is the older—the distinction between them must disappear at about magnitude 4 simply because the Universe is still so young."

If the distinction disappears at about magnitude 4, how can one know that there are different populations in the lower levels?

"That is a very interesting question which we are investigating," answered the astronomer. "If the diagrams of the two populations completely coincide, the distinction indeed becomes meaningless. But if the diagrams should not coincide precisely, it will make Professor Martin Schwarzschild of the Princeton Observatory, one of our guest investigators this year, very happy. He has obtained very strong spectroscopic evidence that there is a difference in chemical composition between stars of the two populations. Those of Population I seem to have a higher admixture of metals than those of Population II. Since we know that the probable temperatures inside the stars (only a few million degrees) are much too low for the transmutation of lighter elements into metals, we must conclude that the original material from which the stars of Population I were formed contained a higher percentage of metals than the material from which Population II stars were formed.

"Now we know," Baade continued, "that Population I stars are found only in systems that contain dust. In the Andromeda Nebula dust is richly strewn all through the spiral arms, and it is here that we find the blue giants and other Population I stars. Similarly in other nearby galaxies and in our own—the Milky Way—wherever dust clouds are present, there you find Population I stars, and where there is no dust, there is no Population I. Moreover, this dust is richer in metals than is the interstellar gas, because the atoms of the metals easily stick together when a grain of dust is formed of the interstellar gas, whereas the much more abundant hydrogen atoms of the gas won't stick and so evaporate back into space. Professor Schwarzschild therefore guesses—and it is probably a good guess—that the stars of Population I have been and still are being formed from the interstellar dust, whereas those of Population II were formed from the gas at an earlier epoch, before it had time to produce dust particles. If Schwarzschild can prove that even among the stars much fainter than the Sun there are the two types of stars, one with the higher abundance of metals (type I) and the other with the lower (type II), he will have won."

The Cosmic Dust

It's a dusty Universe. In all the nebulae that have been resolved, dust is abundant in the spiral arms, though absent from the central nuclei. The Sun with its Earth and other planets is believed to be situated far out in one of the spiral arms of the Milky Way, and even a small telescope shows many of the nearby dust clouds, such as the dark patches in Orion and the Coalsac near the Southern Cross. All about us are stars of Population I, born, it is believed, of the cosmic dust.

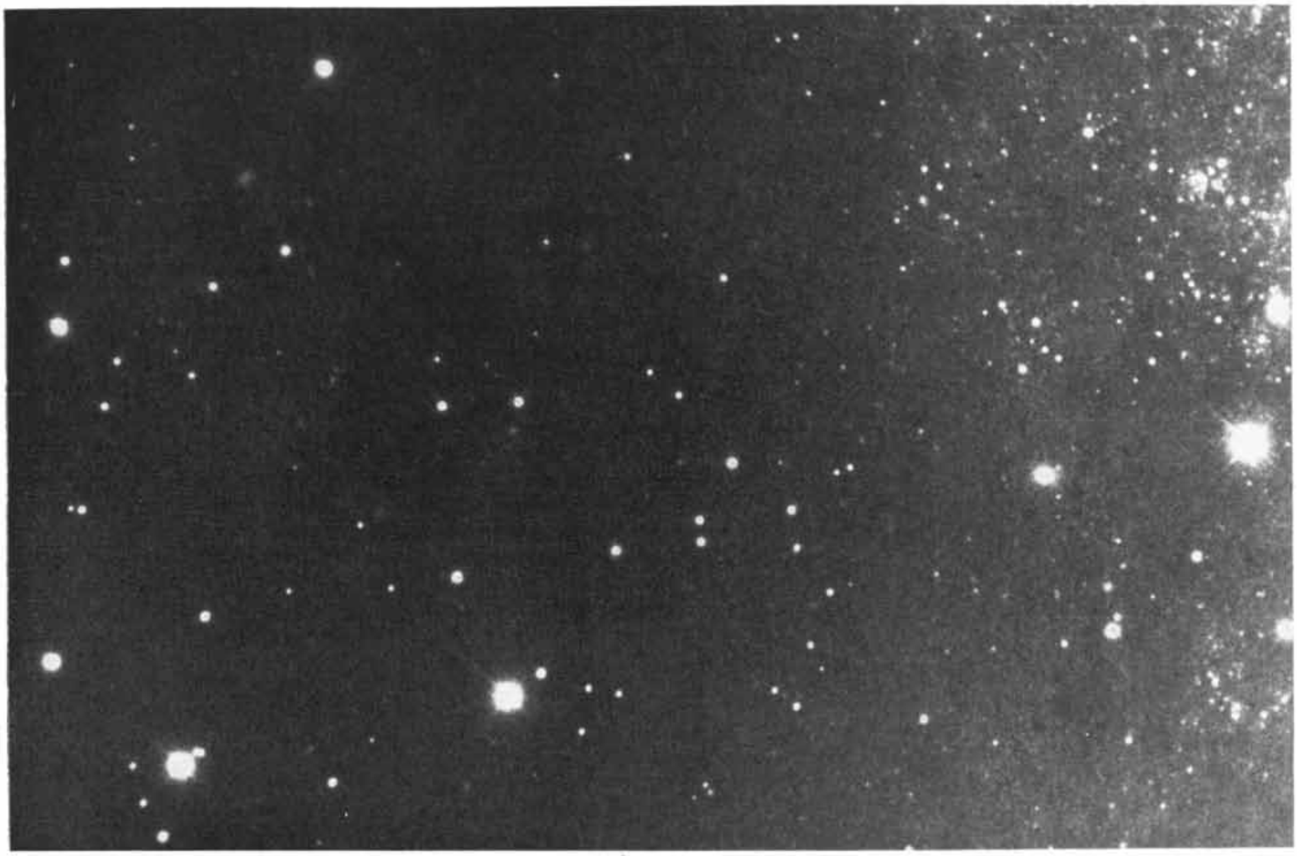
Among Population II stars explosions are frequent. The Andromeda Nebula continually shows fireworks: in a single year some 15 novae, an average of more than one explosion a month, were found in its photographs. Novae also flare up frequently in Messier 81, the large spiral in the Big Dipper, which like the Andromeda has a large representation of Population II. But they are relatively rare in the two Magellanic Clouds, those satellite galaxies which attend our Milky Way and which are composed almost entirely of Population I stars.

One upsetting result of Baade's discovery is that the cepheid variable stars, which have been used as yardsticks of distance, turn out to come in two types. Harlow Shapley used the cepheid variables in the globular clusters that attend our galaxy to measure the distances of the clusters and so estimate the dimensions of the Milky Way. Hubble used cepheids in the spiral arms of the Andromeda Nebula as yardsticks with which to measure the distance and dimensions of that galaxy. But Baade finds that the cepheids in the globular clusters are of Population II, whereas those in the Andromeda Nebula are of Population I. Current studies suggest that Population I cepheids may be about half a magnitude brighter than Population II cepheids of the same period of variation. If the suggestion is confirmed, it will follow that either the Milky Way is smaller than we have supposed or the Andromeda Nebula larger. In either case our own stellar system will no longer rival the Andromeda in size.

As a consequence of Baade's findings an extensive program of calibration is now under way at Palomar. All the familiar distance indicators are being reexamined, retested and standardized in a grand survey centered on globular clusters and nearby spiral nebulae. The key instrument of this survey is the 200-inch telescope, using photoelectric tubes to measure the magnitudes of the stars it reveals. Two spirals in particular are being sifted for stars of all colors in both populations: the Andromeda Nebula and Messier 81, the large spiral in the Big Dipper. Because the Andromeda is the largest known spiral and is less than a million light-years away, it will yield a wealth of new stellar data of the kind that we are unable to obtain from our own galaxy, for we can never examine the Milky Way as a whole—we cannot see our forest for the trees. Messier 81 is farther away than the Andromeda—its estimated distance is three million light-years—but even so, the 200-inch can break its massed brilliance into individual stars, and the plan is to use Messier 81 to check the conclusions obtained from the Andromedan survey.

"These studies are crucial," said Hubble. "All of our ultimate problems—the evolution of stars, their association in stellar systems, the nature of the Universe itself—demand that we acquire reliable information concerning distances, luminosities and masses. When these preliminary objectives are won, we shall turn to the cosmological problems with new confidence. We shall then be able to state our observational results positively, within known limits of error or uncertainty, and it will become possible to test and eliminate theories. The long array of possible worlds will be reduced to a few that are compatible with the existing body of knowledge. And possibly, just possibly, we may be able to identify in the shortened array the specific type that must include the Universe we inhabit."

George W. Gray, author of Electrophoresis *and other articles that have appeared in this magazine, visited Palomar Mountain as a representative of the Rockefeller Foundation.*



BLUE-SENSITIVE PLATE made by the 200-inch shows the edge of the Great Nebula in Andromeda as it is outlined by its spiral structure. The stars of medium brightness on the right side of the picture belong to Type I.

RED-SENSITIVE PLATE shows the same region. The dense field of faint stars contains the brightest members of Type II. This shows that the spiral structure of the nebula is embedded in a much larger disk of Type II stars.

FROSTBITE

Some recent studies show that the scourge of winter soldiers and high-altitude fliers may best be treated by rapid thawing, and that some time-honored "remedies" may actually be harmful

by Emlen T. Littell

FROSTBITE has ever been a curse of winter armies, from Valley Forge to Smolensk to Korea. The hazard has now acquired a new dimension, for high-altitude flying exposes men to temperatures even more severe than those in the field. A gunner who takes off a glove to fix a gunsight finds his fingers becoming numb and stiff within a matter of seconds; within minutes the damage may go so far that he will lose his fingers. The frostbite problem began to receive systematic investigation during World War II, and the war in Korea of course has further stimulated this research.

Surprising as it may seem, until recently very little was known about how frostbite injures the tissues or about how it should be treated. The injury process is not yet clearly understood, and there is still controversy as to the best method of treatment, but enough has been found out to show that some of our folklore—such as the idea that frozen fingers should be rubbed with snow—was all wrong. This article will report some new findings on the pathology of frostbite that shed light on possible methods of treatment.

The bodily functions of warm-blooded animals are in no small part directed toward defending the stability of the internal environment against outside vicissitudes. When cold threatens the internal environment, the lower brain-centers automatically signal the aptly named sympathetic nervous system to mobilize the body's defenses. The sympathetic nervous system controls such adjustments as the blood temperature, heartbeat, breathing rate, perspiration and the dilation and contraction of blood vessels. The body makes adjustments to protect its general temperature at all costs, even if this means the sacrifice of some of its parts.

The particular adjustment with which we are here mainly concerned is the dilation and contraction of the very fine blood vessels in the capillary bed—that network at the end of the circulatory system where the blood passes from the arteries to the veins. Here the blood delivers its oxygen and nourishment to the tissue cells and begins its return to the lungs and heart for a new load. A capillary is a loop not much more than a millimeter long, w'th a bore just large enough to permit the passage of red blood cells in single file. The capillary walls have to be permeable enough to pass oxygen and food to the tissues, but not so permeable that they lose the blood fluids. From a fine artery (arteriole) at the beginning of the loop, the capillary gradually changes to a fine vein at the end. The arteriole section has a much thicker wall than the vein, and in its wall is a layer of muscle. It is this muscular coat which, activated by the nervous system, constricts and dilates the blood vessel.

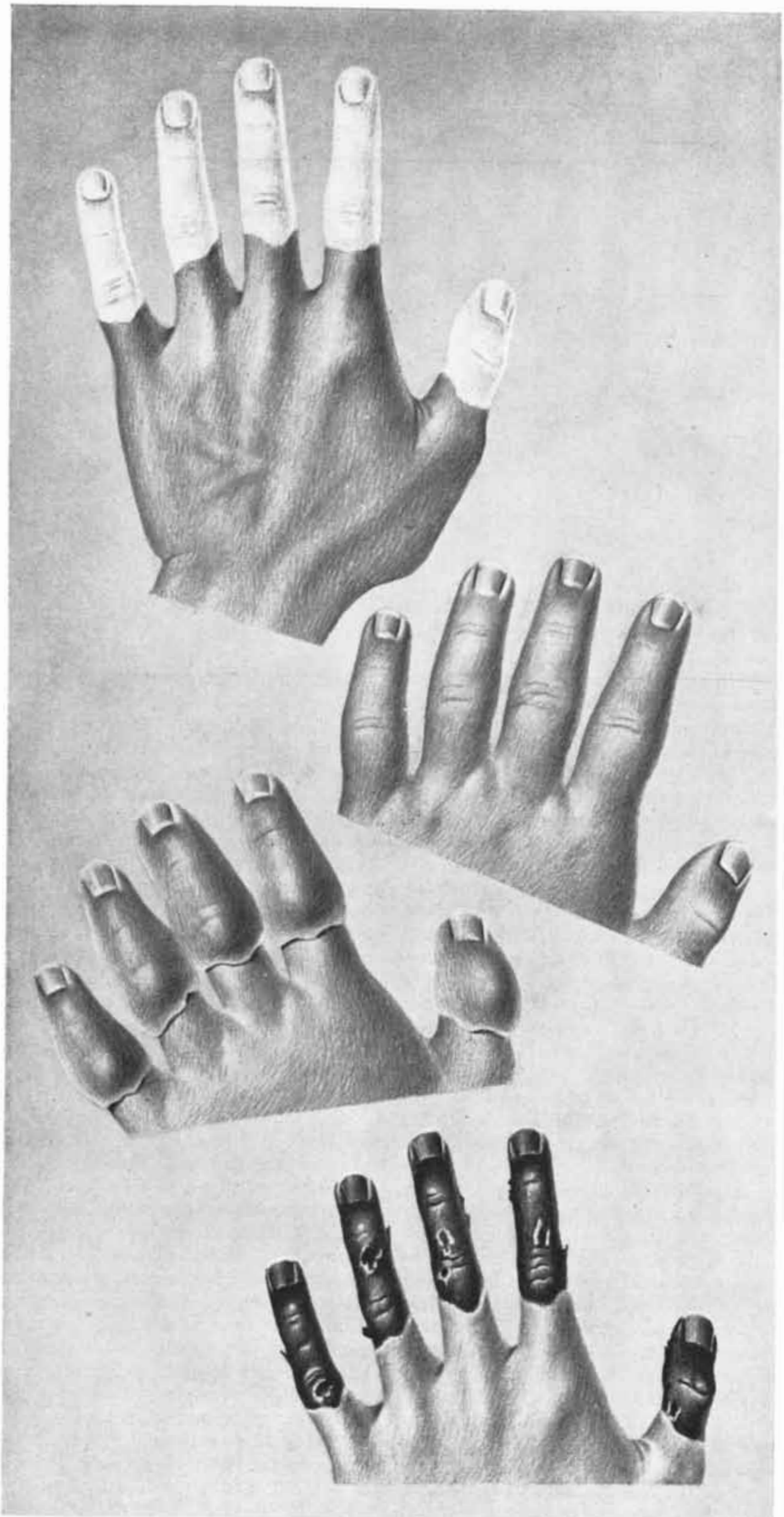
WHEN a person's skin is exposed to cold, the sensory nerves at once send a message to the brain, which in turn automatically sends out through the sympathetic nervous system a signal to "man the ramparts." To reduce the volume of blood exposed in the skin, and thus reduce the heat loss from the body, the nerves cause the arteriole muscles to contract and cut down the flow of blood to the chilled tissues. This is known as "vasomotor spasm." If the exposure is sudden and the external cold severe, the result may be frostbite. The circulation of blood through the capillaries of the hands or feet, as the case may be, stops completely, and the chilled extremities turn blue as the oxygen supply is shut off from the stagnant blood. The skin becomes white, the flesh hard, the limbs numb. Activity within the cells almost ceases. Soon ice crystals probably begin to form within the cells. Finally all the tissues freeze hard, and the fingers, toes, hands or feet become stiff and rocklike.

The damage may be temporary or permanent, depending on the severity and length of exposure. About the nature of this damage there is considerable debate. Wiley Forbus of Duke University lays the blame on starvation of the tissues due to the shutoff of the blood supply. William Boyd of the University of Toronto noted that the cell fluids crystallize and rupture the cell walls, so that the capillaries are damaged and clots of a glassy protein substance form within the capillaries. In 1947 R. Quintanilla, F. Krusen and H. Essex of the Mayo Clinic discovered a very significant fact by means of some remarkable experiments on rabbit ears. They cut a hole in a rabbit's ear and put a mica window in it. Fine capillaries expanded from the intact part of the ear and grew between the "panes" of the window. The experimenters then froze a section of the capillaries by putting a piece of dry ice on the window. The capillaries disappeared. When the spot was thawed again, the capillaries reappeared, and the blood flowed freely in them for 5 to 10 minutes. Then the blood flow seemed to slow down; eventually the vessels were packed with stationary red corpuscles. The red cells appeared to cling together, but they did not form a true blood clot. Apparently they had come to a halt because they had lost their fluid vehicle—the blood plasma.

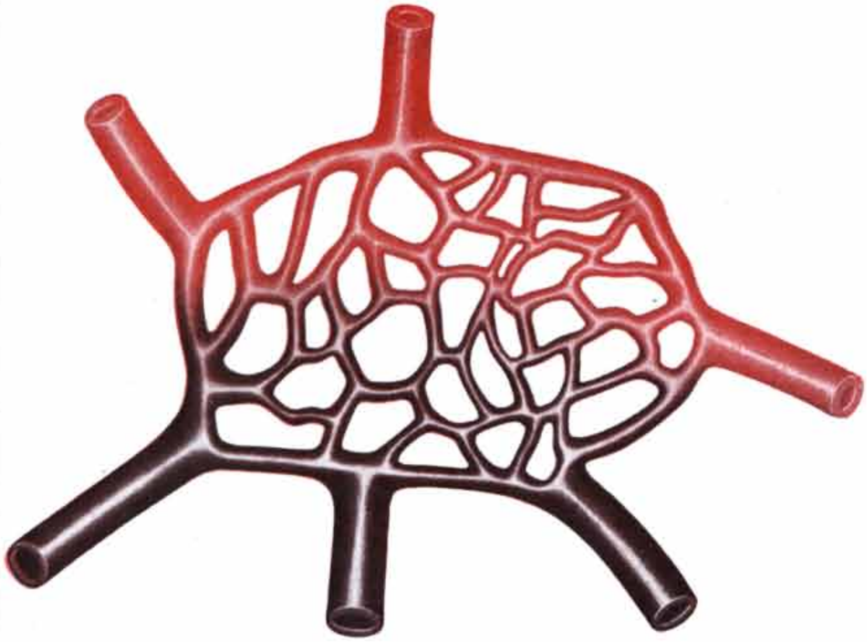
Obviously the plasma must have oozed into the surrounding tissues through the capillary walls. But what made the capillary walls permeable to plasma? This is still unknown. The increased permeability might be due either to damage by minute ice crystals or to prolonged oxygen starvation of the walls. As for penetration of the cells, it may be that alteration of the salt concentration within the cells causes the plasma to pass through the cell walls by osmosis. This would account for the swelling observed after frozen fingers and toes have been thawed.

IN MILD cases of frostbite, thawing produces dilation of the blood vessels and swelling of the tissues. The arterioles overdilate in compensation for their previous overconstriction. The swelling is partly a result of the overcompensation and excessive blood return to the extremity, but primarily a consequence of fluid escape into the tissues. After several hours the swelling subsides, as the plasma is reabsorbed into the capillaries or returned to the central circulation through the lymphatic system. Because of the overdilation of the vessels, the frostbitten part remains red and tender.

In more serious cases of frostbite, where the damage has proceeded fur-



FOUR ASPECTS of a severe frostbite of the fingers are shown in these drawings. In the frozen stage the flesh is hard and white. In the second phase, when the fingers have thawed out, the whole hand is swollen and red. In the third phase huge blisters form as fluid seeps out of the capillaries. In the fourth phase the fingers turn black as gangrene sets in. In such a severe case the fingers would probably be amputated at the second joint.



CAPILLARY BED is the primary site of damage due to frostbite. In this schematic drawing the arterioles (*bright red*) join the venules (*dark red*).

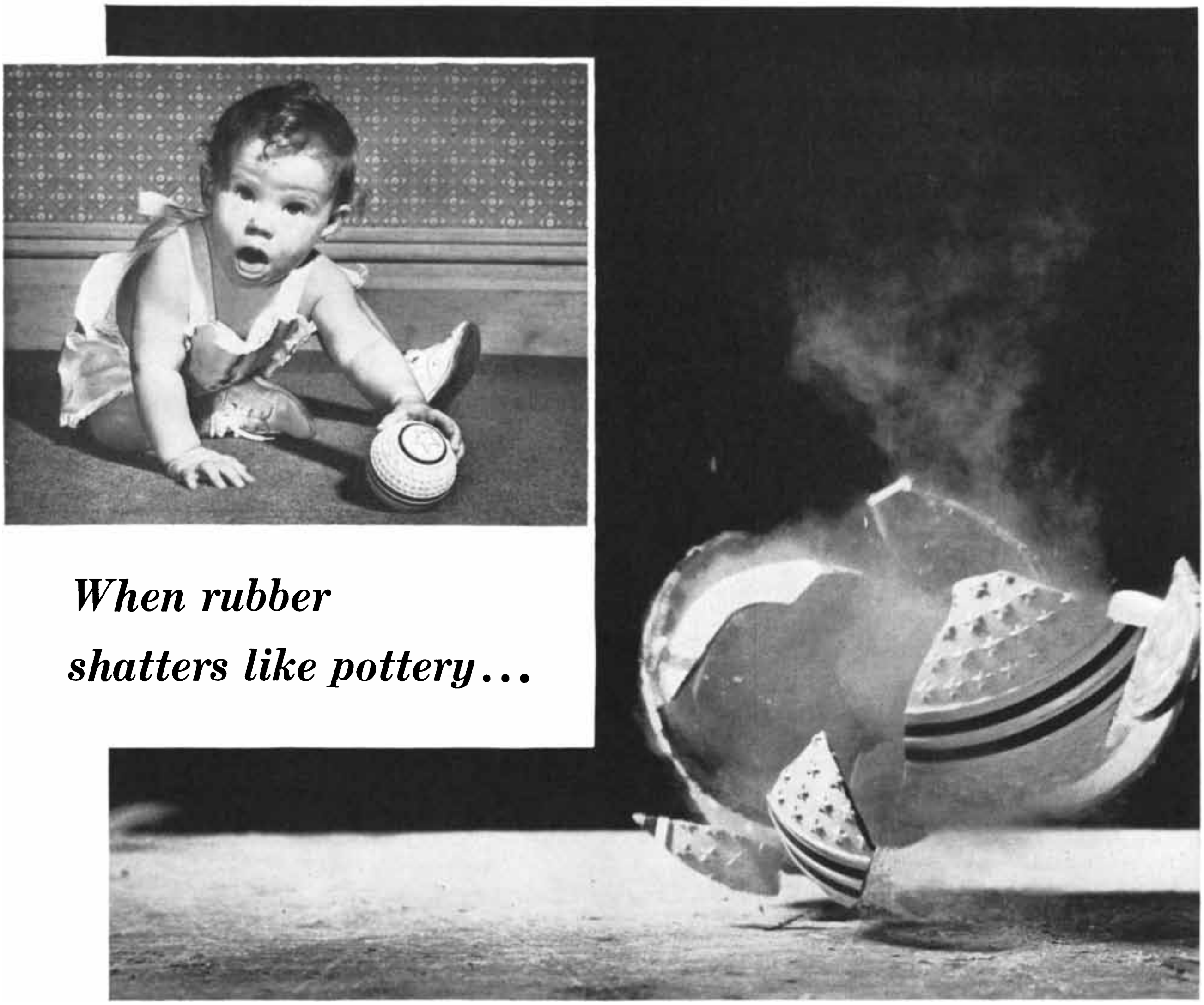
ther, there is quite another story. These cases can be divided into several categories depending on the degree of damage. The first effect is a loss of sensation and muscular paralysis which may last for weeks after thawing. The second stage in damage is represented by cases in which there is some destruction of muscle cells. The muscle, a highly specialized tissue, is apparently quite sensitive to cold. Examination of frostbitten experimental animals has shown that there are often spots of dead muscle-tissue in limbs where the overlying skin shows no overt damage. On healing, the damaged muscle island is replaced by fibrous connective tissue. The functional ability of the muscle is reduced in proportion to the amount of tissue destroyed. Because the damage is not visible on the surface, these injuries are often overlooked.

When the damage proceeds to the third stage, the skin very clearly shows injury and there is a greater amount of dead muscle-tissue. As in the less severe cases, there are large blisters in the skin where fluid has accumulated. These blisters cannot be drained by incision. When they are cut open, fluid oozes out of them for hours. The fluid appears to be held in large reticular cavities, the walls of which are in the tissues. Eventually the skin, including the nails, sloughs off, sometimes retaining the form of the fingers like a wax cast. In some cases the damage extends through the layers of the dermis down to the "regerminative layer," from which the process of skin growth is started. The unfortunate victim is left with a thin, shiny red skin, highly sensitive to temperature changes and to the touch. The affected extremity is painfully sensitive to cold until it grows a new dermis and epidermis, which may take months.

Finally, in the most severe cases of frostbite, there is a wholesale death of tissue, including skin, muscle and bone. In these cases the vasospasm is never relaxed. The surface of the extremity becomes hard and white. When it is thawed, it turns a dusky gray hue. The part becomes swollen and remains numb and paralyzed. In a few days the skin and flesh become coal black. Mummification follows, and finally spontaneous amputation starts to take place at the line where the dead flesh begins. Scar tissue eventually grows around the wound, and the finger, toe or foot is again able to function—minus, of course, the part that has been lost.

TO SUM UP, then, in all forms of frostbite the blood vessels are acutely constricted, the tissue cells are damaged, pseudoclots form in the capillaries at the junction of the fine arteries and veins, and blood plasma leaks out through the injured capillaries into the tissues, producing swelling and blisters. In the more severe cases there are varying degrees of destruction of tissue. The effects at each stage have been more or less precisely measured in experimental animals at various temperatures.

The findings make clear that household remedies like treatment with snow or continued cold were entirely on the wrong track—actually harmful. Even the method of spontaneous rewarming in a warm room is ineffectual; it merely delays the re-establishment of normal metabolism in the cells. Those who have studied the problem have suggested various treatments—rapid rewarming, pressure bandaging, anticoagulants and



When rubber shatters like pottery...

Natural rubber ball, chilled to minus 320.4° F., shattering on impact. Electronic flash tripped by microphone 1.035 milli-seconds after contact. Photos by Ralph Bartholomew, Jr.

Natural rubber *will* shatter, up in sub-stratosphere planes, at minus 50°F. Don't shiver; that's *warm* compared to temperatures some chemical equipment must take in stride.

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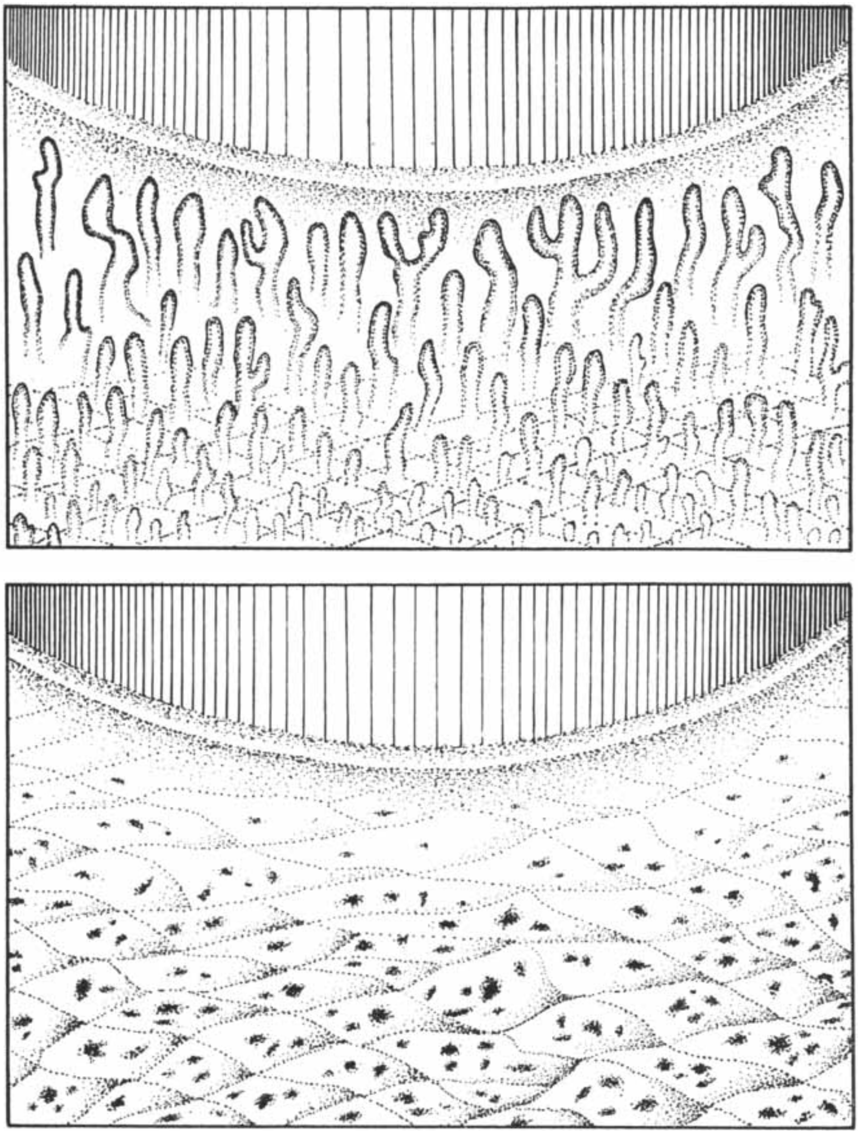

ARTERIOLES at the base of the fingernail demonstrate an effect of frostbite. The drawing at the top shows the tiny loops of healthy arterioles; the drawing at the bottom, the stumps of arterioles that are frostbitten.

substances to stimulate the dilation of blood vessels. F. S. Furman and J. M. Crismon of the Stanford University School of Medicine, who have made an exhaustive study of several techniques for therapy of severe frostbite, found that the anticoagulants Dicumarol and heparin were ineffective in preventing tissue loss. R. E. Lempke and H. B. Shumacker of the Yale University School of Medicine reported that rapid initial thawing, followed by vasodilation with tetrammonium chloride ion, was most effective. Josef Pichotka and Lieutenant Colonel Robert B. Lewis of the U. S. Air Force School of Aviation Medicine in Texas have approached the problem from the point of view that the injury is due to the direct action of cold upon the tissue cells. Their studies have indicated that rapid rewarming has a beneficial effect. The experimental animals that they treated with this method exhibited a better general appearance and regained the use of the injured limbs to a greater extent than did animals left to spontaneous rewarming. Rapid rewarming almost completely prevented gangrene of the skin.

Since these methods are still under investigation, at present it is not possible to recommend one treatment exclusively. Nevertheless, the one procedure which all of the investigators have found to be of definite value is rapid thawing. It is hoped that the studies undertaken, and greater attention to the problem, not only with respect to treatment but better clothing protection, will greatly reduce the frostbite casualties in Korea this winter.

Emlen T. Littell is publications officer of the U. S. Air Force School of Aviation Medicine.

Glass Code	Type	Color	Principal Use	Thermal Expansion Coeff.—/°C	Upper Working Temperatures (Mechanical Considerations Only) Annealed Normal Service °C	Annealed Extreme Limit °C	Tempered Normal Service °C	Tempered Extreme Limit °C	Thermal Shock Res. Plates 6"x6" Annealed 1/8" Thk. °C	1/4" Thk. °C	1/2" Thk. °C	Thermal Stress Resistance °C	Viscosity Strain Point °C	Annealing Point °C
0010	Potash Soda Lead	Clear	Lamp Tubing	$91x10^{-7}$	110	380	—	—	65	50	35	19	397	428
0041	Potash Soda Lead	Clear	Thermometers	$84x10^{-7}$	110	400	—	—	70	60	40	19	426	460
0080	Soda Lime	Clear	Lamp Bulbs	$92x10^{-7}$	110	460	220	250	65	50	35	17	478	510
0120	Potash Soda Lead	Clear	Lamp Tubing	$89x10^{-7}$	110	380	—	—	65	50	35	17	400	433
1770	Soda Lime	Clear	General	$82x10^{-7}$	110	450	220	250	70	60	40	19	470	503
2405	Hard Red	Red	General	$43x10^{-7}$	200	480	—	—	135	115		36	506	537
2475	Soft Red	Red	Neon Signs	$91x10^{-7}$	110	440	—	—				17	466	501
3321	Hard Green Sealing ..	Green	Sealing	$40x10^{-7}$	200	470						39	497	535
4407	Soft Green	Green	Signal Ware									17	485	518
6720	Opal	White Opaque										19	499	531
6750	Opal	White Opaque										8	445	475
6810	Opal	White Opaque											496	529
7050	Borosilicate	Clear											461	496
7052	Borosilicate	Clear											438	475
7070	Borosilicate	Clear											455	490
7340	Borosilicate	Clear										20	538	575
7720	Borosilicate	Clear								130	90	45	484	518
7740	Borosilicate	Clear						290	180	150	100	48	515	555
7760	Borosilicate	Clear				450	250	250	160	130	90	51	475	515
7900	96% Silica	Clear		10^{-7}	800	1090	—	—	1250	1000	750	200	820	910
7900	96% Silica (Multiform)	White Opaque	High Temp.	$8x10^{-7}$	800	1090	—	—	1250	1000	750	200	820	910
7910	96% Silica	Clear	Ultra Violet Transmission	$8x10^{-7}$	800	1090	—	—	1250	1000	750	200	820	910
7911	96% Silica	Clear	Ultra Violet Transmission	$8x10^{-7}$	800	1090	—	—	1250	1000	750	200	820	910
8870	High Lead	Clear	Sealing or Electrical	$91x10^{-7}$	110	380	180	180	65	50	35	22	398	429
9700	....	Clear	Ultra Violet Transmission	$37x10^{-7}$	220	500	—	—	150	120	80	42	517	558
9741	....	Clear	Ultra Violet Transmission	$39x10^{-7}$	200	390	—	—	150	120	80	40	407	442

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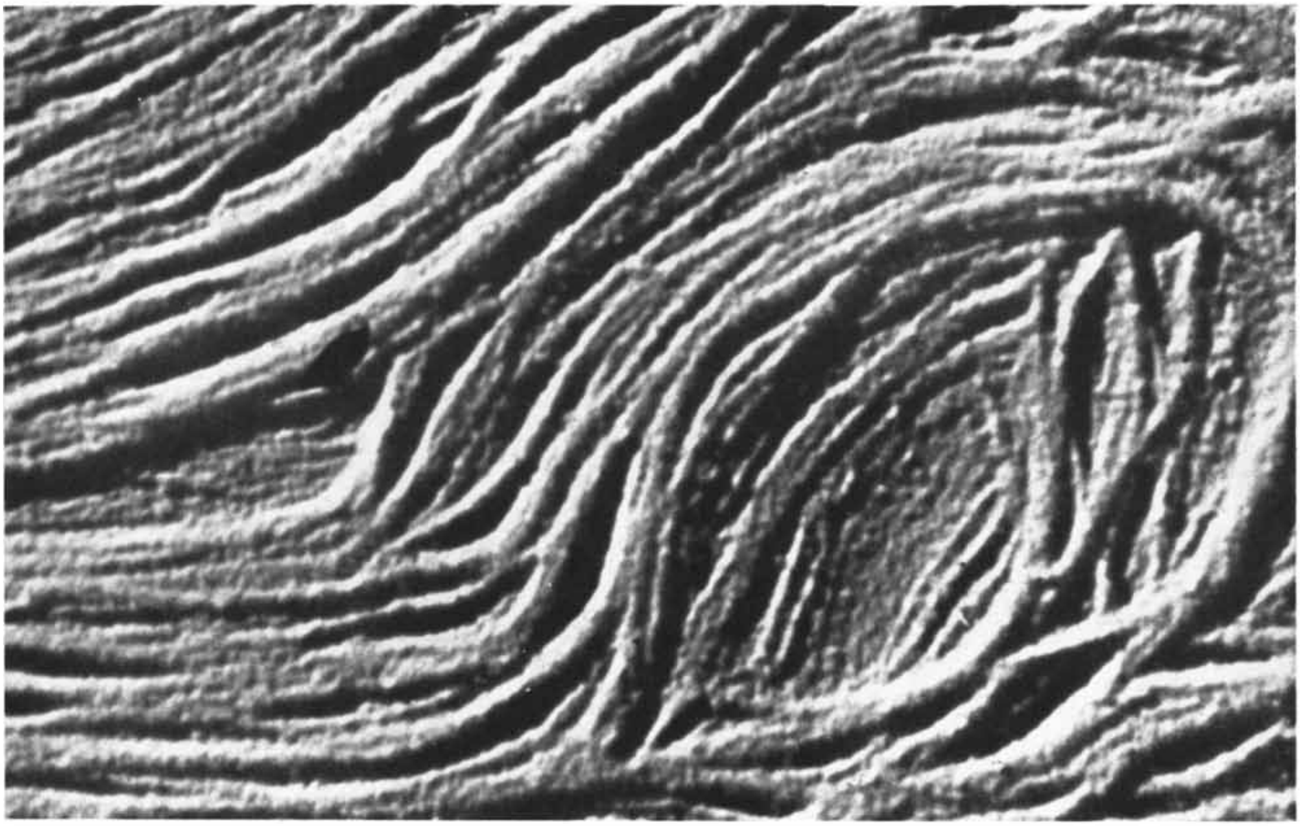
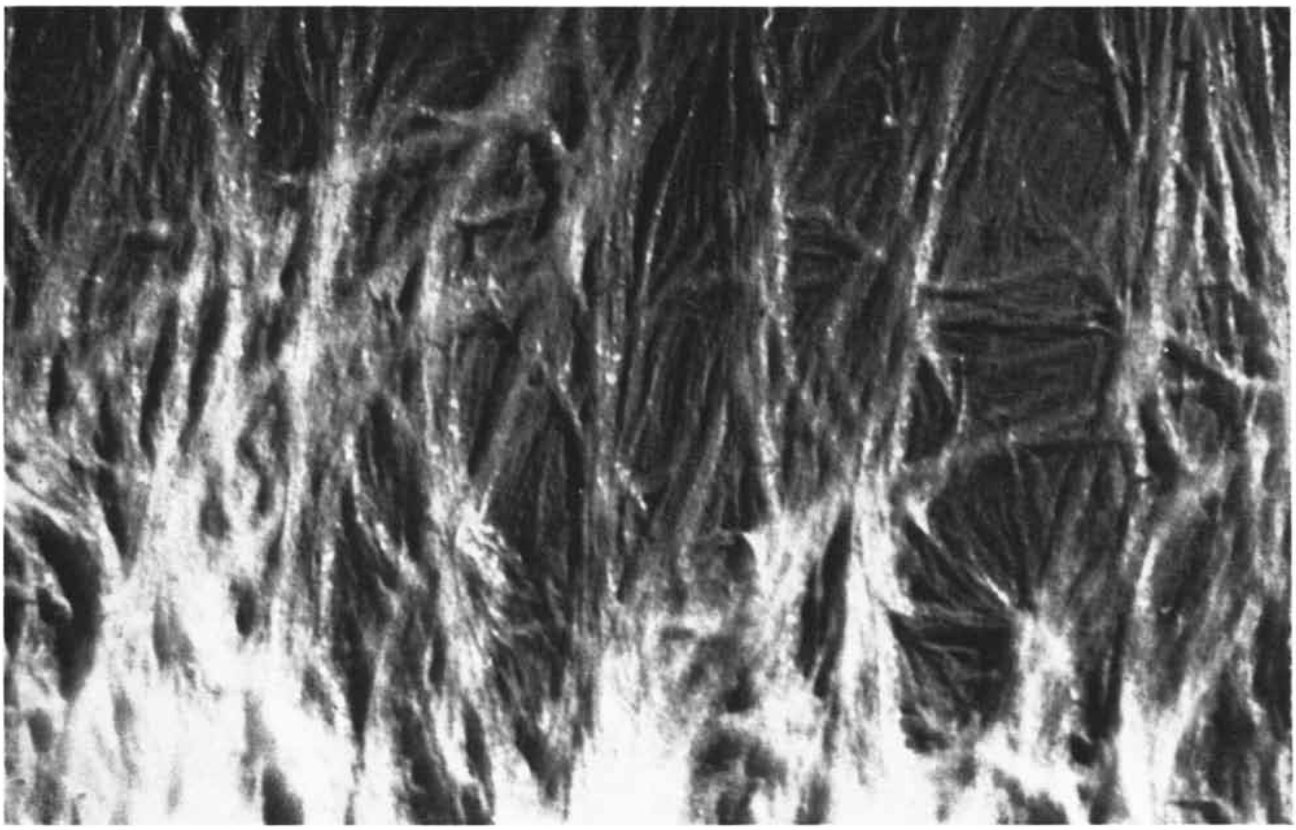


PURE ALKALI SOAP sodium oleate is shown by a Bureau of Standards electron micrograph to be composed of fibers in a swirled, hairlike array. The total magnification of this picture is 44,000 diameters.



TOILET SOAP is composed of more than one soap, but this micrograph shows the structure of sodium palmitate. Another part of the soap has structure of sodium oleate (*opposite page*). Magnification: 24,500 diameters.

SOAP MICROGRAPHS

Structure of cleansing substances is revealed by electron microscope

ALTHOUGH soap is a familiar substance, the physical and chemical reasons for its cleansing properties are still imperfectly understood. In recent years these properties have been intensively investigated at the National Bureau of Standards. A relatively new tool in these investigations has been the electron microscope.

Common everyday soap is usually the sodium or potassium salt of a fatty acid. When a film of such a soap is deposited on a surface, shadowed with metal and viewed under the electron microscope, the structures into which these molecules are assembled are seen to be a tangled mesh of fibers.

The fibrous structure of each soap is characteristic. The fibers of the pure soap sodium oleate (*top of the opposite page*) are swirled and ropy; the fine fibers of sodium palmitate tend to radiate from clumps. The fibers not only provide evidence of how the molecules in a soap are associated; they are also a convenient means of identifying the pure soaps in an unknown mixture. By this and other techniques the Bureau of Standards hopes to put the evaluation of soaps and synthetic detergents on a basis more scientific than the consumer's standards of suds, feel and smell.

SAME TOILET SOAP contains sodium oleate. Magnification: 25,500.

MONGOLISM

Although it is unlikely that this unhappy condition can ever be cured, some new experiments with animals suggest that it and many other congenital defects may someday be prevented

by Theodore H. Ingalls

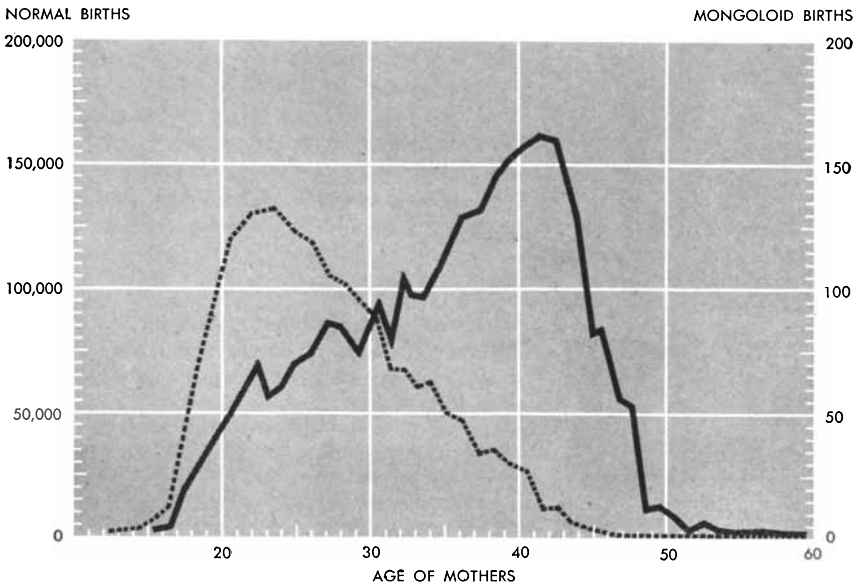
THE story of mongolism is a medical whodunit. In the 85 years since the condition was first recognized as a classifiable defect by Langdon Down, an eminent British neurologist, many theories have been proposed as to the cause and possibilities for cure of this dread affliction. One of the most popular theories has been that the condition is due to "defective germ plasm." The phrase caresses the ear with the sweet ring of reason, but it possesses little scientific meaning. If the defect is in the germ plasm, is it hereditary or acquired, and if acquired, how and when? The germ-plasm theory is a fence-straddler that leaves the basic problem untouched.

About two of every 1,000 babies born are found to have mongolism. The marks of the condition are stamped plainly on the victim's face—a foreshortened skull, a flattened nasal bridge, folds at the corners of the eyelids. This Oriental-like cast of the features was dragged as a red herring across the trail, in the standard tradition of detective fiction, at the very beginning of the story. Down seized on this feature to name the disability "Mongolian idiocy," and early in this century a melodramatic scientist, carried away by the name and the sloe-eyed appearance of the patients, wrote a popular work entitled *The Mongol in Our Midst*. The condition was portrayed as an atavistic throwback through Oriental forebears toward the orangutan. Although patently an unjustified, unscientific slur on Oriental peoples, the name, now softened to mongolism, has stuck like a burdock in the beard of the Western physician.

It is the mental retardation, due to malformation of the brain, that makes the disease so tragic. The mother of a mongoloid baby slowly learns with heartaches and secret tears that her child will never be capable of caring for himself or bringing the usual pride and joy to his parents. Hope for a "cure" dies hard, but it is only fair to admit that the task of therapy for mongolism baffles the scientific imagination. How can one expect to reform the intricately disordered gyri of a brain that is nourished by anomalous blood vessels, is contained in an abnormal skull and looks out at the world with eyes that are already markedly defective at birth? Let the surgeon try with his knife, let the pediatrician try with his endocrines, but let them not allow their research activity to be misinterpreted as promising or even hinting of promise, for the evidence is all against the possibility of a cure in the foreseeable future. In this era of vitamins, hormones and antibiotics it is no feat at all to make mongoloid children taller, longer-lived and healthier than they used to be, but to restore missing cells to crippled brains and eyes is asking too much of "miracle drugs."

ONE can, however, speak optimistically about the possibilities of prevention. In searching for the means of prevention it is necessary to keep constantly in mind a basic principle of modern epidemiology—namely, that there is never a single cause for any disease. This truth has been ably expressed by the famous epidemiologist Karl Meyer: "Today, the doctrine that there is a single specific cause for each disease entity is untenable. A purely bacteriologic (or chemical) explanation pays little heed to the fact that the essentials of disease are two—an animal and an organism (or a physical or chemical agent); these interact, react, and are acted upon by external forces. The more quickly it is recognized that causation is a constellation of predisposing, provoking and perpetuating factors, the more certain will progress be made."

In short, disease is a complex process that depends on the interactions of an injurious agent, a susceptible patient and a particular environment. Not everyone exposed to syphilis, for example, gets the disease. Not all people who contract syphilis get it in the same way or exhibit the same symptoms—for social, economic, anthropological or constitutional reasons that have nothing to do with the germ. The old may differ from the young, men from women, the colored from the white, the rich from the poor, the educated from the uneducated, military from civilian populations. By the same token, a given disturbance may be produced by several different agents.



MOTHERS of mongoloids (*solid line; from 2,882 cases*) tend to be older than mothers with normal infants (*dotted line; from 1934 U. S. births*).

Boiling water from a broken pipe or scalding oil from a kitchen pot may cause exactly the same kind of burn. Suffocation from lack of oxygen may be caused by hemorrhage, diphtheria, carbon-monoxide poisoning, drowning, flying in the stratosphere or swinging too long on a gallows. In each of these conditions, despite the differences in causation, the end result in terms of the oxygen content of blood and tissues may be identical.

All this emphasizes the unreasonableness of trying to incriminate a single cause for mongolism—whether it be a poison, a virus, hypothyroidism, "uterine exhaustion," something inherited or something the mother ate. Three cases chosen almost at random illustrate how various the causes may be. A mother who bore mongoloid twins recalled in a letter to me that about the eighth week of her pregnancy she had suffered a uterine hemorrhage in an automobile accident. Another mother of a mongoloid child reported that she had had a tooth pulled, and been made sick by the anesthetic, during the seventh week of pregnancy. In the third case, the mother of a mongoloid child had undergone a thyroidectomy for a large tumor before her pregnancy. Although it is not claimed that these events were the sole cause of the offspring's mongolism in each case, the three cases obviously are different.

The causes of mongolism can be investigated along three lines—clinical, epidemiological and experimental. The clinical, of course, involves the examination of individual patients (meaning both mother and child) and their symptoms. The epidemiological approach means the study of the incidence and manifestations of the disorder among groups of people over periods of time and in the social and geographical context. The experimental line is the testing of hypotheses in the laboratory by work on animals.

The analogy between medical investigation and detective work recalls an observation made by Sherlock Holmes, who, between puffs on his pipe and passages on his violin, once remarked: "When you follow separate trains of thought, Watson, you will find some point of intersection which should approximate the truth." In the investigation of mongolism the point of intersection of the clinical and epidemiological trains of thought lies somewhere in the first three months of pregnancy; that is to say, this seems to be the critical period for the origin of the disorder. It is significant that many of the secondary defects associated with mongolism—absence or stunting of one or both nasal bones, frequent lack of the second permanent lateral incisor teeth, dwarfing of the middle phalanx of the little finger,

MONGOLOID CHILD sometimes appears to be normal. When the mother of this child saw the photograph above, she wrote on the back of it: "Hopeful."

SAME CHILD was photographed a few minutes later. When the mother of the child studied this photograph, she wrote on the back of it: "Mongol."

MOUSE FETUSES were surgically removed from their mother on the 18th day of gestation; on the eighth day the mother had been exposed for five hours to an atmosphere similar to that at 25,000 feet. The fetus at right is normal; the fetus at left is dwarfed; the fetus in center is anencephalic, *i.e.*, it has a gross defect of the head. Also removed from the mother were another dwarfed fetus and the remnant of one that had died.

defective compartmentation of the heart—involve structures which begin their budding during approximately the eighth week of the embryo's life. The inference, of course, is that this is the period during which the mother's health and the condition of the embryo should be scrutinized most carefully in the search for causes.

LET US see what clues epidemiology provides. The mean age of mothers of mongoloid babies is 41, an age at which chronic disturbance of the endocrine system begins to become common in women. It is probably significant that malfunctioning of the thyroid gland is more frequent among mothers of mongoloid babies than would be expected on the basis of chance alone. Nearly 10 per cent of mothers of mongoloid babies have had acute infections in or about the eighth week of pregnancy. The Australian ophthalmologist Ronald Lowe, after a study of eye defects in 52 mongoloid persons, concluded that these defects must be established at about this stage of pregnancy.

In about 25 per cent of the mothers of mongoloid babies the uterus has been found bent backward to a significant extent, which may affect circulation between the uterus and placenta, though whether it actually does so is not known. About 20 per cent of mothers of the defective babies are known to have had vaginal bleeding during the first three months of pregnancy; this should not be construed, however, to mean that a mother who bleeds in early pregnancy is in danger of producing a mongoloid child, for the over-all risk of mongolism, as the statistics show, is small.

The epidemiologic evidence suggests, in other words, that mongolism may stem in part from an acute injury to the embryo due to placental hemorrhage, threatened abortion or infection, or from a chronic disturbance resulting from abnormal functioning of the uterus or of the thyroid gland. The embryologist George W. Corner has pointed out that a mechanical disorder of the uterus which does not allow sufficient space for development of the embryo is likely to result in an anatomically abnormal child, if it succeeds in being born. The statistics indicate that 90 per cent of the time chronic rather than acute disturbances of pregnancy are the underlying causes of mongolism. A severely deformed or backward-bent uterus, disturbed metabolism or significant anemia—any such influence may act as one of multiple triggers to blight the "fruit of the womb."

AT FIRST it is difficult to conceive how investigation of the causes of mongolism can be approached experimentally in the laboratory. How, for example, could one recognize mongolism in a mouse, even if he could produce it? Actually the investigation is not impossible, for the investigator can produce gross cerebral and skeletal defects in animals of a kind similar to those associated with mongolism. In other words, it is possible to study, not mongolism as such, for that is restricted to the human species as surely as stuttering, but the principles governing both hereditary and acquired congenital deformities.

In 1910 the Cornell University biologist Charles R. Stockard found that he could produce cyclopia (a single, central eye) in fish by exposing fish eggs to the action of a solution of magnesium chloride at a critical moment, between the 13th and 15th hours of the fertilized egg's development. Further, he demonstrated that various other agents—alcohol, chloroform, ether—could likewise cause eye defects and anomalous development of the central nervous system. His work showed not only that a particular defect could be induced by different agents but also that, in fish at least, characteristic and specific defects are directly related to a particular moment in development of the embryo; they can be produced only by injuring the embryo at that moment.

During the past 15 years many experiments have made clear that congenital anomalies can similarly be produced in higher animals. In the laboratory of the Department of Epidemiology at the Harvard School of Public Health Richard Prindle and the writer have done such work on some 300 pregnant mice, bearing a total of about 2,500 embryos. Within a plastic chamber the pregnant mice are subjected to rarefied atmospheres deficient in oxygen. Each mouse is exposed for five hours on a single occasion. In this manner from 10 to 20 litters have been subjected to intrauterine anoxia on each of the first 17 days of pregnancy. On the 18th day the young are delivered by surgery (when defective offspring are born naturally, the mother usually devours them). The

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VERTICAL SECTION through the head of an anencephalic mouse shows the defect at the top of the skull.

delivered fetuses are then examined for gross defects. The quantitative aspect of the method is its important feature. One fires bullets, so to speak, at the embryo during selected stages of its development rather than subjecting it to a continuous dietary or metabolic disturbance. In this way it is possible to ascertain quantitatively the result of an acute rather than a chronic upset, not only at the cellular and clinical level but at population levels of the epidemiologist and geneticist.

We find a whole series of deformities in these fetuses, the nature of the defects depending on the intensity, duration and timing of the oxygen deprivation. Of the litters subjected to anoxia on the eighth day of development, about a third have members that are born with grossly defective brains. Those injured on the 14th day of development may produce offspring with a cleft palate; those so treated on the 16th day produce significant numbers of mice with a defect known as "open eye."

This experimental method also makes it possible to study genetic susceptibility and resistance to abnormalities. For example, in a study that the writer made during the summer of 1951 with Francis Curley, Fred Avis and Howard Temin at the Jackson Memorial Laboratory at Bar Harbor, Me., fetuses of the so-called dba strain of light brown mice were exposed to anoxia on the 7th, 8th and 9th days of gestation. Over 15 per cent of them developed umbilical hernia. Normally from one to two per cent of fetuses of this strain have this defect. On the other hand, among more than 2,500 young of an albino strain that had been subjected to anoxia at the Harvard School of Pub-

lic Health none had umbilical hernia.

THE investigation of mongolism is part of the much broader problem of congenital anomalies in general. Mongoloids, Siamese twins, "monsters" without a brain or with only one eye and infants with lesser defects, such as congenital heart disease or a cleft palate, give every suggestion of being naturally related as members of a family of anomalies. The anomalous individual is only an isolated unit of a larger dynamic process, like a single "still" removed from a moving-picture strip, or like a person with congenital syphilis. The evidence suggests that many anomalous children have survived a period of anoxic distress, just as the mouse with cleft palate has survived a period of anoxic distress. Others have survived infections, metabolic upsets or nutritional deficiencies.

In any event, modern research has clearly demonstrated that environmental factors account for a substantial proportion of all congenital anomalies and crippling defects. The pendulum which, as a result of Gregor Mendel's classical discoveries, swung away from the Lamarckian preoccupation with environment toward a fruitful concentration on the genes, seems to have swung too far in that direction. Actually heredity and environment are overlapping influences; as Theodosius Dobzhansky has remarked: "The so-called nature-nurture problem is not to distinguish which traits are genotypic and which environmental, for all traits are genotypic and environmental." The indications are that every human embryo is a potential candidate for mongolism, just as he is for measles, sunburn or an auto accident. I am in full accord with the statement by L. S. Penrose of University College in London that "at the present time the mode of action of the hereditary background is obscure and is much less important, from the point of view of preventive treatment, than the environmental factors dependent upon maternal conditions." In his introduction to Penrose's book *The Biology of Mental Defect*, J. B. S. Haldane says: "It is entirely possible that a suitable hormonal treatment of elderly mothers could halve the frequency of mongolism." There is more to the problem than the use of hormones, however. Present knowledge suggests that coordinated and energetic study of congenital defects will result in a significant contribution to public health. The objective is an improved quality, rather than quantity, of the human race—the kind of thing we might hope for were the application of eugenics as practicable among mankind as it is among pets and beasts of burden.

Theodore H. Ingalls is associate professor of epidemiology at the Harvard University School of Public Health.

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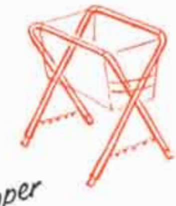

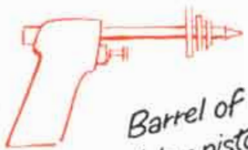

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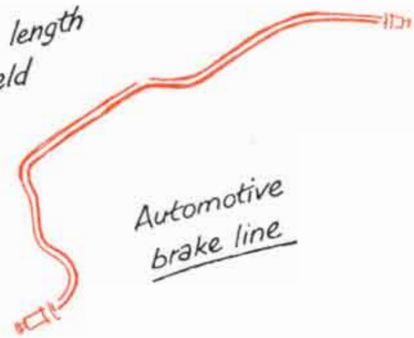

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Man's Genetic Future

Is the hereditary endowment of the human species improving or deteriorating? As our knowledge and control of the situation increase, we will face unprecedented and momentous decisions

by Curt Stern

WHATEVER fate may be in store for our civilization, one assumption must underlie all thoughts about the future: Man will continue to exist on this globe. Assuming the human species is here to stay, what is likely to happen to us genetically? Will the human stock improve, deteriorate or remain the same? Is the future predestined, or can we direct it?

To answer such questions we must consider mankind's hereditary endowment as a whole and the distribution of this endowment among individuals. When a human being begins existence, he is compounded of an egg produced by his mother and a sperm furnished by his father. The egg and the sperm each contains thousands of different genes. Let us assume, as we may for the purpose of this discussion, that the human germ cell has exactly 20,000 genes. The individual genes can be identified by the numbers 1 to 20,000. The egg contains 20,000 genes and the sperm has the same number, each a counterpart of the corresponding gene in the egg. Thus when egg and sperm unite, the new human being starts out (as a fertilized egg) with 20,000 pairs of genes, or a total of 40,000. Some of the pairs are identical; for example, the number 7 gene from the egg may be exactly the same as number 7 from the sperm. Other partners are slightly different; thus the sperm's number 8 gene may be distinguished by minor peculiarities from the egg's number 8, so that we may call one 8_1 and the other 8_2. We can designate the differently numbered genes (*e.g.*, 7 and 8) as species, and the different kinds of genes of the same species (*e.g.*, 8_1 and 8_2) as varieties.

As the fertilized egg develops, the genes multiply. Each gene builds up next to itself a faithful reproduction of its own structure, and as the cells divide each new body cell is provided with a complete endowment of the two sets of 20,000 genes with which the fertilized egg started (except that in male children a few genes lack partners).

Every one of the more than two billion people alive on our globe today has the same 20,000 species of genes. Some of the species probably have only one variety, so that gene 7, for instance, may be exactly alike in everyone. Other species may occur in two, three, four and perhaps up to as many as 100 varieties. In any case, the total pool of genes in the earth's population at present is some 80 trillion (two billion people times 20,000 pairs of genes each). This is the storehouse from which the genetic future of man will be furnished.

THE number of different possible combinations of the varieties of genes is very large. When a new individual draws on the genes that he has received from his mother and father to make a new set in his own germ cells, he may reshuffle the genes in a multitude of different ways. Take, for instance, just two genes, each of which is present in two varieties. Suppose the individual receives 8_1 and 9_1 from his mother and 8_2 and 9_2 from his father. From these he can form four different combinations to transmit to his children—8_1 and 9_1, 8_2 and 9_2, 8_1 and 9_2 or 8_2 and 9_1. With many gene pairs and varieties to choose from, vast numbers of different combinations are possible. The number is so huge, indeed, that of the hundreds of billions of sperms one man produces during his lifetime, no two are likely to be identical in the combination of genic varieties. The shuffling of the genic cards makes it unlikely that any person on earth (with the exception of identical twins) has ever exactly duplicated any other person in genic make-up, or ever will in the future.

This does not mean, however, that our inheritance is an entirely random affair. If men and women were completely promiscuous in mating—socially, racially and geographically—then one genic combination would be as likely as any other, and people might vary individually much more than they actually do. There are times and places where man does approach such random mating, for example, during great migrations and large military occupations, when one group may sow its genic varieties among those of another group. As a rule, however, a potential child within a given group does not draw on the whole storehouse of mankind's genes. Usually his genes will come from a socially, nationally and racially segregated part of the store.

Yet for thousands of years the barriers separating the store of human genes into compartments have been progressively lowered, and with the increase of human mobility in our era of world-wide transportation many barriers will undoubtedly disappear. Tribes, minor races and other subgroups will vanish. How far this process of joining the genetic endowment of mankind into large pools will go, we can only guess. A diffusion of genes from one group to another is bound to occur, however slowly and gradually, and in time it will tend to eliminate all partitions in our storehouse.

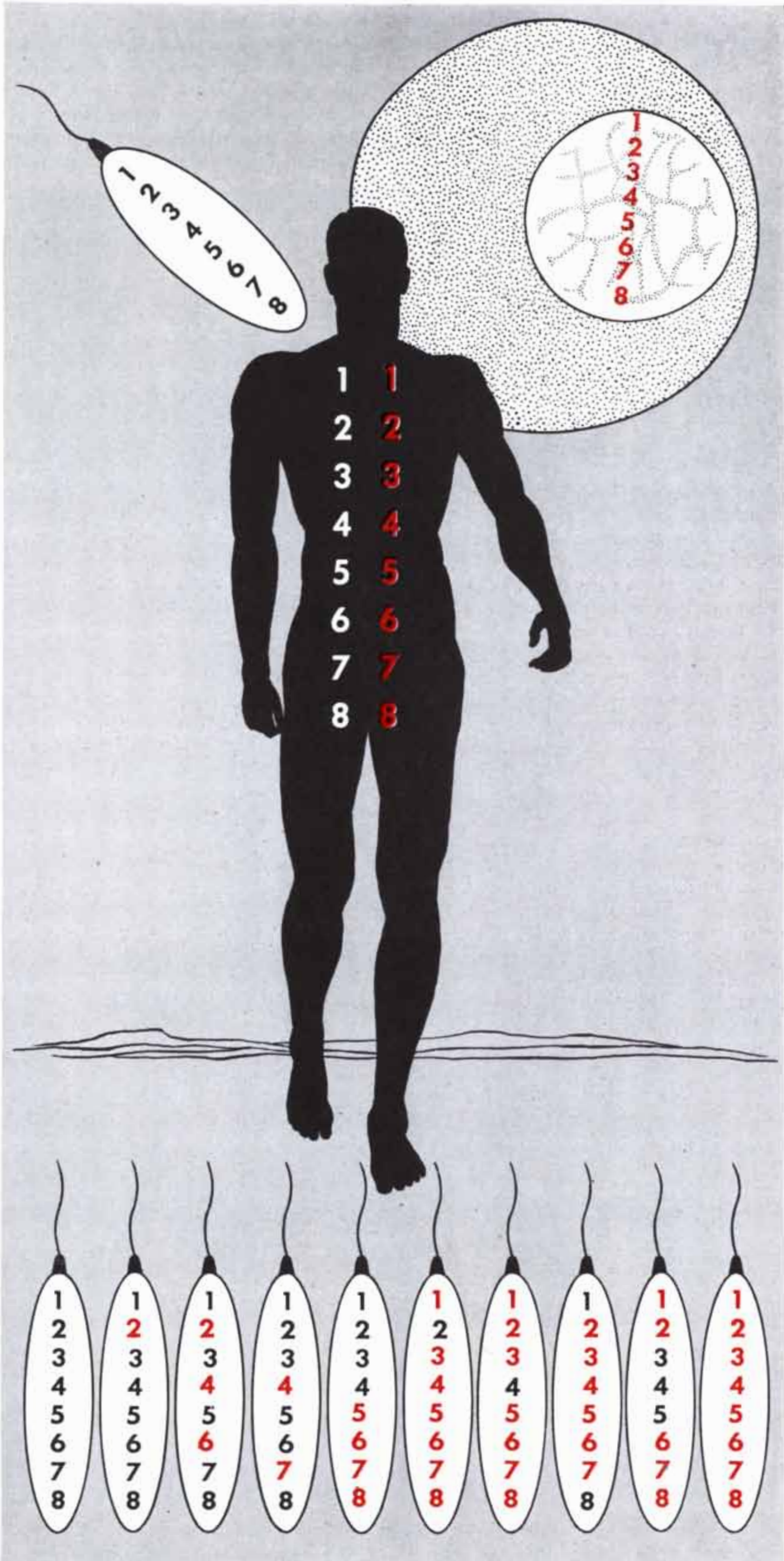
WILL this be good, bad or immaterial for mankind? We cannot answer this question without evaluating the racial differences of the present. Have the present combinations of genic varieties originated in a haphazard way or are they the result of selective forces in the earliest prehistory of mankind which adapted the different races to specific environments? It is probable that both chance and design have played a role. Thus the racial differences in blood types (Rh and so on) seem to be just accidental and of no adaptive significance. On the other hand, it is likely that the differences in pigmentation and breadth of nose between the Africans and the Caucasians were evolved to fit the differing climates in which these peoples lived. Does this mean that the leveling of the genic partitions will make the world's peoples less fit to cope with their respective environments? Such a conclusion might be justified if we could assume that the originally adaptive traits have the same significance today as they had 100,000 years ago. But has not man created new influences which effectively alter his environment in such a fashion that the external physical factors continuously decline in importance? Housing and clothing, food and medicine, occupation and training have changed radically, and it may well be that these new factors have superseded the old ones.

What of mental differences among races? Whether or not such differences exist has not been established; exact knowledge of the genic distinctions between groups is most lacking where it most matters. This is not only because psychologists have found it difficult to invent standard tests to measure the inborn capacities of different races but also because there is great variability in mental traits within any one group.

The 20,000 pairs of genes in the fertilized egg control a multitude of interactions whose full complexity far transcends our understanding. In every trait of the individual numerous genically induced reactions are involved. There is no absolute, one-to-one relation between a specific gene and a specific trait—no gene for dark hair or for height or for "mental endowment." Each gene is only a link in the development of a trait; it is necessary for the process that results in the specific trait, but it does not invariably produce the trait in question. A gene for clubfoot, for instance, makes for an inclination, a potentiality, toward the appearance of clubfoot, but whether this potentiality will become reality depends on the interplay of life processes. A slight variation in timing or in the environment may decide one way or the other. The clubfoot defect may appear in one foot, in both feet or in neither.

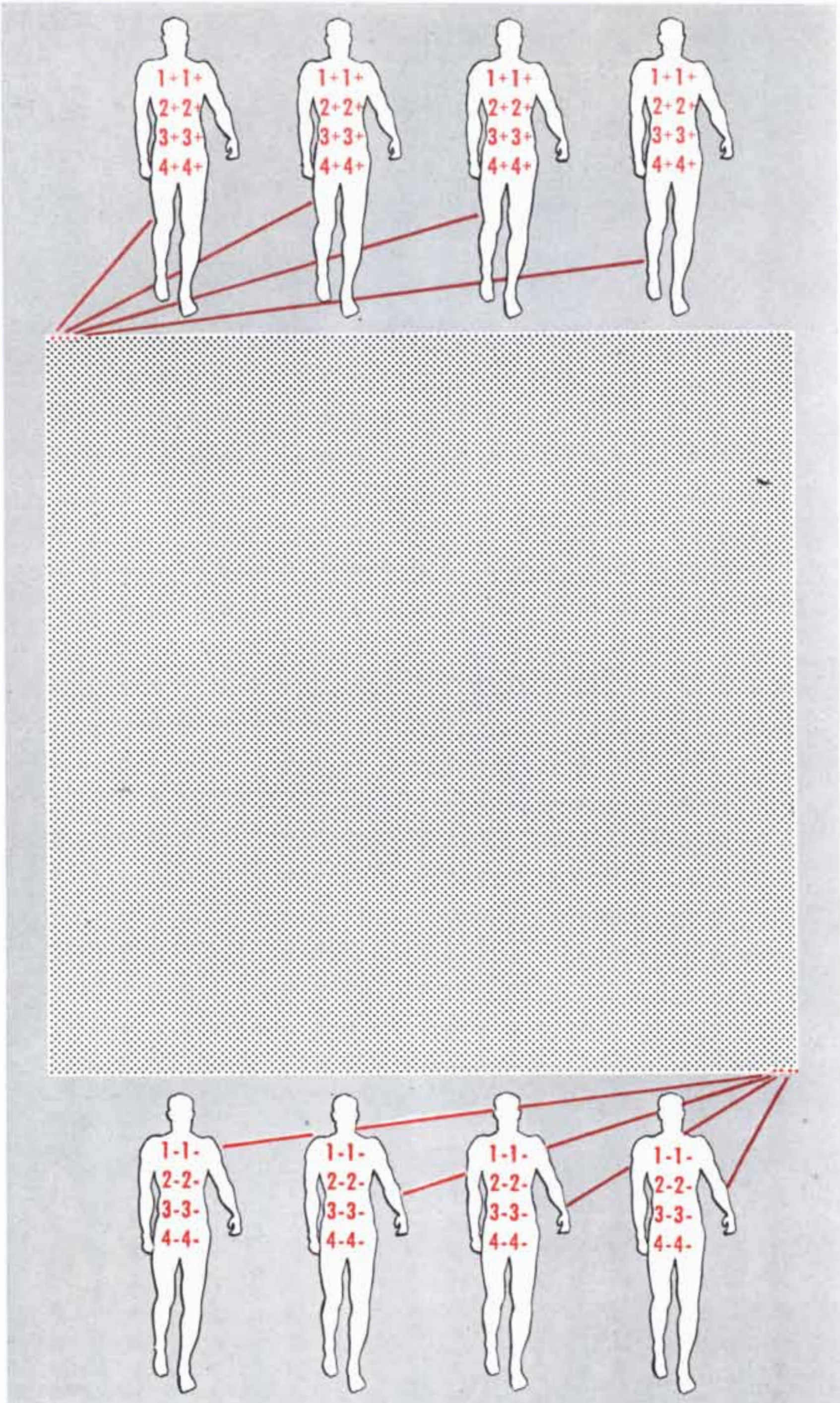
The amount of variation in some life processes is small, in others large. A man's blood type, for example, remains the same throughout his life, but the color of his hair changes. Are the traits that distinguish different races variable in expression or invariable products of their genic endowments? It seems as a first approximation that genes for physical traits are more rigid in expression than those for mental traits. The Caucasian's hair remains straight or wavy and the Negro's kinky, regardless of any change in environment or training. It is otherwise with mental traits. A normal man's genetic endowment provides him with a wide potential for mental performance, from very low to very high. As with a rubber balloon, the state of expansion of his mind at any given time is hardly a measure of its expansibility. In human evolution those genes that allow the greatest mental adaptability, that possess the greatest plasticity of expression, seem to have undergone preferential selection in all races. If this is actually so, then the different genic varieties for mental traits may be comparably distributed among all human groups, and the disappearance of the present barriers subdividing man's genic storehouse would not greatly affect mankind's mental potentialities.

What role will differences in reproduction play among the various so-



GENES ARE SHUFFLED when those of a sperm (*upper left*) are combined with those of an egg (*upper right*) in an individual (*center*) and divided again in his sperm cells (*bottom*). Only 10 of 256 combinations of a hypothetical system of 8 genes are shown. Each individual may have 20,000 genes.

cio-economic groups within populations? It is well known that the lower socio-economic layers of Western societies have higher birth rates than the upper ones. Do these layers differ in their stocks of genes? We cannot say with any certainty. The difficulties of research in this important field are great. We do not know, for instance, to what extent intelligence scores reflect true genetic factors in addition to education and environment, which they certainly reflect to a large degree. Nevertheless, the evidence strongly suggests that hereditary mental differences between socio-economic groups do exist. The mean intelligence scores of children at the higher socio-economic levels are consistently higher than those of lower groups, whether the tests are made in the U. S., in the U.S.S.R. or in any other country. That environment is not the sole reason for such differences is indicated by comparative studies on comparable groups of children, particularly twins reared together and separately. It is hard to avoid the conclusion that there are mean differences in the genetic endowment of different socio-economic groups, although the individual endowments within each group cover the whole range from very low to very high.



GOOD AND BAD GENES are usually mixed. The dots in the center of this chart represent 1,000 individuals. Each hypothetical individual has 4 pairs of genes. Each of these 8 genes may be either favorable (+) or unfavorable (—). The possibility that all the favorable genes or all the unfavorable genes will occur in one individual is such that only 4 individuals will possess all the favorable genes (*top*) and 4 all the unfavorable (*bottom*). The remaining 992 individuals will possess from 1 to 7 favorable genes.

If there are genetic differences between groups, then the differences in their birth rates will result in selective increase of some genic varieties and decrease of others in the population as a whole. Since the groups that seem less well endowed intellectually produce the most children, a deterioration of the genetic endowment of the population should result.

This large-scale difference in reproduction rates is a rather recent phenomenon. It is primarily the result of birth control, which did not become an important social practice until the second half of the 19th century. So far the upper and middle groups of Western countries have adopted birth control much more widely than the lower ones. But there is reason to believe that the use of contraceptive measures will spread through the whole population, and that the group differentials in fertility will be diminished, although perhaps not obliterated.

Before we become too alarmed over the possibility that the genetic stocks of Western peoples may deteriorate, it would be well to obtain an estimate of the rate of this suspected deterioration. Such analyses as have been made suggest that the decrease of valuable genic varieties is probably much smaller than a naive consideration would suggest. High intelligence undoubtedly is based not on single varieties of genes but on the cooperation of many genes. The valuable varieties must be present, singly or in partial combinations, even in the great mass of individuals who score low in intelligence. From there they can, in the course of a single generation, reconstitute an appreciable number of the "best" combinations. In other words, the population at large constitutes a great reservoir, and the possible loss of valuable genic varieties possessed by the small upper layers of the population tells only a part of the story.

THOSE who consider man's genetic future usually lay emphasis on the possibility that the human race is pre-

serving and accumulating genes that cause physical and mental defects. In former times, it is argued, most of the unfortunates who inherited these defects died an early death, often before they could transmit their unfavorable genes to another generation, whereas now medical and social care keeps these people alive and permits them to pass on the bad genes to the next generation. There is some truth in this argument, but the case is overstated. The most severely handicapped individuals, such as idiots and complete cripples, usually do not reproduce, either because they cannot or because they are kept in confinement. Furthermore, civilization has neutralized some of the so-called defects; thanks to the development of clothing, for example, the naked modern man is able to live in cold climates as well as his hypothetical furry ancestor. In other words, the survival of "bad" genes in modern times is often possible because the ingenuity of modern man provides for environments in which the "bad" genes lose their adjective.

Nevertheless, there *are* many defective genes in the human storehouse that are loading man's genetic future unfavorably. They are the anomalies, such as the inherited juvenile cataract, the cleft palate, the predisposition to schizophrenia, which are not serious enough to prevent reproduction but cannot be remedied readily or completely by medical treatment. It would seem desirable to exclude the bearers of such unfavorable genic varieties from reproduction. But this is a matter of some difficulty: even assuming we could adopt feasible measures for doing this, how are we to identify all those who should be prevented from reproducing? Many, indeed the majority, of the bearers of bad genes do not themselves show any abnormality; they are merely carriers, and the defect appears only in their descendants.

Any consideration of man's genetic future must also, of course, take account of sudden changes, or mutations, that may produce new varieties of genes, and of the possibility that the 20,000 species man now possesses may increase or decrease in number. Most mutations, however, seem to produce genic varieties not very different from those already in existence, and the processes that might add to or subtract from the basic set of 20,000 genes are so rare that their significance for the future of man appears very limited. Most likely man's future will be determined by recombinations and changes in the proportions of the known varieties of genes, rather than the creation of new varieties.

The changes in mankind's genic substance proceed more or less automatically. The eugenics movement proposes to make the process less haphazard in the future by applying nationally designed population policies, looking toward the elimination of genetic misfits and an in-

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crease in the number of those with superior genetic endowments. The difficulties of such a program are great, and the enthusiasm of its proponents, who have often been motivated by race or class prejudices, has been a drawback rather than a help to the success of the movement. It is now clear that we need very much more knowledge before a far-reaching blueprint can be designed. Fortunately, it is also clear that the problem is not as urgent as it seemed to past generations. The storehouse of human genes is so immense that neither mankind as a whole nor any of its groups is likely to undergo any serious genetic deterioration within the next century or two. If the threatened breakdown of our civilization on the cultural level can be avoided, we shall have time to work out the tasks of the genetic future.

THESE still utopian tasks will be threefold—biological, political and ideological. In the biological realm we need first to learn how to recognize the presence of undesirable and desirable genic varieties even when they are borne by apparently normal carriers. We may attempt to suppress bad genes, not only by controlling reproduction but, better still, by identifying and separating the desirable germ cells from the undesirable ones, which are likely to be present in every individual. We may attempt to improve our endowment of genic varieties by artificial mutation with radiation and chemicals. Mutations are usually toward the worse, but the future may well place specific tools in our hands with which we can change less desirable into more desirable genic varieties. We will also make further progress on the road toward the artificial culturing of human ovarian and testicular tissues and the rearing to maturity of human embryos obtained by fertilization in such cultures.

Progress in these biological fields very likely will run ahead of our social and political thinking. When the biologists have discovered how to put together combinations of genes for given traits, they will have to be told what traits are desirable and what undesirable. And when they can grow human beings in culture vessels, society will have to decide what use should be made of that feat.

The decisions to be made will be revolutionary for man's thinking, his private life and his social organization. They will carry with them the danger of his loss of freedom. They will force man to a reconsideration of the problems of free will *versus* determinism, in a more urgent form than ever before. Shall we be glad that we do not have to decide all these problems in our time?

Curt Stern is professor of zoology at the University of California.

What GENERAL ELECTRIC People Are Saying

C. G. SUITS

Research Laboratory

FILM THICKNESS COMPARATOR: A new optical device for measuring the thickness of film consists of a film of barium stearate deposited in a series of successive monomolecular layers upon a plate of special glass. Each layer has a thickness of 0.1 microinch, and the successive layers are deposited in such a way as to build a series of steps that differ in thickness by 1 microinch. When the step gage is illuminated by white light, each step reflects a color, which is determined by its thickness. The steps are thus seen as a series of colored stripes on the glass plate. The colors are produced by the interference of light reflected from the front and back surfaces of the film. Since the colors are produced by interference rather than by selective absorption, they are not subject to fading.

The step gage serves as a standard for comparison with other films that reflect interference colors—such as those produced by evaporation, sputtering, and plating. The measurement is simple and direct; the color of the unknown is matched with that of one of the steps and the thickness read directly from the scale. A correction must be made for the refractive index of the material.

General Electric Review
November, 1951

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M. C. LEVERETT

Aircraft Nuclear Propulsion Project

AIRCRAFT NUCLEAR PROPULSION: One pound of uranium-235 will liberate heat, on undergoing fission, equivalent to the energy liberated by burning 1,700,000 pounds of gasoline. It is at once evident, if a means can be found for converting the energy of nuclear fission into thrust, that aircraft can fly for very long times on very small amounts of fuel. Indeed, fuel consumption would be measured not in thousands of pounds per hour, but in pounds per day.

In many respects the propulsion of aircraft is an ideal use for nuclear energy. Here, to a higher extent than in any other application, the advantages of a highly concentrated source of heat can be used to good result. Although the goal of producing a nuclear powered aircraft is an admittedly ambitious one, it is only such high-performance, premium uses of energy which can today justify the consumption of as rare a resource as uranium-235 or plutonium-239. Moreover, it is inescapable that a development of this type has great military significance.

In recent months the government has announced that the nuclear aircraft program is entering a new phase. In this new phase, the Aircraft Gas Turbine Department of the General Electric Company has been given the responsibility for the propulsion system, and the Consolidated Vultee Aircraft Corporation is to supply an airframe.

My belief is that our efforts to fly an aircraft on nuclear power will be successful. The difficulty of the task and the value of the result combine to form a challenge which is, in my opinion, unmatched.

Chicago Section,
Institute of the Aeronautical Sciences
October 4, 1951

★

J. G. HUTTON
T. E. USHER

General Engineering Laboratory

RECENT DEVELOPMENTS IN MASS SPECTROMETRY: In the fields of chemical analysis and process control, recent years have seen many attempts to provide new and improved methods for accurately determining the qualitative and quantitative composition of gaseous and/or liquid mixtures. Numerous physical methods employing the use of refractive indices, densities, and various excitational and optical phenomena have been devised. Infrared and ultraviolet absorption and the Raman effect have been found useful in the examination of many of the simpler mixtures, and have been proved very satisfactory in this work.

All of these methods suffer from rather severe limitations, either because of their very nature or because of restrictive practical considerations.

By contrast, in the present state of the art, the mass spectrometer can be generally extended to all mixtures whose components are fully vaporized at a pressure of 20 to 40 microns at normal temperature.

The clarity of the spectral data available from the mass spectrometer is at once evident upon comparison with the spectrum obtained from the optical methods previously mentioned. Here one is measuring by electronic means a fundamental unit—that is, mass. One rather serious drawback, however, which until recently has seemed to place a limit on the scope of applications for the mass spectrometer, is the high initial cost of the instrument in its conventional commercial form.

The recent advent of what may be referred to as high-frequency mass spectrometers may largely alter the outlook for mass spectrometer application. By offering the possibility of meeting the demand for a relatively low-cost instrument of limited mass range without losing any of the fundamental advantages of the general mass-spectrometric method, these new instruments may soon play an important role in industrial processes.

General Electric Review
November 1951

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BOOKS

A new book about parasitic organisms and their strangely specialized ways

by James R. Newman

Parasitic Animals, by Geoffrey Lapage. Cambridge University Press ($4.00).

THIS most recent addition to the Cambridge Library of Modern Science deals with a fascinating subject that lies outside the realm of most popular books about biology. Dr. Lapage, lecturer in animal pathology at Cambridge University, has written for the student and general reader a survey of parasitic animals and their relationships with their hosts. The subject is of major biological, social and economic importance; it is also bewilderingly complex and, in some of its aspects, distinctly unpleasant. Dr. Lapage handles this difficult material with skill. He is erudite and writes clearly and interestingly; he also maintains an admirable detachment, neither overemphasizing nor withholding the often horrifying details of parasitism. It is not a book to be read straight through, but you will probably not fail to finish it once you have begun it.

A parasite is not any one kind of animal but "an animal which has adopted a certain way of living." Biologists recognize several forms of "association" between animals. When the animals share a common food supply the association is called commensalism, literally "eating at the same table." A more intimate form of association is symbiosis, illustrated by the relation between termites and the single-celled organisms that live in their food canal and assist them "to digest the cellulose in the wood upon which they feed." Parasitism is an association impelled by the same need as commensalism and symbiosis, but it differs markedly from them. The partnership between a parasite and its host is a one-sided affair: they do not share a common food supply; the table at which the parasite dines is the body of its host; the parasite not only contributes nothing to the host but invariably inflicts injury upon it. In some relationships the injury is fatal; in others it constitutes disease; in others it causes the host no more than "temporary inconvenience," or is so slight that it is "discernible only by the methods of the experienced biologist." Regardless of the severity of the mischief, the host is always adversely affected. This, says Dr. Lapage, is the "reliable feature" by which parasitism is defined.

In the course of evolution many kinds of organisms have become parasitic. The group includes malarial protozoa, midges, mosquitoes, leeches, fleas, ticks, lice, liver flukes, sheep nasal-flies, ox warble-flies, horse bot-flies, hagfishes, hookworms, lungworms, tapeworms, tongueworms, roundworms, trichinaworms, mites, bloodsucking bats and barnacles. Most parasitic animals are invertebrates, yet this assertion has an interesting qualification. Different organisms are parasitic at different phases of their life history: the large stomachworm of sheep, for example, is parasitic as an adult and in its older but not its younger larval phases; warble-flies and rainworms, on the other hand, reverse this arrangement, being nonparasitic as adults and parasitic only in the earlier larval states. This suggests that the mammalian embryo might be considered parasitic on the mother while it is developing in the womb. Apparently this view prevails among parasitologists. The embryo is entirely dependent on the mother for its food and exerts "profound effects" upon her physiological processes; while it usually does her no harm, it is capable of doing her physical injury, of causing disease, of lowering her resistance to other species of parasitic animals, *e.g.*, bacteria. "It is possible that, when this method of development of the young first appeared in the course of evolution, it was the cause of much more mortality among the mothers than it now is." Thus there is no reason to exclude the mammalian embryo from the accepted definition of the parasite, however dispiriting it may be to learn that in the early stages of our lives our biological economy resembled that of warble-fly larvae.

Parasites penetrate their hosts in different ways, each in turn related to such factors as the structure and habits of the host, the parasite's methods of locomotion, its life history, its carriers and the like. The mouth is the most common portal of entry, the parasitic egg or larva traveling with the host's food or drink. The other openings of the body also provide access to its interior. Larvae may crawl or wriggle to their destination; when equipped with the necessary tools they can bore through the skin of the host and thence, by the bloodstream or other routes, travel to the parts of the body where they feed and develop. Such species as the mosquito and the leech, known as temporary parasites, feed on the host merely by sucking blood from its surface; others tarry much longer, passing through their larval phases, adulthood and breeding periods inside the host.

Sydney Smith's couplet—*Tory and Whig in turn shall be my host, I taste no politics in boil'd and roast*—epitomizes the disposition of the higher parasites; the lowliest members of the group are often more fastidious. The host is not any animal that happens along or even any animal the parasite can get into. Each parasitic relationship derives from a nonparasitic association between the ancestors of the parasite and of the host, and the evolutionary process has defined the character and boundaries of the relationship. To cite two examples: the parasitic larva of the swan mussel has as its host a species of fish which seeks the same environment as that of the swan mussel; human malarial parasites, originally parasitic only in mosquitoes, were later transmitted to man when the female mosquitoes fed upon human blood. Evolution has also effected drastic alterations in the structure and function of parasitic animals. The tapeworms have lost stomach, anus and food canal, feeding entirely through the surface layers of their bodies. *Pediculus humanus*, the common louse, which transmits the microorganism causing epidemic typhus, has developed teeth and stabbing devices to suck blood. Fleas, lice and sheep keds are among the parasitic insects which have lost their wings and have developed claws by means of which they cling to their hosts; other parasites have hooks, claws, forks, anchors, threads and adhesive pads on their feet for the same purpose. A flea named *Rhynchopsylla pulex* burrows into the skin of Columbian bats and casts off its limbs. A species of the whipworm, parasitic in man and some monkeys, buries itself in the lining of the intestine and secretes digestive juices that reduce "the host's tissue to a fluid which the worm sucks in." *Cymbasoma rigidum*, a member of the family *Monstrillidae*, at one phase of its life cycle degenerates into nothing more than a horrendous eye with a mass of surrounding cells; later this mass acquires a skin and becomes a parasitic larva "with two processes which are said to be derived from the second pair of feelers and the jaws"; still later the larva "bores its way out of the worm upon which it has fed, throws off the feeding appendages, and bursts to set free the adult female, which lives a brief life on the surface of the sea, where fertilisation of the eggs occurs. The adults have, however, lost their mouth parts and the mouth is only a narrow opening, so that they cannot feed."

Two chapters of Dr. Lapage's book deal with representative life histories of parasitic animals. One or two instances may be offered of the author's exemplary presentation, the effectiveness of which is enhanced by the remarkably ingenious diagrams drawn especially for the purpose. The large stomachworm of sheep lives happily in the acid environment of the sheep's stomach. The female stomachworm lays 5,000 to 10,000 eggs a day for many weeks; these pass down the food canal of the sheep and out with its droppings. "Each egg is about 77 microns long by about 45 microns broad, a micron being one-thousandth of a millimetre or one twenty-five thousandth of an inch." Under favorable climatic conditions, the eggs divide repeatedly until a first larva is formed. The larva feeds on bacteria in the droppings and elsewhere in its surroundings; after a period of growth it sheds its skin and is transformed into a second and then a third larva. This stage, retaining the loose sheath of the second larva, is picked up by grazing sheep. Thus transported into the stomach of the sheep, it emerges from its sheath and begins its parasitic life. It bores into the stomach walls, causing them to bleed, and after three or four weeks and a fourth and fifth larval stage, becomes an adult which then begins to lay eggs. Several typical aspects of this cycle are worth noting: first, only the third larva is infective; second, drought, frost and other factors reduce the first larva's chance of survival, but the droppings themselves provide food, warmth and other conditions favorable to its growth; third, the stomachworm has extended its range of hosts to include goats, cattle and other animals which chew the cud; fourth, the cycle is of the simplest kind, from the anus of the host to the soil to the mouth of another host, no intermediate host being required.

Among the parasites requiring an intermediate host are Bancroft's filarial worm, the beef tapeworm, the broad tapeworm of man, the human malarial parasite and *Fasciola hepatica*—the liver fluke of sheep, cattle and other animals. The cycle of the liver fluke is particularly interesting. As an adult this creature is 30 millimeters long, about 13 broad, has a "flattened oval body tapering to a point at each end, so that it is shaped rather like a leaf," and is parasitic not in the food canal but in the bile ducts of its host. The eggs of the liver fluke, each fitted with a lid at one end, are passed out of the liver with the bile and emerge from the host in its droppings. A larva equipped with eye spots and swimming hairs hatches out through the open lid of the egg and is then picked up by a small, amphibious, air-breathing snail. Having bored its way into the snail by "spinning on its long axis and driving in the papilla on its anterior end," the larva migrates through lymph channels and blood vessels to a part of the host where food is abundant. By successive transformations the larva becomes a cercaria, an organism resembling a minute tadpole which wriggles through the tissues of the snail into the water in which it lives. The sole use of the tiny tail is to enable cercaria to swim about for an hour or two before climbing up a blade of grass or other vegetation; immediately on reaching this haven the tail is shed. Cercaria now envelops itself in a protective cyst, inside which the larva undergoes further structural changes. It becomes a metacercaria, the organism which, on its blade of grass, awaits the arrival of a sheep or another host. If conditions are not unduly adverse the inhabitant of the small cyst may survive as long as 12 months. When the larva has been swallowed by the right kind of host—man is included in this category—the protective covering is dissolved by the host's digestive juices and the liver fluke emerges, fully armed for its excavations. It bores first through the host's intestine; after three days it reaches the liver and pierces its covering. Once in the liver, metacercaria wanders destructively through the tissues to the bile ducts, where it lays eggs. The whole life history from egg to egg requires about four to five months, but sometimes may be completed in two to three months.

Nowhere has nature been more lavish with its ingenious mechanisms and processes—and its grotesque forms—than in the world of the parasite. It has been noted that most parasitic animals are very small, yet there are exceptions. The broad tapeworm of man develops 3,000 to 4,000 segments, each complete with male and female organs, and may reach a length of 60 feet; the beef tapeworm has been known to reach a length of 80 feet. The hydatid cyst of the dog tapeworm sometimes grows large enough in the human body to hold 50 quarts of liquid. The bladderworm larvae of tapeworms turn themselves inside out when the beef in which they are encysted is eaten by man, so that the head of the tapeworm tucked inside the larva can attach itself to the walls of the host's small intestine. Bancroft's filarial worm, a parasite of humans, appears in the blood vessels of the skin and enters parts of the body, but only during the night. Moreover, if the host sleeps by day, "the microfilarial larvae appear in the peripheral blood during the day." The reason for this is "not yet known." Dr. Lapage offers impressive evidence for the prowess of the bloodsucking bat *Desmodus.* These "cunning" parasites "stalk their victims . . . and, when they are asleep, they walk or sidle up to them and scoop out a piece of flesh so delicately that the sleeping animal is often not aware of the bite until the bleeding is discovered in the morning."

One of the most astonishing evolutionary modifications of parasites is exhibited in their reproductive processes. The parasitic animal is often fragile and the probability of its surviving the vicissitudes to which it is exposed, and of its reaching its goal in a suitable host, are very small. It has been estimated, for example, that the chances are 18 million against one of a male and female hookworm getting into the same host and "living successfully in it" so that the female can lay its quota of fertilized eggs. But this dim prospect of the species' survival is much brightened by the egg-production of the lucky females which have found a home and a mate. The female of the hookworm *Ancylostoma duodenale* lays 25,000 to 35,000 eggs per day, has a life expectancy of five years and therefore an egg-production expectancy of 18 to 54 million eggs. Even so the hookworm, compared to other species, is only a modest egg-layer. The large roundworm of man and pig produces 200,000 eggs a day, 60 million per year; the pork tapeworm, 850,000 eggs daily, 700 to 800 million annually.

Besides presenting a detailed—at times, perhaps, too detailed for the general reader—account of parasites and parasitic life, Dr. Lapage deals with such subjects as tissue reactions and the immunity of the host, the avoidance of parasites, the economic and world-health aspects of parasitism, and, in his conclusion, expresses philosophical and moral opinions prompted by his survey of the parasitic relationship.

The measures taken by the host to protect itself against parasites include blocking, expelling or destroying the invader, localizing the disease and other injurious effects, repairing the damage done. The host may inherit immunity or acquire it. While careful not to impute to animals motives not susceptible of scientific proof, Dr. Lapage points out that "avoidance" seems "to describe exactly the behavior of some hosts to some kinds of parasitic animals." A graphic and convincing illustration is provided by the behavior of cattle with respect to the warble-fly, whose eggs, deposited on the cattle's hairs, hatch into small grubs which burrow through the skin and produce intense inflammation. The warble-fly itself neither bites nor stings, yet its approach markedly disturbs cattle in the field. They grow restless, make "sudden rushes," and have been known to stampede over cliffs in their attempt to avoid the flies. More sensibly, cattle will wade into shallow water or seek shade when the warble-fly is on the wing. "It seems as if they have learnt what men know, namely, that the warble-fly, like the tsetse fly which is one of its near relatives, avoids the shade and does not usually cross open water, and that by immersing their feet and legs in water they protect the areas of their bodies on which the warble-flies most often lay their eggs."

The number of persons infected by parasites, according to the figures quoted by Dr. Lapage, is "almost incredible." Norman Stoll, the U. S. helminthologist, has calculated that 644 million persons are infected with the large roundworm, 209 million with the seat-worm, 27 million with the pork trichina-worm, 114 million with the blood flukes, 189 million with Bancroft's filarial worm, 39 million with the beef tapeworm. In 1950 the World Health Organization reported that every year malaria kills 3 million persons and 300 million new malarial infections occur. In the Pacific theater of the last war, during a five-month period between September, 1943, and February, 1944, the ratio of battle casualties to casualties caused by malaria, dengue fever, dysentery, scrub typhus and skin diseases was one to 15. The loss of domesticated animals to parasites is also very great. To give one example, in 1942 parasitic damage to farm stock in the U. S. was set at almost $300 million by the Department of Agriculture. One of the less harrowing of the diseases caused by parasites, which I cannot refrain from mentioning, is the affliction known as "Collector's itch." This is a skin disorder acquired in the neighborhood of Ann Arbor, Mich., by biologists "seeking for animals in muddy or swampy areas inhabited by snails which are intermediate hosts of flukes whose adults cannot live in man, although their cercariae can penetrate human skin."

Dr. Lapage is at pains to point out in his last chapter that the study of parasites must entirely dispel the notion that the universe was created for man's convenience. It is difficult to believe that this notion has wide currency in the world today. As for his brief moral disquisition on the paradox of a universe in which both man and the malarial parasites exhibit "the lineaments of God," it cannot be said that Dr. Lapage brings much original insight to this admittedly vexed, if hackneyed, issue. We are promised, "if circumstances permit," a more "contemplative" volume in which these matters will be dealt with fully; meanwhile, we may be grateful for a popularization of exceptional merit.

POSITIVISM: A STUDY IN HUMAN UNDERSTANDING, by Richard von Mises. Harvard University Press ($6.00). This is among the most stimulating essays on philosophy to have appeared in many years, a book distinguished no less for its breadth and good sense than for the keenness of its insight. Dr. von Mises defines positivism as that interpretation of experience which adheres meticulously to the fundamental precepts of scientific research: rationality, disinterestedness, a vigorous skepticism coupled with a ready hospitality to fresh ideas and freedom from prejudice, mystical thinking and fanaticism. He examines in turn the application of positivistic theory to the problems of language and communication, to mathematics and logic, to the physical sciences, social studies, literature, law, ethics, poetry, religion and the fine arts. In each case his position is moderate and reasonable; in each case he makes a genuine contribution to understanding. Particularly noteworthy are Dr. von Mises' analyses of the subtle questions of mathematical philosophy, of probability, of the relation between the tautologies of mathematics (*e.g.*, $2+2=4$) and the common experience of mathematical truths (*e.g.*, 2 cows + 2 cows = 4 cows), and his appraisal of the value of metaphysical speculation and intuitive judgments. He makes it abundantly clear that there is no sphere of human interest inaccessible to rational thought, just as there is no discipline so firmly established as to be above reexamination and modification on the strength of new evidence. Dr. von Mises' study is a translation of his *Kleines Lehrbuch des Positivismus*; it is proof of the excellence of the book that it survives a translation which is nowhere better than passable and in many places practically opaque.

AN EXPERIMENT IN THE PREVENTION OF DELINQUENCY: THE CAMBRIDGE-SOMERVILLE YOUTH STUDY, by Edwin Powers and Helen L. Witmer. Columbia University Press ($6.00). High hopes attended the beginning of this experiment, in which one group of delinquent boys was counseled for several years, whereas the matched control group received no special attention prior to the final checkup. The counseling, as one boy described it, "was like social work—only friendly." Unfortunately none of the evidence clearly indicates that counseling affected delinquent behavior patterns. However, a number of other significant conclusions emerged from the study. One of these is the reaffirmation of the principle that severe emotional disharmony in the home is the root cause of delinquency. Perhaps relatively superficial counseling can never overcome a serious emotional disturbance, from which delinquency certainly seems to stem.

HORSES, by George Gaylord Simpson. Oxford University Press ($6.50). A history of the horse family through 60 million years of its development from

Eohippus to *Equus*. Dr. Simpson's main concern is with the animal itself, not with its use. He discusses, among other things, the physical characteristics, distribution and habits of the horse; its domestication and breeding; the inheritance of its various characters; the "relationship between structure and [its] way of life"; the discovery of its fossils and their interpretation. This is a pleasantly written study, summarizing modern knowledge in several interconnected fields and dealing authoritatively with a rich variety of subjects from the gaits and coat colors of horses to "the history of the earth and its life."

THE PERCEPTION OF THE VISUAL WORLD, by James J. Gibson. Houghton Mifflin Company ($4.00). Traditionally the theories of visual perception have assumed that objects are seen in an abstract, unfilled space. When these theories failed during the war to contribute to the solution of the perceptual problems encountered in flying, Dr. Gibson, then an Air Force psychologist, was led to challenge this premise and to develop alternate hypotheses. He now believes that surfaces and edges are the things that we see, not air, and that they are always seen against a background. This view requires a search for the specific factors in experience which provide the data of which perception is made, and this brilliant book describes the factors so far discovered. Dr. Gibson's study can be recommended to the scientist, the painter, the philosopher, indeed, to anyone interested in the problem: Why do things look as they do?

AN INTRODUCTION TO THE SCIENCE OF PHOTOGRAPHY, by Katherine Chamberlain. The Macmillan Company ($6.50). A well-illustrated survey by a professor of physics at Wayne University of the history of photography; the characteristics of various modern cameras, lenses and exposure meters; the way to develop, print and enlarge film; and the elements of the theory of optics. Most of Dr. Chamberlain's account is for the advanced amateur rather than the carefree, if occasionally frustrated, summer photographer.

THE PSYCHIC SOURCE BOOK, compiled by Alson J. Smith. Creative Age Press, Inc. ($4.50). Selections dealing with the vexed and, in the opinion of the majority of scientists, still uncertain field of parapsychology and psychical research. Mr. Smith offers a mixed lot of sobrieties, fascinations and occasionally plain rubbish from various pens, including those of C. G. Jung, J. B. Rhine, P. A. Sorokin, Lord Balfour, Sir Oliver Lodge, F. W. H. Myers and Eileen J. Garrett. There is a glossary (aboulia to telergy), a brief list of biographies and a bibliography. A sincere and at times intriguing book; yet the bulk of its evidence is so ectoplasmic that one may doubt that anything resembling a serious discipline can be reared on such foundations.

CLIMBS IN THE CANADIAN ROCKIES, by Frank S. Smythe. W. W. Norton and Company, Inc. ($4.50). The adventures of a noted mountaineer in scaling difficult peaks and exploring uncharted regions of the Canadian Northwest. Mr. Smythe, who clambered indefatigably over most of the world's rock piles from Kanchenjunga to the Matterhorn, was a gifted writer with a sensitive eye for trees, flowers, the weather, the habits of beavers, bears and lightning, the beauty of glaciers and rivers, the majesty and geology of mountains. He had also a considerable talent for swift narrative. An engagingly honest, often humorous, immensely readable book. Photographs.

RUSSIA'S SOVIET ECONOMY, by Harry Schwartz. Prentice-Hall, Inc. ($6.65). An examination in considerable detail of all major sectors of the Soviet economy, particularly with respect to its organization and operation during and since World War II. Mr. Schwartz, having drawn heavily on Soviet materials, asserts that the statistical data published by the U.S.S.R. "are basically accurate in the overwhelming majority of cases, though not all; to mask secrets about their economy, Soviet leaders prefer ambiguity and withholding of data rather than outright statistical prevarication." An objective, intelligent labor based upon a thorough search of the most reliable sources. Maps, figures and many tables.

COOPERATION AMONG ANIMALS, WITH HUMAN IMPLICATIONS, by W. C. Allee. Henry Schuman, Inc. ($3.50). This revised edition of a work of outstanding interest and importance, Dr. Allee's *The Social Life of Animals*, deals with the cooperative processes among animals, the nature of group behavior and group organization and the bearing of this knowledge on the study of social relationships among men and, especially, on their attempts to achieve international order and world peace.

COSMIC RAYS, by L. Jánossy. Oxford University Press ($9.00). The second edition of a standard work. The author, pending the outcome of current investigations of fundamental problems, has made only minor revisions incorporating scientific advances since the first edition appeared in 1948.

A HALF CENTURY OF COLOR, by Louis Walton Sipley. The Macmillan Company ($8.00). Mr. Sipley, director of the American Museum of Photography, describes the development of color photography, lithography and other methods of reproduction from the latter part of the 19th century to the present. This is a specialist's history, packed with technical and business details. It is authoritative but often dull and difficult. There is nothing dull, however, about the many well-selected illustrations, several of which are extraordinarily beautiful as well as of considerable historic interest.

Psychological Analysis of Economic Behavior, by George Katona. McGraw-Hill Book Company, Inc. ($5.00). The "economic man" of traditional economics seems to be an abstract creature who views economic matters with a dispassionate rationality perplexing to those of us who worry about, among other things, the high cost of living. Katona, who holds a joint appointment in economics and psychology at the University of Michigan, wishes to endow economic man with desires, attitudes, expectancies, beliefs and misconceptions. To do so, he reviews sample interview studies of consumers and businessmen and indicates how psychological factors are related to saving, spending, production and the like. This book represents a significant step toward an integrated approach to economic problems.

Education in the Humane Community, by Joseph K. Hart. Harper & Brothers ($3.00). Crisis and Hope in American Education, by Robert Ulich. The Beacon Press ($3.75). Both of these writers express dissatisfaction with our highly verbal, factual and unrealistic schools. The late Dr. Hart recommends that children again experience community living, as they did in the days of small villages, and that the schools emphasize the child's place in the "larger world of humanity within which, alone, he can become the completely human personality." Real problems and real conflicts must be experienced if the student is to be satisfactorily educated for living, and the adolescent also must live his life in the community in order to discover himself, his assets and his deficits. Dr. Ulich generally approves of current elementary education, but sees real failure in the high school. He would provide there for a common emotional education, but would treat students according to their intellects and interests in academic work. Neither in the colleges and universities nor in adult education does he see adequate stress upon moral and intellectual values or on the problems and conflicts of a world in disorder. Although the authors of these books discuss issues of importance to American education, it is difficult to see the solutions proposed as being at present anything more than Utopian.

World Railways 1950-51, edited and compiled by Henry Sampson. Rand McNally & Company ($25.00).

The first edition of a companion publication to Jane's surveys of fighting ships and aircraft, presenting a survey of operations and equipment of representative railroad systems throughout the world. The format resembles that of *Jane's*; there are hundreds of photographs of locomotives, passenger and freight cars, maps, drawings, gradient profiles, tables of locomotive characteristics and kindred information. U. S., British, Canadian and Western European railroads are described in some detail; on the other hand, data on the railways of Central and South America, Eastern Europe, Asia and Africa are often grossly inadequate, and in some cases wholly nonexistent. Sampson's *World Railways* is a much needed book which will serve many professional interests and give pleasure to amateurs, but it has a long way to go before it attains the standard set by *Jane's*.

Also Noteworthy

The Structure of American Economy, 1919-1939, by Wassily W. Leontief. Oxford University Press ($5.75). The second edition of this study of the application to the American economy of input-output method of economic analysis, with four additional chapters and a new table for the year 1939. A more popular explanation of the author's approach to interindustrial relationships appeared in this magazine for October, 1951.

Methods in Structural Linguistics, by Zellig S. Harris. The University of Chicago Press ($7.50). A technical survey of research methods in modern linguistics by a leading specialist in the subject who teaches at the University of Pennsylvania.

Southeast Asia, by E. H. G. Dobby. John Wiley & Sons, Inc. ($5.00). The professor of geography at the University of Malaya offers a handbook of the physical, economic and cultural features of the countries of Southeast Asia, including Burma, Malaya, Siam, Indonesia, Indochina, and the Philippines. Numerous maps and bibliographies.

How About the Weather?, by Robert Moore Fisher. Harper & Brothers ($3.00). An illustrated layman's guide to pressure, temperature, clouds, winds and fronts, and also to the interpretation of the dark mysteries of weather maps. Acceptable, although the narrative occasionally loses its way in a thicket of details.

Agricultural Resources of China, by Tsung-han Shen. Cornell University Press ($5.00). A survey of basic agricultural resources, of the development of crops and livestock, and of agricultural and economic conditions in contemporary China. The statistics are necessarily skimpy; this is nevertheless a useful work and the first of its scope.

THE CONCISE OXFORD DICTIONARY OF CURRENT ENGLISH. Oxford University Press ($4.00). This edition of the famous Oxford *Concise* has been enlarged, completely revised and reset; a new system of pronunciation has been adopted and improvements made in the use of space-saving symbols.

HISTORY OF PHARMACY, by Edward Kremers and George Urdang. J. B. Lippincott Company ($7.50). The second edition of a standard work, the first having been published in 1940. Revisions have been made and a chapter added on the development of pharmacy in Spain. A detailed, authoritative but lamentably pedantic survey; it is difficult to believe that the history of pharmacy was as drab as this book makes it appear.

PRINTING TYPES, by Daniel Berkeley Updike. Harvard University Press ($12.50). A reissue of the second edition of the classic history of typography. A considerable debt is owed the Harvard University Press for making available once more, at a moderate price, this masterwork, indispensable to the scholar and a feast for the eye and mind of anyone who cares about printing.

THE PHILOSOPHY OF MATHEMATICS, by Edward A. Maziarz. Philosophical Library ($4.00). The author traces the history of philosophical speculations on the nature of mathematics from ancient times to the present, and proffers his own solutions of major problems in this sphere of thought. The book has a serviceable but by no means exhaustive bibliography.

THE RESTLESS UNIVERSE, by Max Born. Dover Publications, Inc. ($3.95). A revised and enlarged edition of one of the best popularizations of modern physics by a leading scientist who is also a first-rate expositor. Warmly recommended.

ELEMENTARY PARTICLES, by Enrico Fermi. Yale University Press ($2.50). A discussion for students and experimental physicists of "some of the most significant results of the field theories of elementary particles." Based on the 1950 Silliman Memorial Lectures at Yale University.

BOOKS AND READERS IN ANCIENT GREECE AND ROME, by Frederic G. Kenyon. Oxford University Press ($1.75). The second edition of a brief survey of reading habits, and the appearance and manufacture of books, in classical antiquity. An authoritative, readable and most attractive little volume.

Conducted by Albert G. Ingalls

MANY readers of this magazine nibble a year or two at this monthly department before they decide to join the legion of the lost and make a telescope. Their careful approach resembles that of a black bass that follows a trolling line for half a mile wondering, "Is this my lunch or does it hide a hook?" In the four accompanying drawings the illustrator of the department shows what happens when the victim bites. The beginner has made the simplest telescope, had a season's fun with it and learned facts about telescopes that books cannot impart. Now he has deserted his first love and has built and is avidly using his second telescope, a larger one. Even the second is not the last, however. At the end of the second season it has been stripped of useful adjuncts and joined the cobwebbed company of attic antiques. Now the mirror for the third telescope, a foot in diameter, is under way, and the builder is becoming an advanced amateur and belongs to astronomical organizations.

A few try for the last telescope first. They usually embody mistakes in it, miss the fun the others have and wind up wiser.

DURING THE past four years a group of amateur and professional opticians and scientists have exchanged about 50 letters with one another and with this department on the possibility of using the natural glass called obsidian for telescope mirror disks. A less expensive material than Pyrex would be very welcome to amateurs planning 18- or 20-inch telescopes and to professionals planning larger ones.

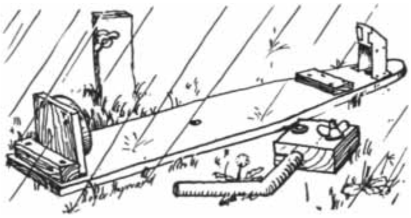
The proposal to use obsidian was first made before 1926. (See page 316 of *Amateur Telescope Making.*) By now a fairly large number of small optical surfaces have been made on it and proved satisfactory, but questions remain about the uniformity, reliability, availability and cost of obsidian disks. G. Dallas Hanna of the California Academy of Sciences describes his experience with obsidian as follows:

"During the late war the California

THE AMATEUR ASTRONOMER

Academy of Sciences was engaged in repairing for the U. S. Navy certain instruments used in navigation, such as azimuth circles, which have a small rectangular mirror made of black unsilvered glass. Spare mirrors were not obtainable. It occurred to some of us that obsidian might be a suitable substitute. C. C. Church obtained the first piece from Glass Mountain, two miles northeast of St. Helena in Napa County, California. It took a brilliant polish. Some of the pieces he brought were made into mirrors and they met all the requirements of the experienced inspectors. Allyn G. Smith and Edwin Over then collected a large supply and more than 100 reflectors were made and used.

"It was soon discovered that the raw material varied considerably in opacity. Some chunks had tiny bands of light gray and black. The St. Helena material was found to be completely free of visible bubbles and crystalline inclusions. It had the appearance of a well-mixed glass. It was harder than any glass we had ground and polished except fused quartz, and we soon noticed that heat effects were practically nonexistent. We



The sad end of an early love

could pass at once from polishing lap to Foucault tester.

"A few optical flats from two to six inches in diameter were made by J. E. Steinbeck, D. O. McLaren, Allyn G. Smith, C. C. Church, L. A. Parsons and Edwin Over, all experienced optical workers. They agreed that from the heat standpoint the obsidian had most desirable properties. We tested these flats from time to time to discover whether they contained strains, and found through the months that they did not change shape.

"One mirror made from St. Helena obsidian was 5.5 inches in diameter and very accurately spherical. The image of the sun from the uncoated obsidian was occasionally reflected upon the ceiling of the workshop to show the employees changes in sunspots. We also brought the moon into the field. Steinbeck, an experienced observer of lunar topography, pronounced the image exquisite in fine detail.

"This little group of workers was not the first to consider obsidian as a possible substitute for glass in some optical uses. In 1926 Russell W. Porter polished a piece flat and gave it to A. G. Ingalls. W. P. Bush of Berkeley, Calif., used obsidian of unknown source for a six-inch telescope mirror which Donald Jenkins of the Tinsley Laboratories tested and considered to have an excellent figure.

"Obsidian is very difficult to define accurately because it varies greatly in chemical composition and physical properties from deposit to deposit. Usually it would be called black, but often thin slivers are greenish or brownish with transmitted light. All true obsidians are presumed to be volcanic in origin. The chemical composition is often very close to that of the volcanic rock rhyolite. However, there are gradations into other rocks, so that it is very difficult to define its boundaries. It often contains bubbles, evidently caused by expansion of gaseous material, probably water. Sometimes there are cavities filled with minerals such as calcite or cristobalite. In some deposits there is a sprinkling of crystals which are softer than the obsidian, making it very difficult to work to an optical surface. A study of obsidian, chemically, physically, optically, geologically and mineralogically, is overdue."

The Mineral Information Service of the Division of Mines, State of California, says that another Glass Mountain in eastern Siskayou County, Calif., contains one of the largest deposits of obsidian in California, if not in the U. S., measuring several miles in length. The side slopes of the flow are composed mainly of talus blocks broken off from the flow. In the Warner Mountains near Davis Creek are several deposits of obsidian. There are also deposits in Yellowstone Park, Wyoming, and in Utah, Oregon and New Mexico.

Mirror makers seeking light on obsidian often look into the dictionary and learn that it is volcanic glass with the same composition as granite or rhyolite. At this point many become confused. If volcanic glass has the composition of granite, how can it be suitable for optical surfaces? The trouble is that the dictionary must be brief. For a more complete understanding of obsidian we must look inside the earth.

Within the earth's crust form molten solutions of mineral molecules, which are atomic groups or associations of oxygen, silicon, aluminum, iron, calcium, sodium, potassium and magnesium. These elements constitute more than 98 per cent of the earth's outer zone. This molten matter is charged with gases, including water, carbon dioxide, sulfur fumes and others. When such an igneous

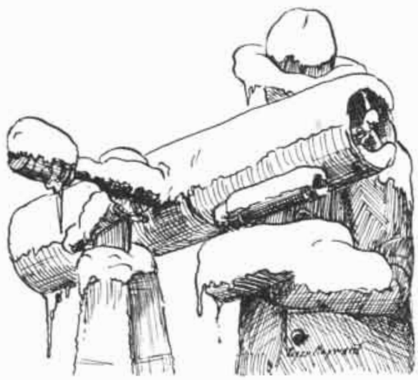
INDEX OF ADVERTISERS

FEBRUARY

1952

magma rises from the depths, is obstructed and cannot reach the surface, it is insulated by the overlying rocks and cools extremely slowly. This allows time for atomic groups to separate from the magma as crystals. The first to crystallize out of a granite-forming magma and to form the mineral hornblende are complex molecules containing oxygen and silicon with calcium, magnesium, aluminum and iron. As the magma cools further, molecules of oxygen with silicon, potassium, aluminum and iron separate as crystals of black mica. Later still come the feldspars, composed of oxygen, silicon, aluminum and potassium or sodium, and last, at lower temperatures, are quartz crystals of oxygen and silicon, to fill the spaces between the other crystals.

The size of all these constituent mineral crystals depends on the length of time of cooling. If it is great, the crystals will be large and the rock described would be a granite. If the cooling time is much shorter, they would be very small and the rock would be rhyolite. Since the quartz has hardness 7, the feldspars 6, the hornblende sometimes 5 and the mica 3 or less, and all have different crystal forms and different physical properties such as coefficient of expansion along each axis, and since most of the crystals have cleavage, it is obvious

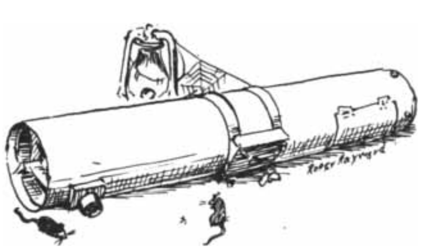


This time it's downright serious

that granite and other crystalline rocks would make poor optical surfaces. The softer minerals would polish to lower levels than the harder. Yet the proposal to use granite has been made to this department about twice a year for a quarter of a century.

Now obsidian most commonly has the composition of granite. Is it not therefore discredited for mirrors? This argument arises nearly every time obsidian is discussed, usually from those who have consulted the dictionary definition, which stresses its composition. The answer is that the decisive property is not chemical composition—in fact, the chemical elements in granite are the same ones used in manufactured glass—but the physical condition of the material. If the magma described above, which cooled to granite or rhyolite, had escaped from a volcano as lava and been chilled too rapidly to crystallize, the rock formed would be obsidian. The important fact for the mirror maker is that this rock is a glass.

What is a glass? Thousands who work with glass do not know what it is. Again, for reasons of necessary brevity, the dictionary definition stressing the chemical content is superficial from the scientist's point of view. A less superficial definition that stresses the physical condition, though it might leave the average dictionary user dizzy, is that glass is a liquid so viscous that it is rigid.



Oblivion under the eaves

Viscosity is resistance to flow in a liquid or plastic. At 68 degrees F., pitch is 10,950 times as viscous as water, and glass is almost infinitely more so. But, however rigid glass is, it is still a liquid, because as it cools there is no freezing point, no change to the crystalline state with its orderly repetition of atomic structure. Instead, there is continuity from the fluid to the rigid condition. Because glass has not crystallized at temperatures at which it is rigid, it is classed as an undercooled liquid. (Sometimes it does crystallize, or devitrify, in cooling, but then it is no longer glass, and the manufacturer is no longer happy.) This does not mean, however, that glass has all the properties of a normal liquid. In the liquid state the atoms of matter are in a random arrangement, and are continually changing neighbors. X-ray diffraction analysis shows that in glass each atom has permanent neighbors. But these are not at definite distances; hence glass is not crystalline.

The nature of glass is discussed by C. J. Phillips of the Corning Glass Works in *Glass the Miracle Maker,* and by George W. Morey of the Geophysical Laboratory of the Carnegie Institution of Washington in *The Properties of Glass.* Morey's definition of glass is more precise than that given in the paragraph above and requires 51 words, with 2,200 words of further explanation—so elusive are the concepts involved, and so imprecise some of the terms we must use. The approximate definition given above is a compromise between Morey's 2,251 words and the dictionary's capsule version.

Since obsidian is in the glassy, uncrystallized condition, it is a full-fledged glass, not an imitation. Not all specimens in the field are entirely free from crystals, however; Nature is less interested in standard production control than the Corning Glass Works with its Pyrex. (Nature, too, has bubble troubles.) The user must therefore either study the subject and know exactly what he is about or live dangerously and gamble on his obsidian. An expedition to secure a few two- or three-ton blocks of obsidian for 18- or 20-inch mirrors might easily cost more than Pyrex if the worker had the evil cost-accounting habit, but if time, gasoline and backaches are ignored the adventure might pay well in satisfaction. Much of the Siskayou County obsidian deposit is in the public domain under supervision of the U. S. Forest Service. There can be no objection to collecting minerals on it.

The next problem, of course, would be cutting the blocks into usable slabs. Some workers, not amateur, have trucked obsidian to monument works and had it sawed into slabs on granite saws of the type used in the monument industry. These are manufactured by the Patch-Wegner Company of Rutland, Vt., and shown in the *Monumental News-Review* of Buffalo, N. Y., a publication which gives some interesting insights into modern methods of working granite. Gangs of six long, heavy parallel strips of metal half an inch thick are reciprocated over the granite blocks by 40- to 100-horsepower motors. With chilled steel-shot abrasive fed abundantly by centrifugal pumps, they saw downward at eight inches an hour. An alternative method uses endless wires and

Now we are out for big game

abrasive grains to saw 16 inches an hour. The amateur telescope maker, who may have used a similar method on a one-armpower scale for sawing glass, could devise his own obsidian saw; the boulders are too large for circular saws. A one-man industry — quarrier, sawyer, dealer — might result, and telescope makers might thereby obtain disks in times of Pyrex shortage like the present.

For some time the Fund for Astrophysical Research, Inc., with the support of the Office of Naval Research, has been studying the usefulness of obsidian for astronomical mirrors. An account of this study, more definitive than the preceding one and with quantitative data, is scheduled to appear in a later issue.

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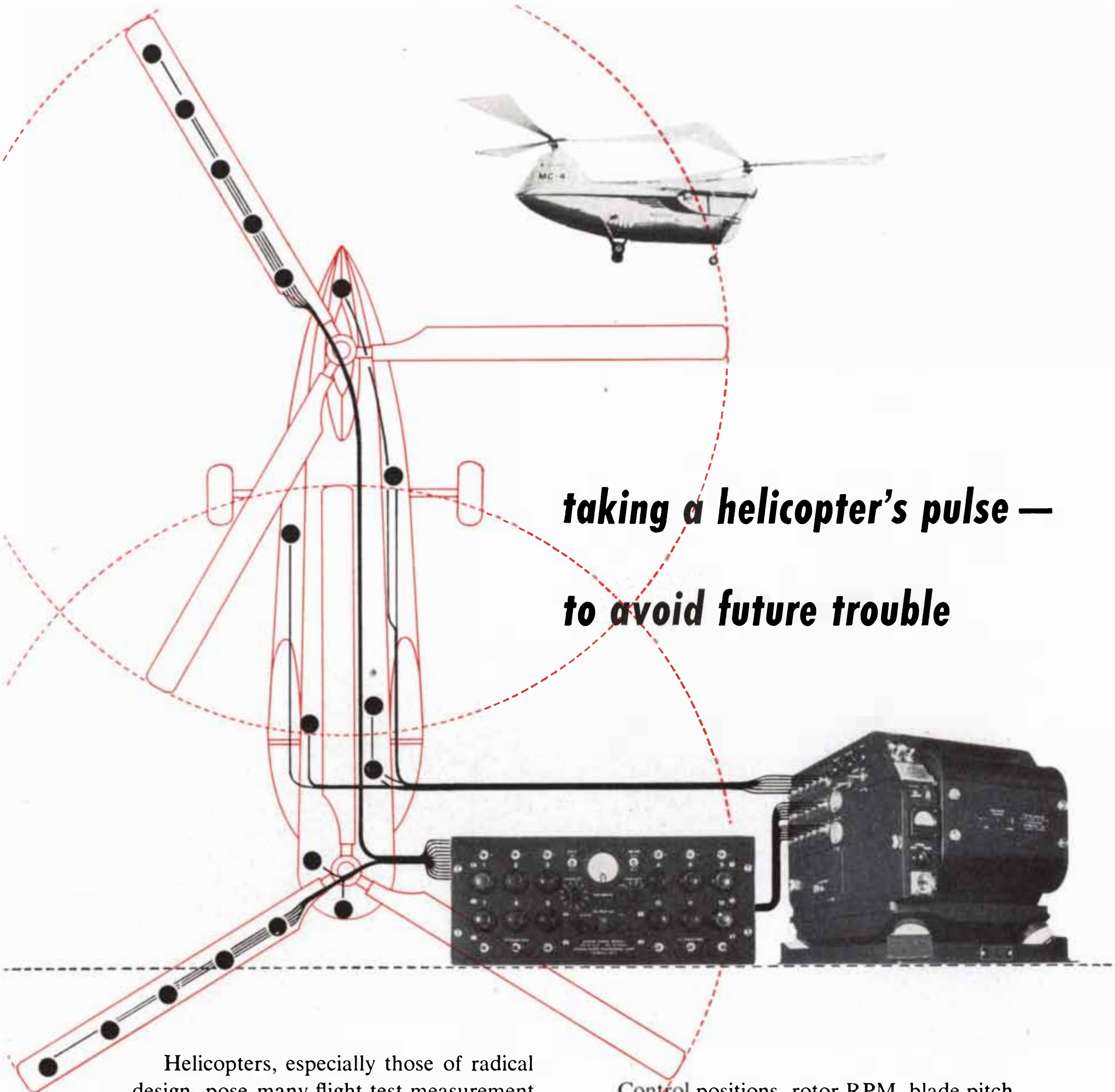

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