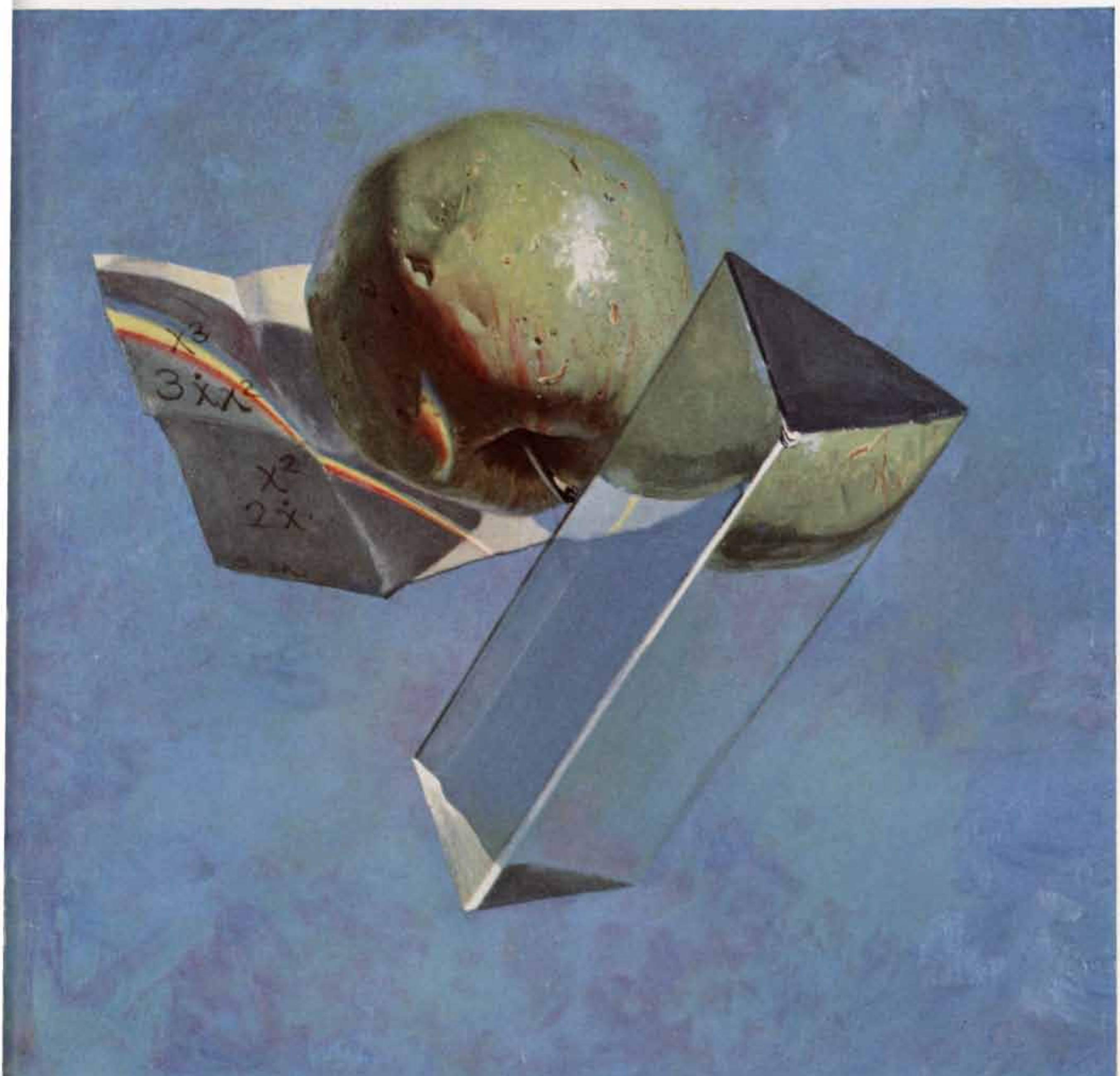
SCIENTIFIC AMERICAN



THREE SYMBOLS OF NEWTON

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December 1955

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An oil refinery uses prodigious quantities of water for boiler-feed, processing, and cooling. To meet its requirements for properly softened water, this giant refinery treats hot, raw water with AMBERLITE® cation ion exchange resins and lime. The process is efficient, economical, and yields water of "zero" hardness.

What's your water problem? Softening? Dealkalization? Deionization? Deacidification? As long as it involves the removal or replacement of dissolved salts, there's an AMBERLITE ion exchange resin ready to help you. You can call on 11 different commercially available Rohm & Haas resins in varying degrees of acidity, basicity, and porosity. Ask your equipment manufacturer or consulting engineer about ion exchange and why the resin that's *right* is AMBERLITE.

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ROHM & HAAS COMPANY

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To keep abreast of atomic energy development, *NDA* has greatly expanded its laboratory, engineering and fabrication facilities. These include enlarged shops, chemistry and metallographic laboratories, liquid metal and high temperature experimental facilities and the Westchester County Computing Center.

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LETTERS

Sirs:

I could not help but note a remark by George Gamow in the biography of authors contributing to your October issue. Dr. Gamow is quoted as stating that fundamental biology is being transformed from "a mostly descriptive into an exact science" by new advances in the field, "thus opening new fields for theoretical studies." If by "exact science" Dr. Gamow means the science of precise and calculable theory, I should like to ask where descriptive studies end and theoretical ones begin? It is difficult to conceive of any biological theory completely devoid of concrete reality. And biologists have been and still are occupied with the task of better understanding this reality by objective and exacting observations, experimental or otherwise.

Biologists have learned that a living organism is a nicely constructed microcosm that maintains itself and increases its kind by the complicated integration of physical-chemical systems. The study of an organism often gives physical scientists, including mathematicians, a bad case of the jitters. Indeed, biologists have apparently horrified these gentlemen by their seemingly muddy thinking and equally hazy experimentation. This has not deterred the biologists a bit; they have blundered along until methods have been perfected that make things much easier for the physical scientist to

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work upon. It would seem that the field of biology has now entered a new phase in its development where it can more efficiently utilize the techniques and minds of scientists from other fields of study.

Physical scientists who become interested in biological phenomena should remember that their intellectual attention must be focused on the organism, a microcosm that is not the metabolism of nucleic acids, nor the energy transfers of the Krebs cycle, nor any of the other marvelously attuned physiochemical systems, but is the product of all. There is still the knotty question that intrigues most biologists: How do all these physiochemical systems bring about the form and substance so apparent in organisms described by "outmoded" biologists?

ALBERT S. ROUFFA

University of Illinois
Chicago, Ill.

Sirs:

In your October issue appeared a letter from an irritated Mr. Irving T. Richards, who, in commenting on "The Changing American Language" by Jotham Johnson, asserted that language change "occurs most frequently and most rapidly among the illiterate and semiliterate." Most specialists, for example see C. C. Fries' *American English*, believe the illiterate and semiliterate to be the conservatives as far as language goes. It is your educated man who will initiate new words, new ways of using them and pronouncing them. The uneducated man may say "put the kittle on to bile" quite as cheerfully as any citizen of Boswell's London might have done.

MARY JO DUCK

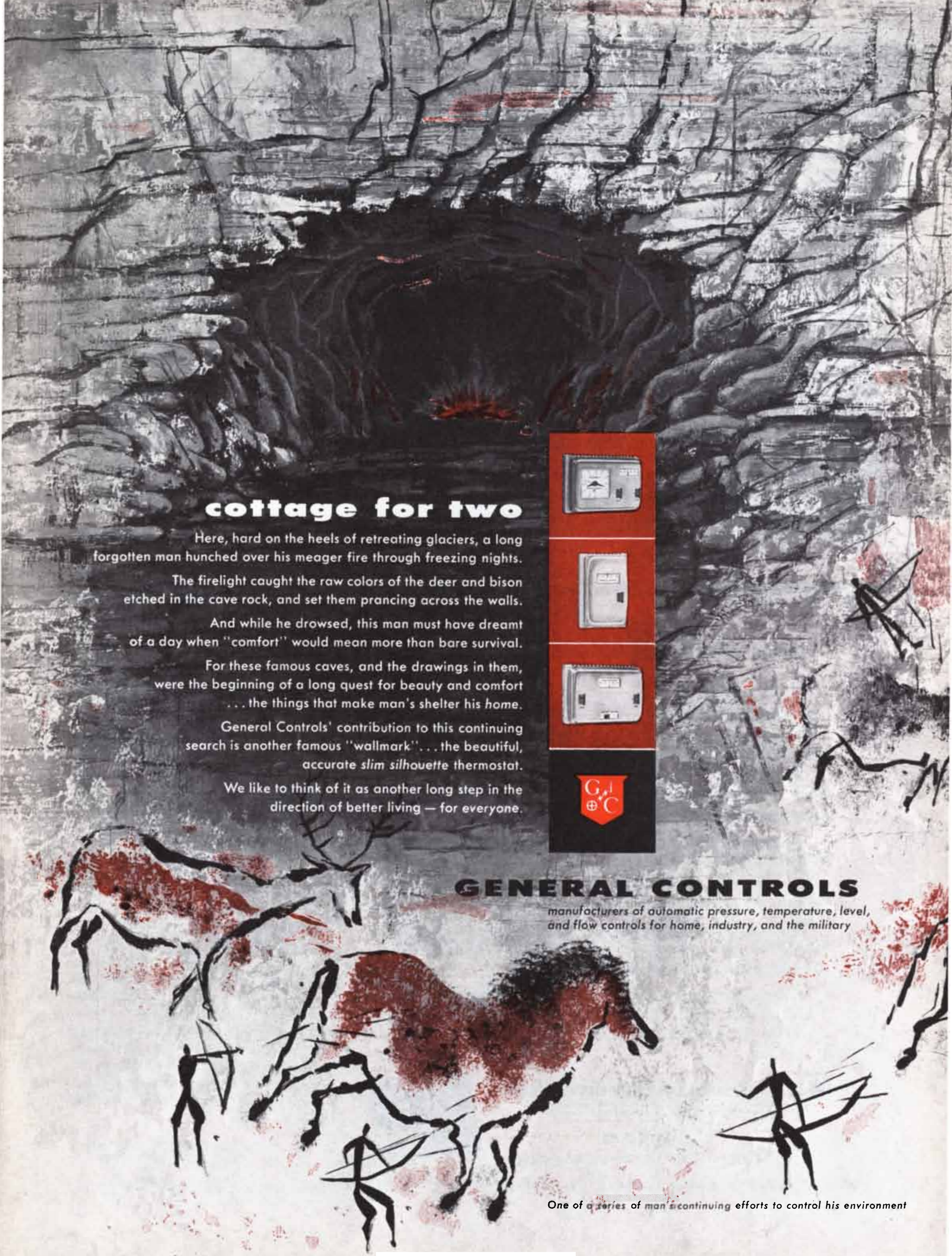
Ranger Junior College
Ranger, Texas

Sirs:

In his article, "Maupertuis, a Forgotten Genius" [SCIENTIFIC AMERICAN, October], H. Bentley Glass implies that the lack of recognition among modern scientists of this pioneer is due entirely to Voltaire's attack on him. Maupertuis was president of the Berlin Academy at the time it denounced Koenig—who was out of the country at the time, and whose essay had been published with Maupertuis's permission. It should not be forgotten that both antagonists—and Voltaire—were competing for the chancy favors of Frederick the Great; furthermore, the tradition of impersonal criticism of scientific work was not much respected at the time, even in the universities. Voltaire's grossly unfair *Diatribe du Docteur Akakia* was written in reply to an essay by King Frederick in which he clumsily tried to shield Maupertuis from criticism. The King's essay was published anonymously, but with the royal coat of arms prominently displayed! Voltaire boiled over, had his essay published without the King's permission and fled into exile. It is true that Maupertuis was ruined (science being an intellectual fad of the time, and Voltaire being Voltaire), but I cannot believe that the subsequent place of Maupertuis among scientists was decided by the literati. Even at the time, he was publicly supported by Leonhard Euler.

Considering the principle of least action itself, the comments of Ernst Mach in his *Science of Mechanics* are apropos: "He (Maupertuis) took as the measure of the 'action' the product of the mass, the velocity, and the space described, or *mvs. Why*, it must be confessed, is not clear. By mass and velocity definite quantities may be understood; not so, however, by space, when the time is not stated in which the space is described. If, however, unit of time be meant, the distinction of space and velocity in the examples treated by Maupertuis is, to say the least, peculiar. It appears that Maupertuis reached this obscure expression by an unclear mingling of his ideas of *vis viva* and the principle of virtual velocities. Its indistinctness will be more saliently displayed by the details." Mach continues with a detailed analysis of the application of the principle to a dynamic case (elastic collision) and a static case (the simple lever). He concludes that, insofar as it applies, Maupertuis's principle is always synonymous with Gauss's principle of least constraint, and that—unlike Gauss's principle—it does not always necessarily hold without correction. He remarks: "It will thus be seen that Maupertuis really had no principle, properly speaking, but only a vague formula, which was forced to do duty as the expression of different familiar phenomena not really brought under one conception. I have found it necessary to enter into some detail in this matter, since Maupertuis's performance, though it has been unfavorably criticized by all mathematicians, is, nevertheless, still invested with a sort of historical halo."

In Euler's hands, the principle was transformed into a statement both rigor-


cottage for two
Here, hard on the heels of retreating glaciers, a long forgotten man hunched over his meager fire through freezing nights.
The firelight caught the raw colors of the deer and bison etched in the cave rock, and set them prancing across the walls.
And while he drowsed, this man must have dreamt of a day when "comfort" would mean more than bare survival.
For these famous caves, and the drawings in them, were the beginning of a long quest for beauty and comfort . . . the things that make man's shelter his home.
General Controls' contribution to this continuing search is another famous "wallmark". . . the beautiful, accurate slim silhouette thermostat.
We like to think of it as another long step in the direction of better living — for everyone.
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manufacturers of automatic pressure, temperature, level, and flow controls for home, industry, and the military
One of a series of man's continuing efforts to control his environment

ous and much more general, as Mach shows in a further analysis. Maupertuis may be credited with inspiring Euler, but the principle of least action, in its valid form, is Euler's and not his.

WILLARD HATCH

East Cleveland, Ohio

Sirs:

. . . It is indeed a fact that Maupertuis was led to his principle of least action on theological and metaphysical grounds. In his *Essai de cosmologie* he writes: "Here then is this principle, so wise, so worthy of the Supreme Being: Whenever any change takes place in Nature, the amount of action expended in this change is always the smallest possible."

Maupertuis originally discovered his principle through his investigations on Newton's corpuscular theory of light where he was led to assume for metaphysical reasons only that *something* should be a minimum.

As a generalization this minimal principle is important if one is to follow the historical development of physical thought. It was Hero of Alexandria who discovered that reflected light travels by the path which makes the total distance traversed a minimum. This was extended by Fermat in the 17th century into a general principle of least time. A hundred years later Maupertuis, Euler and Lagrange developed the dynamical principle of least action and in 1834 Hamilton showed that all gravitational, dynamical, and electrical laws could be represented as minimal problems. Later still Hilbert proved that, on the principle of relativity, gravitation acts so as to make the total curvature of space-time a minimum, or, as Whittaker put it: "Gravitation simply represents a continual effort of the universe to straighten itself out."

Finally, it must not be forgotten that this principle is but a part of the truth. A physical system may go from an initial to a final state in such a way that an appropriately selected magnitude will exhibit the property of an extremum. The early investigators failed to realize that this magnitude could be a maximum as well as a minimum. Thus viewed we must now suppose that the Supreme Being is intent not on economizing but more especially on going to extremes one way or another.

JULIUS SUMNER MILLER

West Los Angeles, Calif.

L·O·F GLASS FIBERS COMPANY INTRODUCES

NEW MICRO-QUARTZ 2000° TO 3000°

Lightweight Micro-Quartz may solve critical insulation problems in aircraft, oil-refining, metal-processing, chemical-manufacturing, steelmaking and atomic-energy fields.

L·O·F Glass Fibers Company, a pioneer in the manufacture of fine ceramic fibers, now announces Micro-Quartz—a remarkable, new insulation for temperatures ranging, under many conditions, up to 3000°!

Micro-Quartz is available in sheet and bulk form. It is light in weight (sheets 3/16″ thick weigh about .047 pounds per square foot) and composed of 98% pure quartz. The average fiber diameter is approximately 0.75 microns or 0.00003 inches. Since it has no organic binder, performance, stability and thermal conductivity are those of the quartz fibers themselves.

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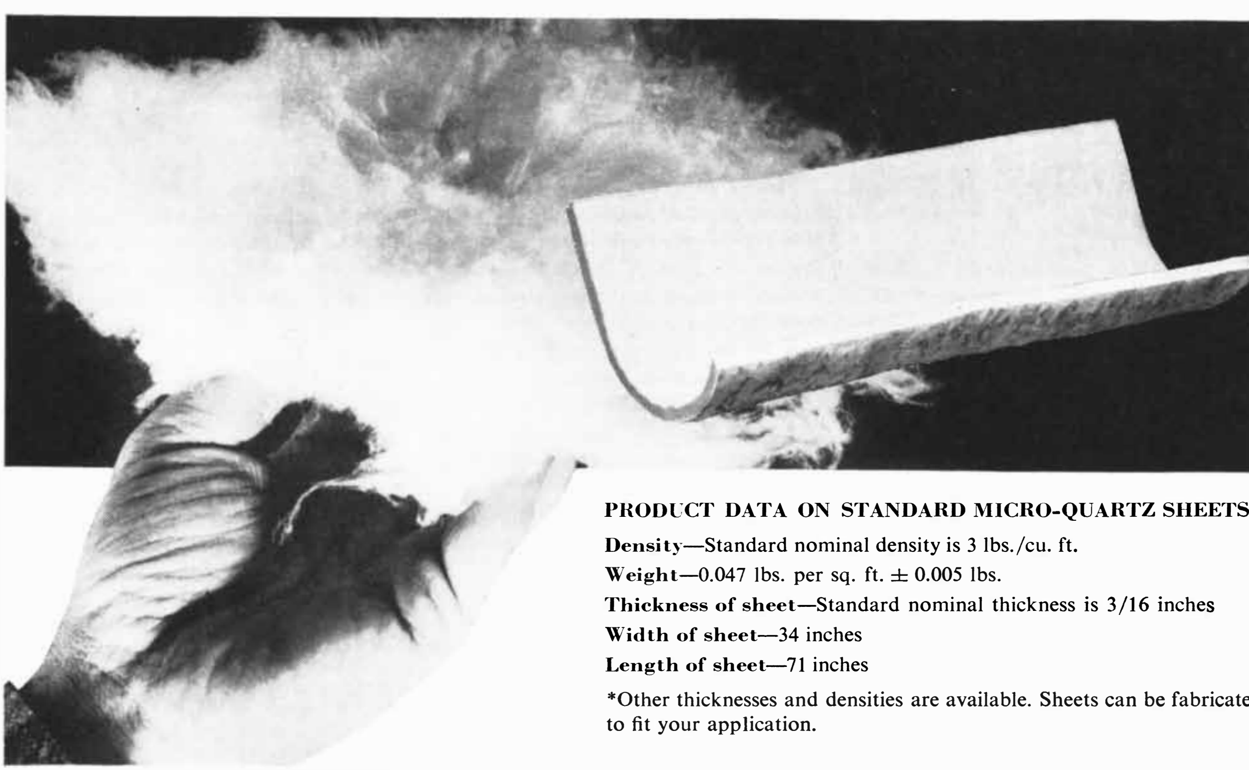
If you have a high-temperature insulation problem, send today for a free sample of Micro-Quartz and additional information. Or, if you need technical consultation on your problem, call on our qualified engineers.



PRODUCT DATA ON STANDARD MICRO-QUARTZ SHEETS*

Density—Standard nominal density is 3 lbs./cu. ft.

Weight—0.047 lbs. per sq. ft. ± 0.005 lbs.

Thickness of sheet—Standard nominal thickness is 3/16 inches

Width of sheet—34 inches

Length of sheet—71 inches

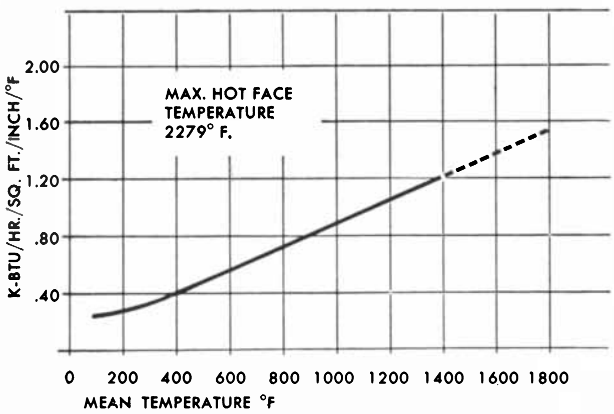
*Other thicknesses and densities are available. Sheets can be fabricated to fit your application.

INSULATION FOR THE TEMPERATURE RANGE

Compression and Recovery

Compression Lbs./Sq. Ft.	Per Cent Decrease in Thickness Under Load	Per Cent Decrease in Thickness Immediately after Removal of Load	Per Cent Decrease in Thickness 16 Hours after Removal of Load
5	5.0	2.0	1.0
10	9.0	4.0	1.5
25	18.0	8.0	3.0
50	30.5	11.0	5.0
100	43.0	15.0	6.0

Thermal conductivity vs. mean temperature of a Micro-Quartz blanket with a bulk density of 3 lbs./cu. ft.



Micro-Quartz is resilient

Since thermal resistance is proportional to thickness, good recovery of Micro-Quartz after compression under service conditions, as shown above, is highly significant.

Micro-Quartz has high resistance to vibration

Under actual test conditions, vibrating a pipe insulated with Micro-Quartz for 48 hours at 100 cycles per second and an amplitude of 0.02 inch, the average increase in thermal conductivity was *only about 1.5 per cent*. This figure is well within the limits of a reasonable test error, and indicates little or no change in efficiency as a result of the vibration exposure.

Micro-Quartz is exceptionally efficient

Note the flatness of the curve and also that it is substantially a straight line. Both facts indicate remarkable performance for a material of only 3-lb. density. The insulation efficiency of Micro-Quartz is exceptional for a material so light.

Micro-Quartz has high resistance to air flow

Resistance to air flow for the standard thickness of 3/16 inches is 3 inches H_2O at a flow rate of 30 feet per minute. This indicates the integrity of the material and helps explain the efficiency of Micro-Quartz in resisting the transmission of heat.

Requests on your business letterhead for more information and a Micro-Quartz sample will receive prompt attention. Write: *L·O·F Glass Fibers Company, Dept. 3-125, 1810 Madison Avenue, Toledo 1, Ohio.*

L·O·F GLASS FIBERS
Micro-Quartz
HIGH TEMPERATURE INSULATION

L·O·F GLASS FIBERS COMPANY

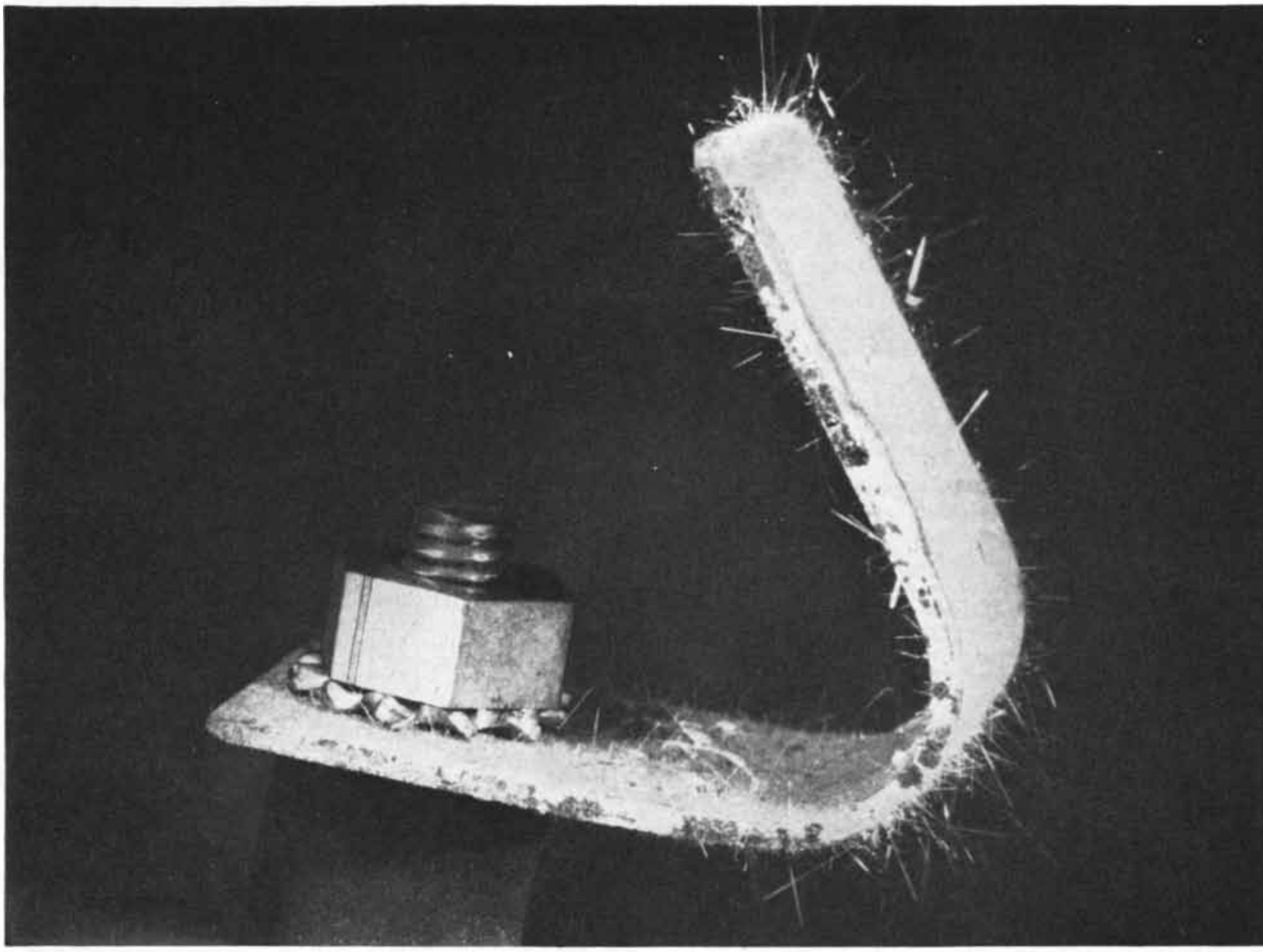
TOLEDO 1, OHIO

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

DECEMBER, 1905: "The report of the Board of Consulting Engineers, appointed by the President to determine what is the best type of canal to construct at the Isthmus of Panama, has not yet been made public, and cannot be for some time to come, at least in its entirety; and at the present writing nothing is certainly known beyond the bare fact that the decision, by a majority of eight to five, will be given in favor of a sea-level canal. Speaking broadly, however, and without any reference to the pending report, we would suggest that in all the long discussion which will follow its publication, whether in Congress, by the daily press, by the technical journals, or even upon the lecture platform it would be well to bear in mind the classic saying of Augustus Caesar, '*Festina lente*' ('Make haste slowly'). Let the nation remember that, although the extra one hundred millions of dollars and the few extra years of time that a sea-level canal may cost, may seem large in our day and generation—ten, fifty, one hundred years hence, this little question of time and cost will be forgotten by a posterity that is reaping the inestimable benefit of an unhindered waterway from ocean to ocean."

"When the history of the development of the marine turbine comes to be written, that period of it which deals with the application of the turbine to the transatlantic steamship must ever be closely associated with the name of the Cunard Company, which was the first seriously to consider the application of the turbine to the transatlantic steamship. The *Caronia*, driven by reciprocating engines, and its duplicate the *Carmania*, driven by turbines, have both been completed and are now sailing in the regular service of the company, the *Carmania* having just made her first successful trip to the port of New York. The two ships are sister vessels in every respect but that of the engines; they have been built by the same firm; they will sail over the same route, and, therefore,



Whiskers on tin-plated steel, enlarged 6 times. Immense yield strength of metals in whisker form was discovered by Bell scientists.

The clue of the metal whiskers

The habit of close observation at Bell Laboratories often turns "tremendous trifles" into important scientific progress. Such a case occurred when unexplained short circuits in wave filters seemed to be associated with a zinc-plated mounting bracket.

Close scrutiny disclosed a whiskery growth on the zinc plating. Similar whiskers of tin were found growing on tin-plated equipment. Studies showed the whiskers to be tiny single crystals of metal.

Suspecting that these unusual crystals might be of essentially perfect structure, alert Laboratories scientists saw an opportunity at last to test an important metallurgical theory.

The scientists studied the whiskers, grew larger ones, and showed that the crystals had enormously high yield strength as predicted by the theory for perfect crystals—a strength far greater than for the same metal in any other known form. This clue has opened new frontiers in the study of what makes metals strong or weak, and has excited metallurgists all over the world.

Thus, another new advance has come out of the Bell Telephone Laboratories practice of scrutinizing *everything* that can play a part in better telephone service.

Through the study of thousands of specially cultivated whiskers, Bell scientists seek to prevent treacherous growths in telephone equipment.

BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS under the same average weather conditions. Hence they afford an ideal opportunity for testing the relative first cost, cost of operation, and all-around usefulness of the reciprocating engine and the turbine in work of this character. At the present writing, it is sufficient to say that so far as the trial trips and the maiden voyage of the *Carmania* are a criterion, the application of the turbine to an ocean liner of the largest size has been a brilliant success, and thereby the last doubt as to the ability of the steam turbine to supersede the reciprocating engine in practically every class of marine service, from the torpedo boat up to the 40,000-ton high-speed ocean steamer, is completely set at rest. As regards the question of speed, the *Caronia* on her trial maintained an average speed of 19.5 knots an hour, with 22,000 indicated horse-power, whereas the *Carmania* showed an average speed of 20.5 knots per hour, for which the equivalent horse-power would be 25,500. The *Carmania* had not been in dry dock for eight months, and her bottom was necessarily foul. With a clean bottom, it is reasonable to suppose that she would have made fully 21 knots an hour."

"The Nobel prizes were distributed on December 10 by King Oscar of Sweden. The recipients were: In physics, Prof. Philipp Lenard, of Kiel University, for researches into cathode rays; in chemistry, Adolf von Baeyer, professor at the University of Munich, for researches relating to the evolution of organic chemistry and the development of the chemical industry; in medicine, Prof. Robert Koch, of Berlin, for researches looking to the prevention of tuberculosis."

"Continued prosperity in the United States is having a marked effect on immigration. For the year ending June 30, 1905, the total was 1,027,421—the first year in which a full million was exceeded."

"Sir William Ramsay and Frederick Soddy have proved that radium, in the course of its disintegration, gives rise to helium, the latter being expelled as a gas, and probably made up of the alpha particles expelled from the radioactive substance. A. Debierne now shows that actinium also produces helium in the course of its disintegration. The gas is found in the mixture of hydrogen, oxygen, and other gases resulting from the decomposition of the water in the salt. The same helium spectrum is ob-

Rare Earths by Ion Exchange

a new system which produces "rare" rare earths
in purities up to 99.99% for research and industrial use

a report by LINDSAY

TALK about excitement! Here at Lindsay we're as thrilled as a kid with a new toy—our new ion exchange unit is a big success and already the talk of the industry.

What's it all about? Well, the "rare" rare earths, as you know, are so identical in their atomic structure that separation by the common fractional crystallization method is impractical for most of them. Yet there has been an increasing number of inquiries from scientists throughout the country for the salts of some of these rare earths in quantities and purities not available commercially.

Fortunately, two gifted gentlemen, Drs. Spedding and Powell of the Ames Institute for Atomic Research, had developed a process for the separation of rare earths by ion exchange. Their pilot plant work demonstrated that highly pure rare earth salts could be produced in commercial quantities.

So this was the solution to our problem! In August we installed a battery of ion exchange columns in our West Chicago plant. The results were spectacular. We have successfully separated commercial quantities of these highly gregarious elements: samarium, europium, gadolinium, terbium, dysprosium, erbium, thulium, ytterbium, yttrium, lutetium and holmium.

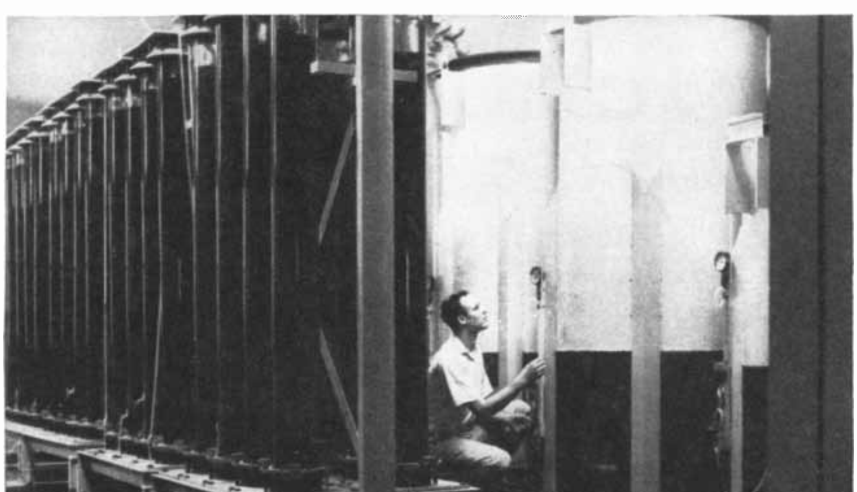
Our first ion exchange unit has been operating at capacity since the installation, and we are now adding a second unit.

Lindsay's ion exchange process works like this. Monazite ore tailings are dissolved in nitric acid and are then treated with oxalic acid to remove impurities. The rare earths are precipitated out as oxalates which are ignited to trivalent oxides. These oxides, dissolved in hydrochloric acid, become a "charge" for the ion exchange column which contains a bed of synthetic resin (sulfonated styrene-divinylbenzene copolymer). Positive ions on the active points of the resin are exchanged for ionized rare earth atoms which are held by the resin and become concentrated near the top of the column.

Separation occurs through elution with an ammonium salt of ethylenediaminetetracetic acid. The least strongly held rare earth is released first and emerges alone at the bottom of the column completely separated from the others and in highly pure form. It is followed by the next strongly held and so on.

We are proud of this addition to our production facilities which marks a milestone of progress for us, for science, and for industry. We feel sure that these highly pure rare earths, now available from our ion exchange production will have significant effect on the improvement of many industrial processes and the advancement of scientific knowledge.

If you are interested in any of these elements for research or industrial use, we suggest that you tell us of your requirements. In the meantime, we are continuing our regular production of other rare earth and thorium chemicals.



Portion of Lindsay's Ion Exchange Plant

LINDSAY CHEMICAL COMPANY
FOUNDED 1902
264 ANN ST., WEST CHICAGO, ILLINOIS

tained with radium salts and actinium salts. When special provision is made for the elimination of radium, the results from actinium salts remain the same."

DECEMBER, 1855: "It is more than twenty-five years since Pennsylvania coal began to be a recognised article of production and commerce. This year the product will amount to no less than six millions of tuns. This, as delivered at the mines, is worth at least twelve millions of dollars—so that this great sum may be regarded as the amount of solid wealth dug annually at the present time, from the bowels of the earth."

"As the remains of tropical animals are found in England, and other countries nearer the arctic regions, some philosophers have concluded that there must be a slow motion of different portions of the earth towards the north, and that England was, at one time, situated in the tropical regions, and will, in the course of ages, be covered with perpetual snows, and lie under the dayless gloom of the Arctic Circle. Another class of philosophers—the plutonists—entertain the idea that the earth was once a mass of molten fire, and having afterwards cooled slowly, the internal heat given out at one period gave a tropical temperature to the present arctic regions, thus enabling tropical animals to flourish there. The advocates of the plutonic theory have been very cautious in fixing the time when the earth was in its intensely heated state, but the 'pole-changers'—those who advocate the different theory described—have not shown so much prudence. At the late meeting of the British scientific association, Evan Hopkins, author of a work on geology, and a believer in the change of the earth's polar position, expressed his opinion in a paper on the geological changes of the earth that about 9,000 years since England basked under a tropical sun and was now slowly drifting up to the North Pole. Mr. Hopkins should have been more cautious; he ought to have placed the period of change 1,000,000 instead of 9,000 years, and then, in all likelihood, he would have acquired a very high reputation for profound investigation and observation. There is nothing like a little obscurity in treating such subjects; most of the philosophical theorists know this."

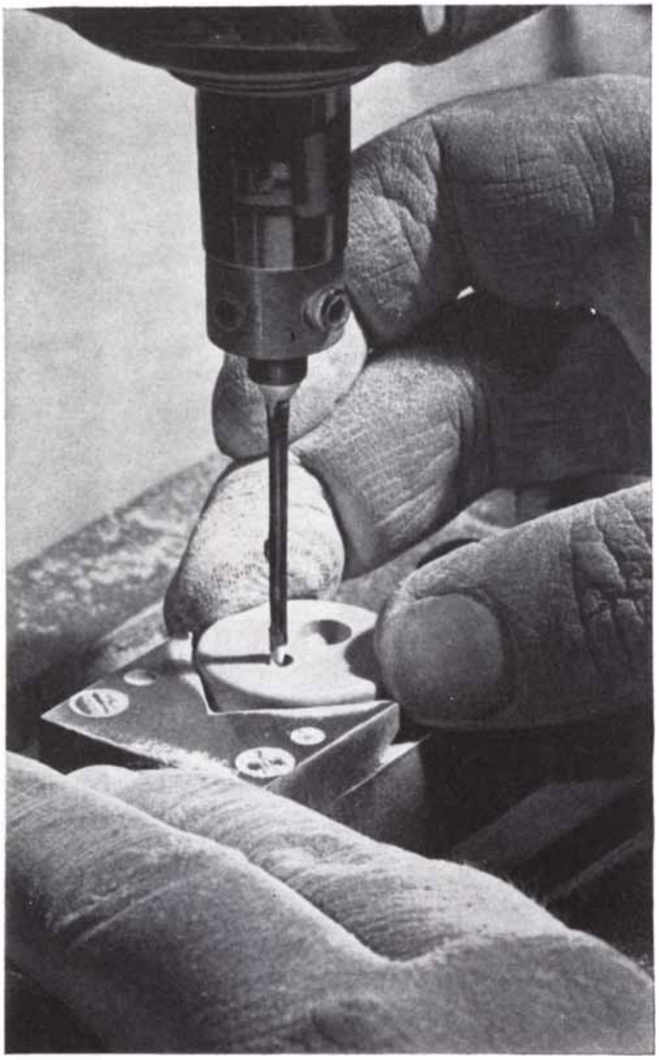
Life on the Chemical Newsfront

DO-IT-YOURSELF ENTHUSIASTS will get a helping hand with home painting from new line of ACCOSPERSE* Pigment Dispersions for rubber-base paints. These pigment dispersions mix easily, with no milling, into latex paints without streaking or specking. They have high color concentration, ideal consistency, wide compatibility with alkaline emulsions and excellent storage stability. Intermixing will provide an almost limitless array of beautiful shades and tints that are free flowing and non-streaking. **(Pigments Division)**

Chemistry comes to the aid of the retailer

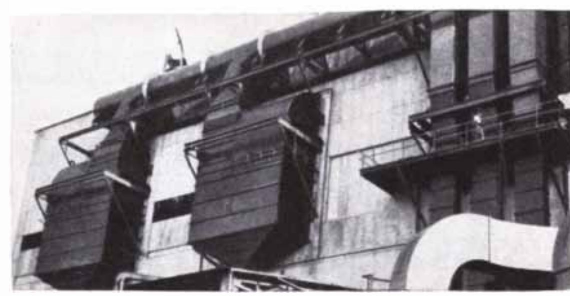
NEW IDEA: protecting merchandise from sun-fading by coating store windows with a film containing U. V. Absorber 9! Transparent to visible light, U. V. Absorber 9 soaks up ultraviolet light and changes it to harmless infrared radiation. Research in suitable film formulations has produced a number that the New Product Development Department is prepared to recommend to interested manufacturers. Other applications of this remarkable product include polyester resins, surface coatings and dyes. **(New Product Development Department, Section A)**

WHITE FABRICS ACQUIRE STRONG SALES APPEAL at the counter through the brilliant whiteness imparted by Cyanamid's CALCOFLUOR* White ST. Applied by the fabric finisher, this whitening agent possesses outstanding ability to absorb ultraviolet light, which is re-emitted as visible light to make the fabric much brighter to the eye. It was developed to give white and pastel fabrics the clear, clean brilliance that makes them stand out on sales counters. Mills are invited to send a swatch of their own fabric for comparison treatment. **(Organic Chemicals Division)**



NEW PRECISION PRODUCTION PROCESSES in ceramic manufacture, like the grinding operation illustrated, require use of binders that give high green strength to unfired pieces. The binder also should give good lubricating properties for easy mold release and internal plasticity so that complex shapes can readily be formed. Binders also must disperse thoroughly in the mixing operation and must volatilize completely on firing. In recent evaluations, HYFORM® Emulsions have proved outstanding in these essential characteristics. **(Industrial Chemicals Division, Dept. A)**

MEDICINE THAT'S EASY TO TAKE. An improved, recently announced ACHROMYCIN® Tetracycline dosage form is cherry-flavored liquid Pediatric Drops, which doctors may prescribe for their little patients to take "straight" from the dropper or mixed with milk, water or fruit juices. **(Lederle Laboratories Division)**



IN THE NEW OXYGEN STEELMAKING PROCESS, pure oxygen is blown against the surface of a molten iron bath. This violent oxydizing reaction removes impurities from the iron in the production of high-grade steel. A Pease-Anthony Venturi Scrubber is employed to prevent air pollution on the first of these operations installed on the North American Continent. This highly efficient scrubber, which removes some 30 tons per day of sub-micron iron oxide from exhaust gases, is marketed by a Cyanamid subsidiary, Chemical Construction Corp.

®Trade-mark

Additional information may be obtained regarding these products by writing on your business letterhead to the Division of American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y., indicated in the captions.

AMERICAN *Cyanamid* COMPANY

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

"Only Chemistry Can Create So Many Things That Are New"

THE AUTHORS

HOMER E. NEWELL, JR. ("The Satellite Project") is a member of the group that is preparing the launching of artificial satellites for the U. S. National Committee for the International Geophysical Year. He was born in Massachusetts and took his bachelor's and master's degrees at Harvard University in 1936 and 1937. He then took a Ph.D. in mathematics at the University of Wisconsin and spent a few years teaching mathematics at the University of Maryland. In 1944 he joined the Naval Research Laboratories in Washington, where he is now head of the Rocket-Sonde Research Branch.

JACQUES MILLOT ("The Coelacanth") has been director of Madagascar's Institute of Scientific Research since it was founded in 1947. His education included two doctorates at the University of Paris, one in medicine (1922) and one in science (1926). He taught, successively, histology at the Medical School of the University of Paris, physiological anthropology at the Paris Institute of Ethnology, and animal biology at the Sorbonne. In 1943 he was appointed to the chair of comparative anatomy at the National Museum of Natural History in Paris. Since his arrival on Madagascar he has studied several curious primitives among the local animals, notably an archaic species of spider which has survived in the island's forests, and of course the coelacanth. As a hobby he collects books and manuscripts of literary and historical interest, "from Racine to Malraux." Millot forwarded the photograph shown below with the caption: *"Joie générale au laboratoire d'anatomie comparée du Muséum à l'arrivée des nouveaux coelacanthes"* ("General rejoicing at the laboratory of comparative anatomy of

Millot **(wearing muffler)** *examines fish*

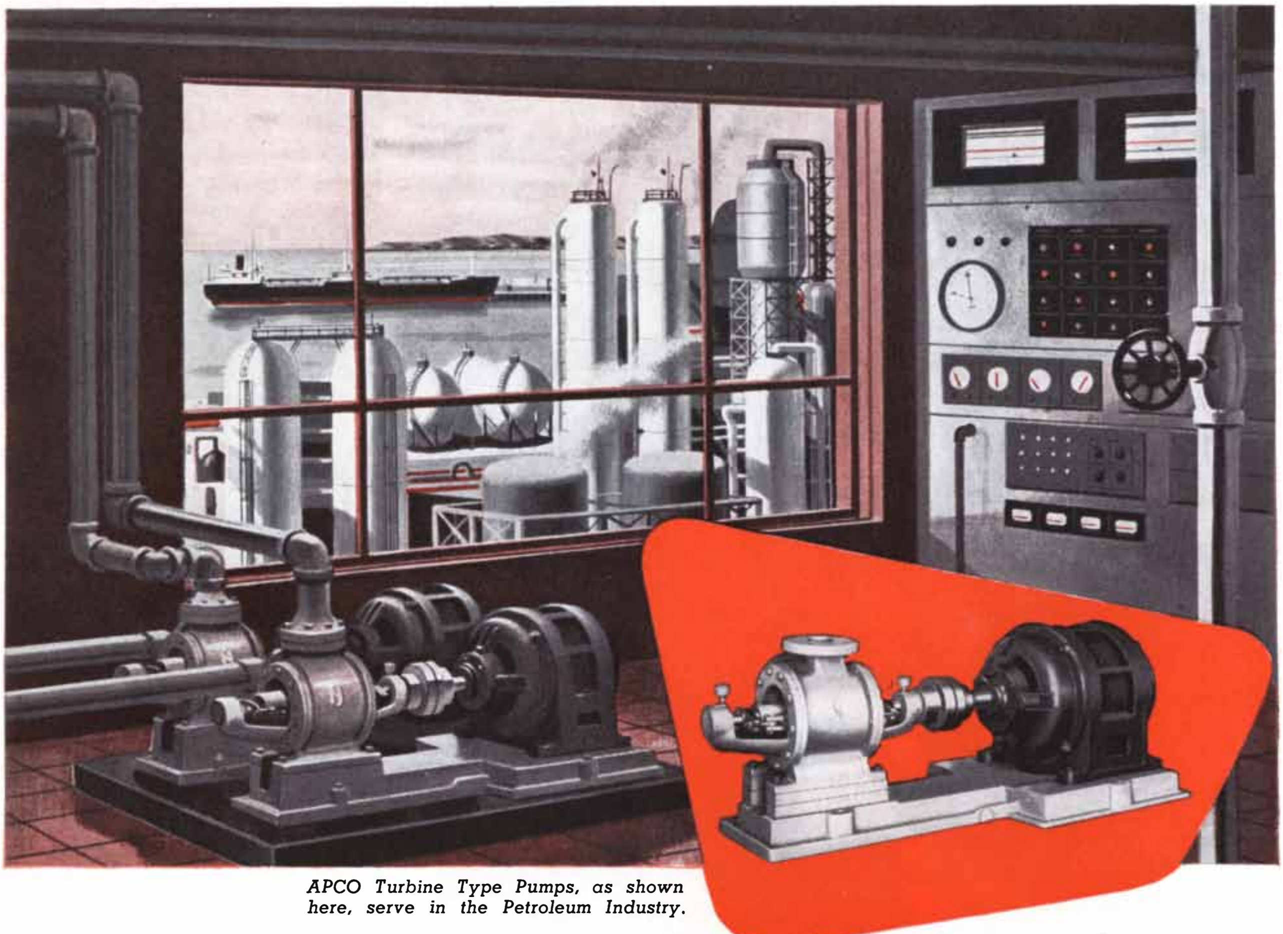
the Museum on the arrival of the new coelacanths"). The picture suggests low temperatures and high spirits.

THEODORE H. INGALLS ("The Strange Case of the Blind Babies") is associate professor of epidemiology at the Harvard School of Public Health. Born in Utica, N. Y., he graduated from Hamilton College in 1929 and took his M.D. at Harvard in 1933. He then trained in Boston at the Peter Bent Brigham Hospital and at Children's Hospital. From 1938 to 1940 he was a research fellow at Massachusetts General Hospital, where he studied bone growth. He entered the Army Medical Corps in 1942. His war experience, he says, prompted him to switch from medicine to preventive medicine. Since then his specialty has been the study of congenital anomalies, about one of which he has written for SCIENTIFIC AMERICAN ("Mongolism;" February, 1952). He combines experimental studies on small animals in the laboratory with clinical observations of human cases, concentrating on stresses upon the pregnant mother and the embryo between fertilization and birth. Ingalls is an associate editor of *The New England Journal of Medicine*.

GEORGE W. GRAY ("Life at High Altitudes"), is a member of the staff of the Rockefeller Foundation. Of his many articles for SCIENTIFIC AMERICAN, the most recent, "Unknown Viruses," appeared in the March issue. The visit to Peru referred to in the present article was part of a tour he made in August, 1953, of a number of research centers in various parts of South America.

I. BERNARD COHEN ("Isaac Newton") is associate professor of the history of science and of general education at Harvard University. A frequent contributor to SCIENTIFIC AMERICAN, he wrote the article "An Interview with Einstein" published in the July issue. Cohen is the editor of *Isis*, the history of science journal. He recently completed a study of Newton's scientific thought and of the tradition it established. It will be published by the American Philosophical Society.

VICTOR F. WEISSKOPF AND E. P. ROSENBAUM ("A Model of the Nucleus") are, respectively, a theoretical physicist and a science editor. Weisskopf, who was born in Vienna, studied with Wolfgang Pauli in Zürich and with James Franck and Max Born at the University of Göttingen, where he took his



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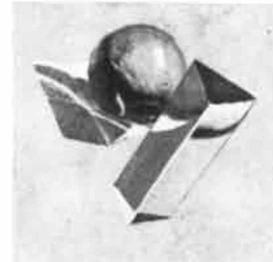
Ph.D. in physics in 1931. He spent the middle 1930s in research in Europe, notably at the Universities of Copenhagen and Cambridge. At Copenhagen he studied with Niels Bohr. On his arrival in the U. S. in 1937 he first taught at the University of Rochester. From 1943 to 1947 he was a theoretical physicist at the Los Alamos Scientific Laboratory. He was appointed professor of physics at the Massachusetts Institute of Technology in 1945. Rosenbaum is a member of the board of editors of SCIENTIFIC AMERICAN. He was born in New Haven, Conn., in 1916, attended both Harvard and Yale as an undergraduate and graduated from Yale in 1937. He then taught mathematics and physics at the Milford School, a preparatory school in Connecticut. During World War II, as a captain in the Air Force, he served at Wright Field as project engineer on the first Air Force radar-directed guided missile. After the war he returned to teaching and administrative work at the Milford School, but then turned to writing, principally for radio and television. He joined the staff of SCIENTIFIC AMERICAN in 1952.

ROBERT L. STRECKER ("Populations of House Mice") is assistant professor of zoology at Miami University in Ohio. He was born 30 years ago in Marietta, Ohio, and attended Marietta College. He writes: "My only productive research work so far, other than the house mice, was a summer spent in Alaska on an Air Force grant to Peter Morrison at the University of Wisconsin. I was a member of the research group, and we were primarily interested in obtaining Alaskan mammals and studying their resistance to cold." Strecker took his M.A. and Ph.D. in 1947 and 1951 at the University of Wisconsin. He has made a hobby of collecting mousetraps. "Maybe," he suggests, "I can get some contributions from your readers."

GORDON RAISBECK ("The Solar Battery") is a member of the technical staff of the Bell Telephone Laboratories at Murray Hill, N. J. He took his B.A. at Stanford University in 1944, then attended Oxford University as a Rhodes Scholar. For two years during World War II he served as a radio technical officer in the Navy, studying radar wave propagation at the Naval Research Laboratory. In 1949 he received a Ph.D. in mathematics from the Massachusetts Institute of Technology. At the Bell Laboratories, where he has been ever since, he is in charge of a research group studying electrical conductors.



THE COVER

The painting on the cover symbolizes three of Isaac Newton's most notable scientific contributions (*see page 73*). On the scrap of paper is a sample of the notation he used in the differential calculus, which he described in his historic treatise the *Principia*. The dot above the letter *x* signifies that it is a differential, now commonly written *dx*. The apple, suggesting the incident that moved him to formulate the theory of gravity, is a variety that grew in England during Newton's lifetime. The prism and the spectrum it casts stand for his optical studies.

THE ILLUSTRATIONS

Cover painting by Stanley Meltzoff

Page	Source
18	Muséum National d'Histoire Naturelle
29	Naval Research Laboratory
30-33	Irving Geis
34	John Langley Howard
35	Courtesy Jacques Millot
36-37	John Langley Howard
38-39	Muséum National d'Histoire Naturelle (*left*); courtesy Jacques Millot (*right*)
41	Paul Weller
42-44	Bunji Tagawa
48	University of California
58	Cornell Capa, Magnum Photos, Inc.
60	Instituto de Biología Andina
61-66	Cornell Capa, Magnum Photos, Inc.
73-80	New York Public Library
84	Brookhaven National Laboratory
85-90	James Egleson
92-96	Eric Mose
102	Anthony Linck
103-106	James Egleson
108-110	Anthony Linck
113-120	Jerome Snyder
125	Eric V. Grave
126-130	Roger Hayward

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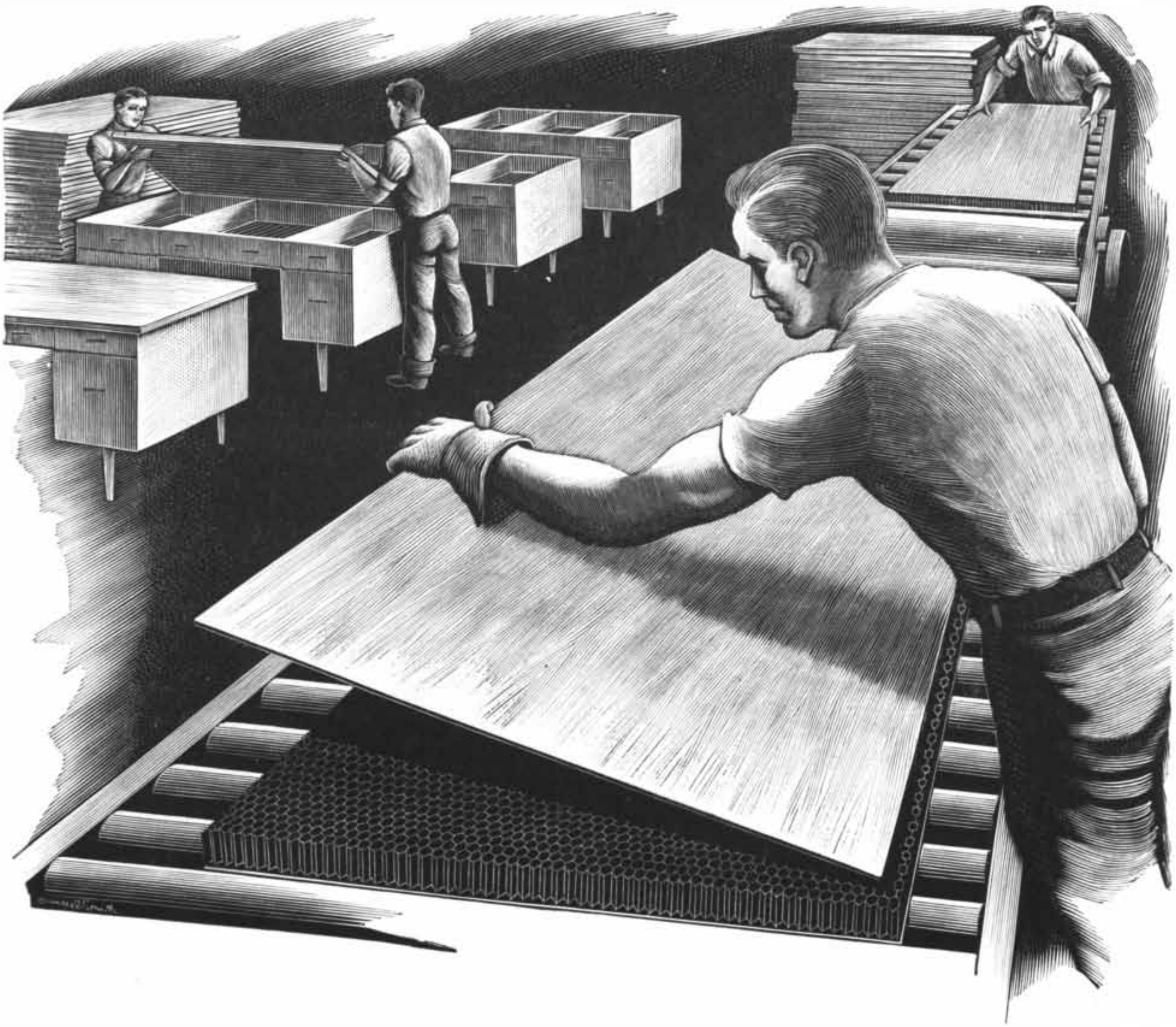
CONTENTS FOR DECEMBER, 1955 VOL. 193, NO. 6

ARTICLES

DEPARTMENTS



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DECEMBER, 1955 VOL. 193, NO. 6

The Satellite Project

Work has only started on specific designs for the artificial moons to be launched during the International Geophysical Year. Surveyed here are some of the possibilities and limitations to be considered

by Homer E. Newell, Jr.

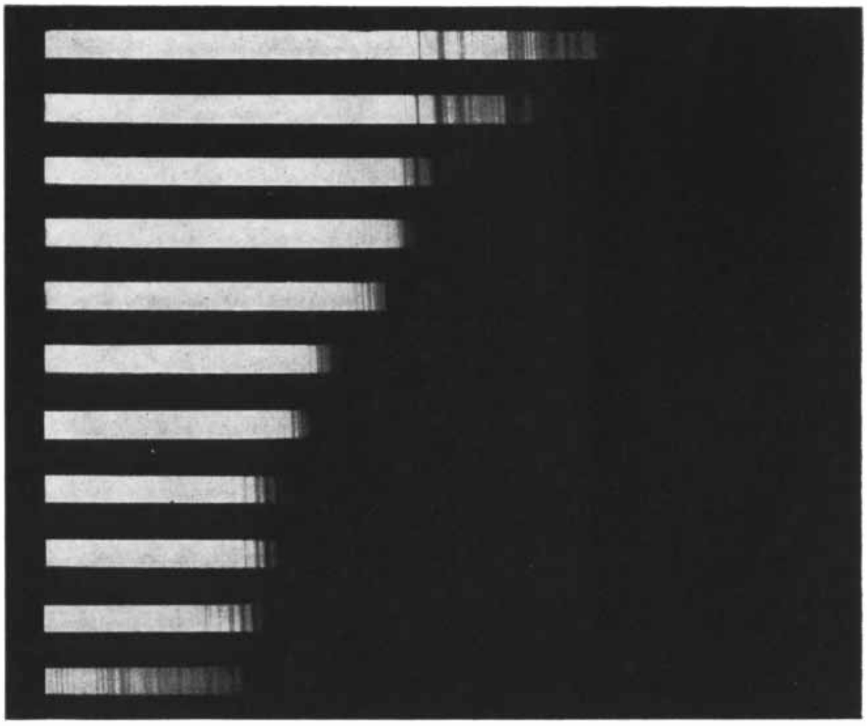
Some time in the next few years a new object will appear in the heavens. It will be quite inconspicuous: only an observer who knows exactly when and where to look for it will be able to see it at all. But as men lift their heads and, watching, catch a glimpse of this faint body racing across the sky, they will feel the excitement of witnessing a great historic event. For the tiny object circling the heavens will be metal that man has touched, a satellite that man has made and flung from the earth into space. It will be mankind's first feeler on the space frontier.

The man-made satellites that the U. S. is planning to launch for the International Geophysical Year (1957-58) are still, of course, only scribbles and sketches on pieces of paper. The design details have yet to be worked out. But there has been enough progress in rocketry in the last few years to make the experts of more than one nation confident that a target date can at last be set for achieving this project—a first step toward mankind's age-old dream of breaking the chains that bind him to the earth.

No specific details of the program for creating the artificial satellite have been announced. This article can, however, outline some of the problems facing the designers, as well as ways in which a satellite may be used to study our planet and outer space. It should be emphasized that the following is not a description of actual plans but simply a review of possibilities.

Exploration by rocket of our upper atmosphere and its borders has been going on for several years. During the International Geophysical Year the U. S. will fire hundreds of research rockets into the atmosphere, and other countries will do the same. But these vertical soundings give us only momentary and local glimpses of our air ocean and the space outside. For at least a decade scientists have been giving serious attention to the possibility of sending up an instrument-carrying platform which would revolve around the earth above the atmosphere and take continuous observations of cosmic rays, the sun's radiations and so on.

A satellite of this kind is truly called



SPECTRA made from an ascending Aerobee rocket show how the short-wave end of the spectrum is extended with altitude. The spectrum at bottom, made at a height of six miles, goes down to 3,300 Angstrom units. The spectrum at top, made at 40 miles, extends to 2,200.

an artificial moon. If it is traveling at the right speed to balance the earth's gravitational pull, it will follow a fixed orbit around the earth, as the natural moon does.

The first problem is to raise the satellite to a height where the drag of air will not slow it appreciably, so that it can maintain its orbiting speed for a considerable time. Eleanor Pressly of the Naval Research Laboratory has calculated that a satellite weighing two pounds per square foot of cross section would not girdle the earth even once if it started out with the circular velocity at an altitude of 100 miles. At 200 miles, it would fly around the earth for about 15 days before falling to the ground; at 300 miles the atmosphere is so thin that the satellite would stay aloft for almost a year.

This means the satellite must be shot to 200 miles or higher. Once there, it must be given a sideways shove to drive it in a circling orbit around the earth. How fast must it travel to stay in this orbit? At a velocity of seven miles per second the object would escape from the earth's gravitational pull and fly off into space. On the other hand, a velocity of, say, four miles per second would allow it to fall closer to the earth on the opposite side from the launching point, giving it an elliptical orbit which it could not maintain long. The speed required to keep it in a circular path around the earth is estimated to be about five miles per second.

The sideways shove must be not only at the correct velocity but also in a precisely horizontal direction. If the "bird" is not propelled exactly parallel to the earth's surface, it will again follow an elliptical instead of a circular orbit. Assuming the satellite were launched at five miles per second at an altitude of 200 miles, a deviation of only one and a half degrees from the true horizontal would cause the object to dip down to within 100 miles at the closest point (perigee) in its orbit. Such an error would greatly shorten the satellite's lifetime.

Besides being projected exactly on the horizontal, the satellite must be launched in a precisely calculated and controlled direction with respect to the equator or the poles, so that we may know its path around the globe and place observing stations accordingly. Here we run into the complications of the earth's rotation and its bulge at the equator (the radius of the globe being about 13 miles longer at the equator than at the poles).

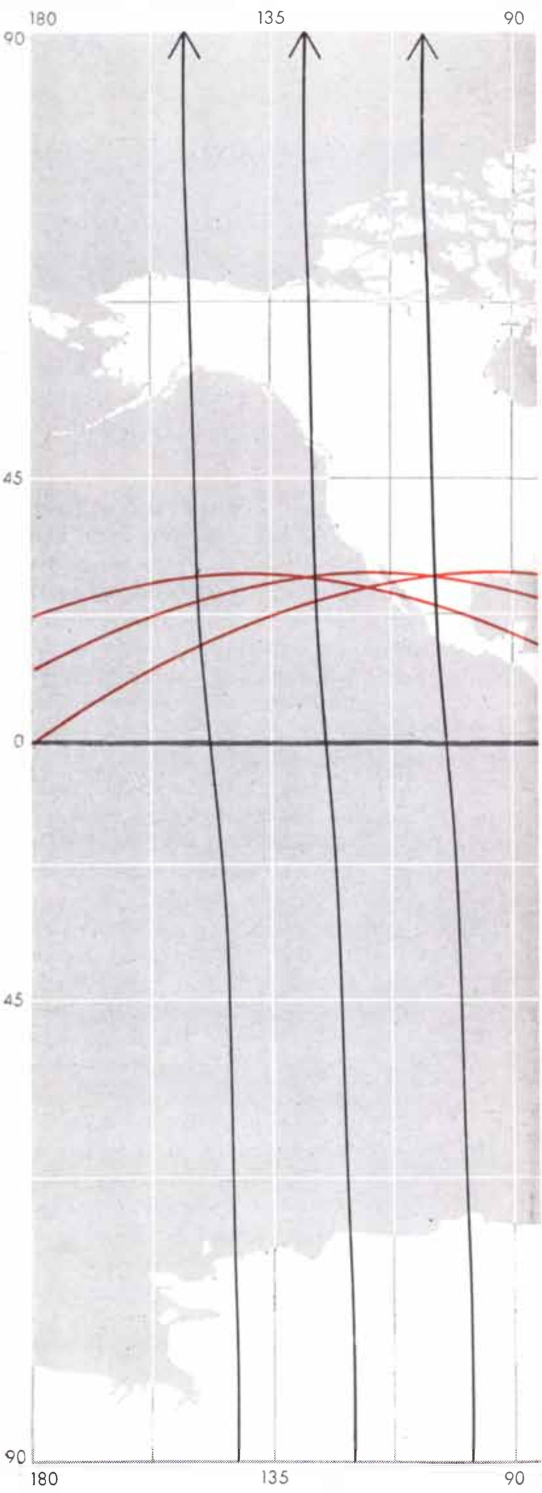
The earth's rotation will call for complicated calculations to plot the places from which the satellite can be seen in successive trips around the globe. If the bird is launched to fly straight around the equator, it can be followed by stations along this line, and the only problem will be to compute how the earth's rotation will affect its time of arrival over each station. But if its orbit is at an angle to the equator, its path will wind in a kind of sine curve back and forth across the equator, and the crossing points will change from one trip to the next because of the earth's spin [*see map on these two pages*]. The satellite's flight will also be influenced by the equatorial bulge, for the excess mass will speed it up and shift its path slightly as the object comes close to the equator. Finally, if the orbit circles the earth in the pole-to-pole direction, the satellite's path will spiral around the spinning globe in a most complicated fashion; the only points at which it will pass overhead on every trip will be the poles themselves.

For different purposes, all three of these kinds of orbits—equatorial, polar and intermediate—will be wanted. To follow the satellite it will be necessary to track it with instruments as soon as it is launched and to plot its expected path quickly by means of computers. An unobserved satellite would be quite useless. Keeping track of the satellites that are launched will require cooperative work by observers in various countries around the globe.

What sort of object will the satellite be? It need not be very large to be useful. A sphere only 20 inches in diameter, it is calculated, would be visible even to the naked eye near the horizon shortly before sunrise or after sunset if it were at an altitude of 300 miles, provided it had a good reflecting surface. The satellite's shell may be aluminum, thin stainless steel, plastics coated with a reflecting surface or almost any other light, strong material. Its shape, except for measurements of air density, will be immaterial; it may be rocket-shaped, to fit into the launching rocket, rather than spherical.

Even a hollow shell carrying no instruments whatever would be useful: as a near moon it might be helpful in mapping and measuring distances on the earth; it might be used to indicate the density of the high atmosphere, and so on. But it is hoped that even the first satellites will be "active," that is, will carry some instruments. A satellite weighing only 20 to 30 pounds could pack some important items of equipment. From the standpoint of the information wanted, probably the most essential items are Geiger counters and instruments for detecting or measuring light radiations, magnetic fields and meteorites, as well as amplifiers and radio transmitters to relay the information to the ground.

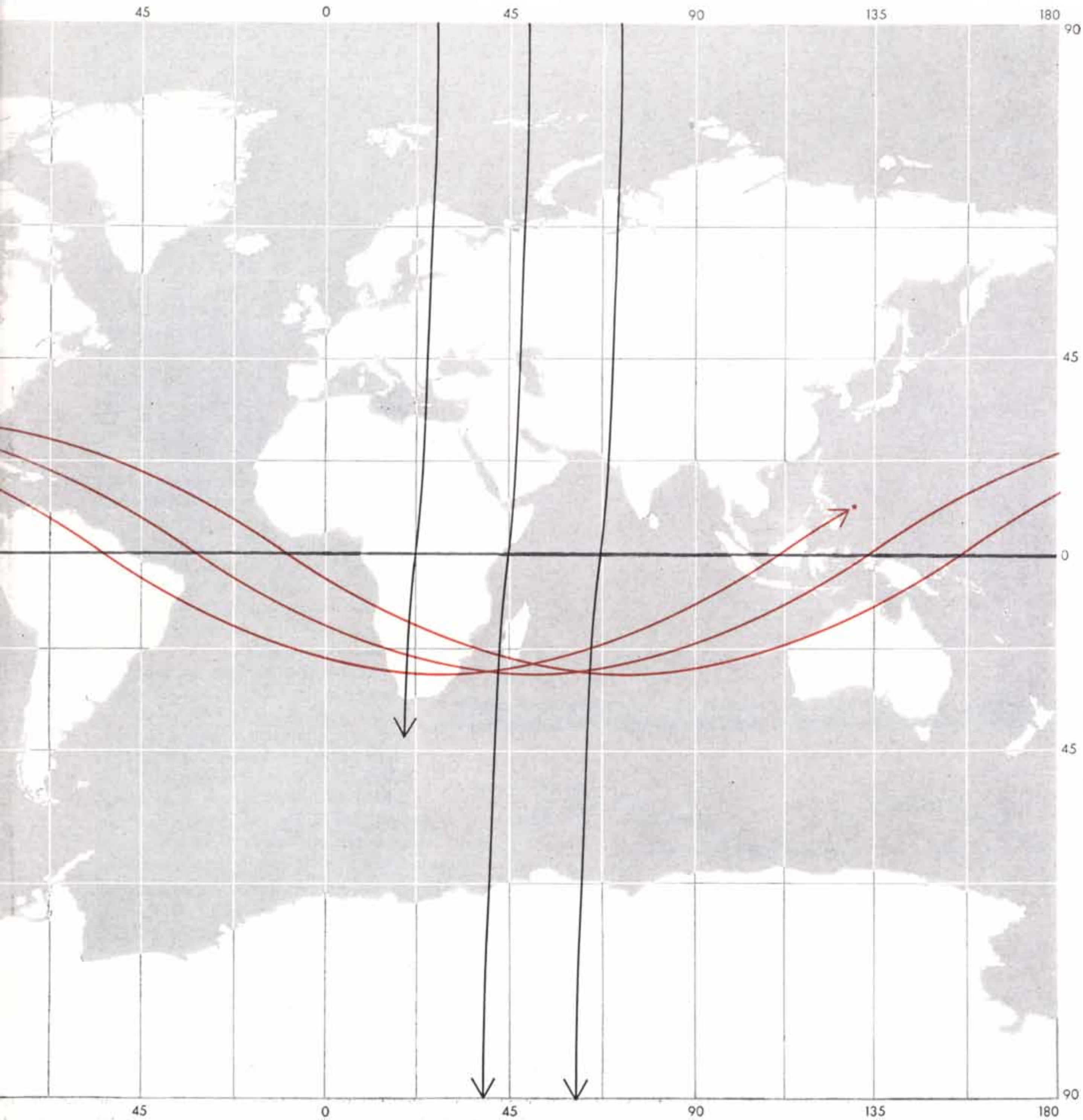
All this will call for a power supply. A small bird probably will be able to carry batteries providing a total of 500



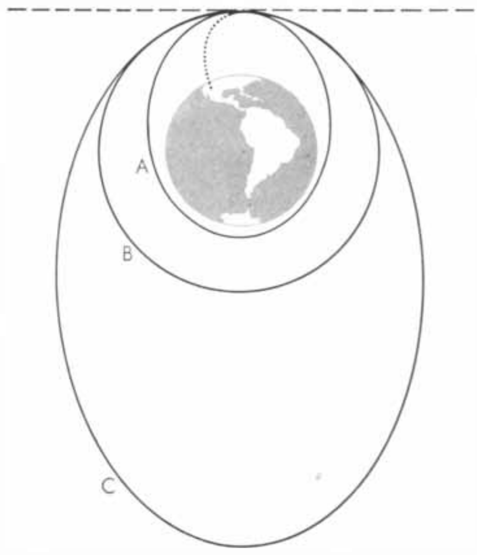
THE SATELLITE'S PATH over the earth will depend on the direction of its orbit.

watt-hours of energy. To conserve the energy, it will be desirable to find ways to turn the instruments on and off by radio from the ground. Eventually devices drawing energy from sunlight, such as the solar battery [*see article on page 102*], may power the vehicles, but it does not appear that we can count on them for the International Geophysical Year. And it is certain that the first satellites will not be able to carry equipment such as telescopes, television or cameras. Aside from the weight question, the problem of getting the satellites back to earth safely, finding them and recovering their film is too formidable at this time.

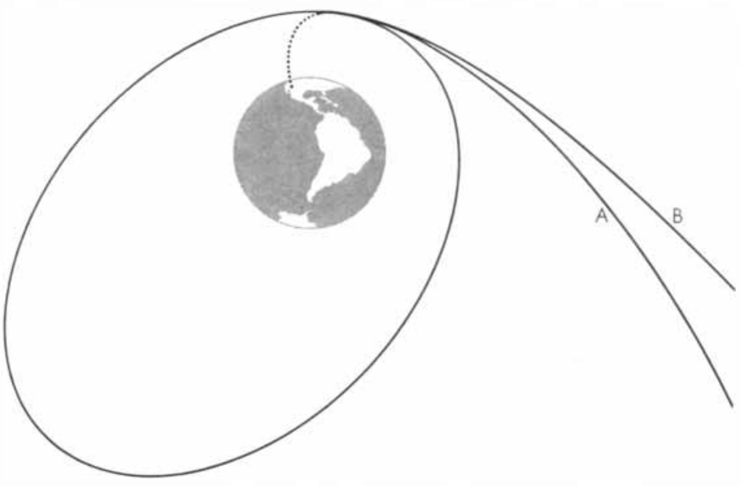
The possible uses of a satellite as a platform for scientific research are limited only by the imagination. Besides the geodetic and air-density measurements already mentioned, a small bird could investigate cosmic rays, the earth's magnetic field, ultraviolet light and X-rays from the sun, the electrification of the upper atmosphere, the bombardment of the earth by meteorites and other particles and even the contents of "empty" space just beyond the borders of our atmosphere. Of course these observa-



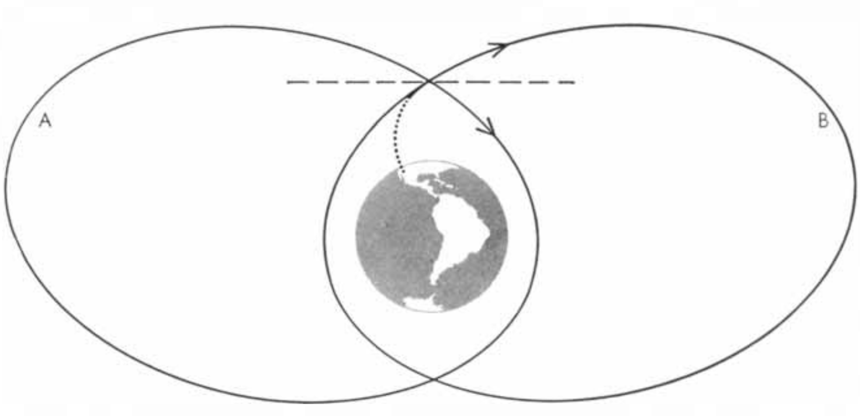
The gray line shows the simple path that would be traced by a vehicle launched along the equator. The colored curves show the course for an orbit that makes a small angle with the equator. The black lines give the spiral path of a satellite in a polar orbit.



SATELLITE ORBIT for a horizontal launching will be a circle (B) if launching speed is about five miles per second. Ellipse A will result from lower speeds and C from higher.



ESCAPE PATH of a vehicle would be a parabola (A) if launching speed equaled escape velocity (seven miles per second). It would be a hyperbola (B) for greater speeds.



NON-HORIZONTAL LAUNCHING would give an elliptical orbit for any launching speed. If aimed down, a satellite would trace out an ellipse like A, if aimed up, an ellipse like B.

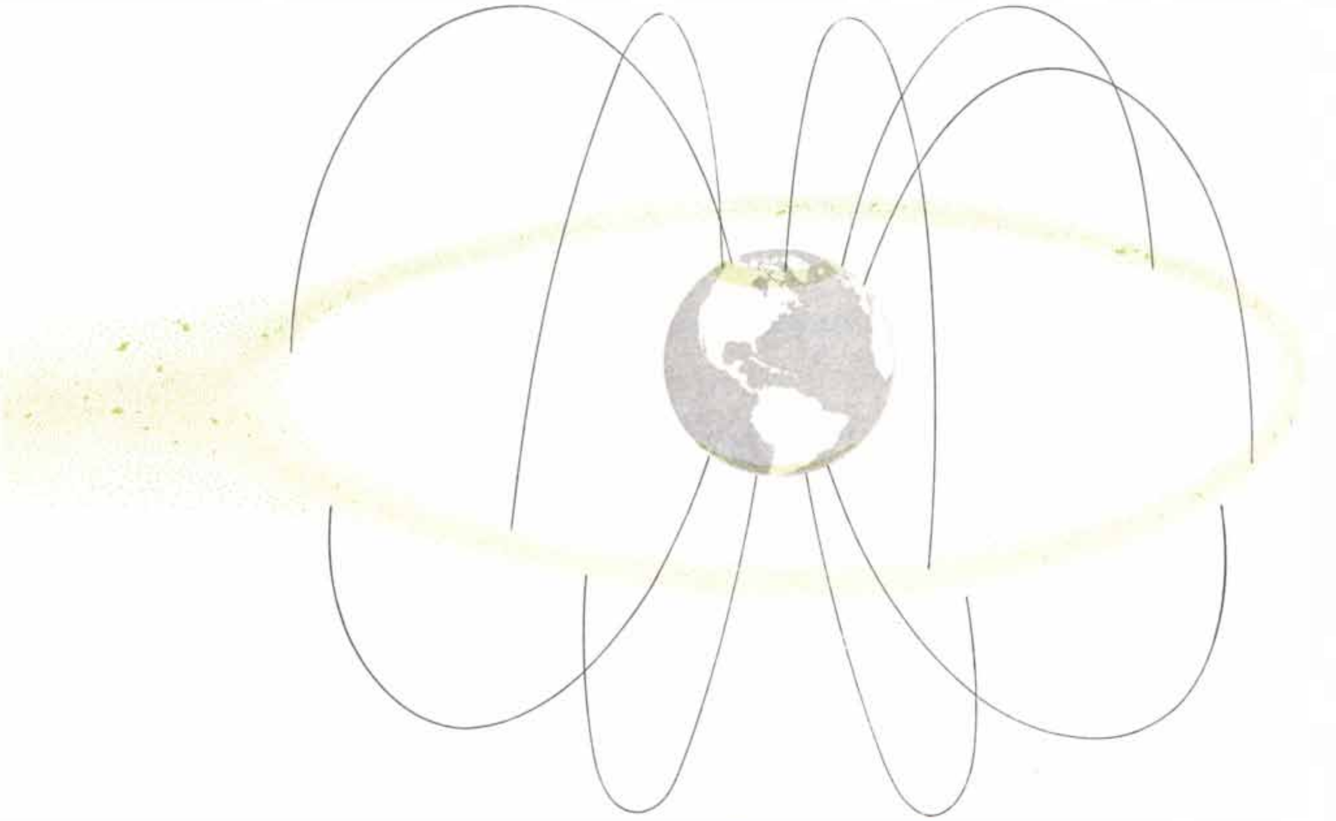
tions could not all be made simultaneously with a single satellite.

Cosmic rays, as is well known, are high-energy charged particles, ranging from protons (about 80 per cent) up to nuclei of fairly heavy atoms. Most of them penetrate into our atmosphere, but those of the very lowest energy do not. Consequently a satellite at 200 to 300 miles altitude, moving in a pole-to-pole orbit along the magnetic lines of force followed by the cosmic rays, would detect low-energy rays we cannot observe near the ground. It could also record fluctuations in intensity, sort out the cosmic particles into different energy groups and perhaps throw light on the mystery of their origin. From a practical point of view, cosmic rays interest the promoters of space flight as a potential hazard to passengers. Astrophysicists are coming to the belief that this hazard is not as serious as used to be thought, but it is certainly desirable to get more data for judging the danger.

What sunlight is composed of before it enters our screening atmosphere, how it affects the upper layers of air and through them the weather—these are matters of great interest about which a satellite vehicle could enlighten us. The ultraviolet and X-ray radiations of the sun are absorbed at high altitudes, and the absorption produces chemical activity, the ionosphere, heating and winds. Monitoring variations in the intensity of solar radiations which accompany sunspot activity and solar flares, a vehicle above the absorbing atmosphere could provide information which would relate these events to our weather, climate and radio communications.

Geophysicists just now are keenly interested in the effects of the ionosphere on the earth's magnetic field. An Aerobee rocket experiment recently detected a sheet of current flowing in the E layer about 60 miles up. Thousands of miles farther out is the Chapman-Størmer current ring—a ring of charged particles from the sun which is supposed to be formed by the earth's permanent magnetism and to encircle the earth around the equator. As the supply of particles from the sun varies, so does the effect of the ring upon the surface magnetic field. Also, one theory has it that particles spraying off from the Chapman-Størmer ring account for the auroras of the north and south.

J. P. Heppner of the Naval Research Laboratory has proposed a satellite experiment to determine the amount of current flow in the Chapman-Størmer ring. It would consist in making simultaneous measurements of the earth's



CHAPMAN-STORMER RING, indicated by the large stream of colored dots, is a current composed of charged particles from the sun. Auroras (*colored bands*) may be caused by particles traveling from the ring to the earth along paths like those shown in black.

magnetic field at the ground and 200 or 300 miles up in a satellite, using a recently developed lightweight magnetometer. From the difference in the field it should be possible to gauge the separate magnetic effects of the Chapman-Størmer ring and thus estimate its current.

For a long time now astrophysicists have been using the figure of one atom per cubic centimeter as the standard estimate of the density of matter in the "empty" space outside our atmosphere. The estimate is based on meager data, and to obtain more information H. Friedman and his NRL co-workers have proposed a most fascinating experiment. Excited hydrogen atoms emit radiation at a certain ultraviolet wavelength—1216 Angstroms. Friedman's group suggests that photon counters in a satellite vehicle could measure the intensity of this radiation both from the direction of the sun and from some other direction in space. The difference in the intensity curves might provide a means of determining the average density of hydrogen atoms and ions in space.

Tiny meteorites, specks of dust only a few thousandths of an inch in diameter, are constantly bombarding the earth's atmosphere. Estimates as to the amount of this material that falls on the earth's surface run as high as 1,000 tons per day. These micrometeorites, as they are called, are believed to contribute a small share of the ionization of the ionosphere. They undoubtedly come in at high speed, but they are soon slowed by collisions with air molecules and drift imperceptibly to the ground. A satellite above the atmosphere could record their first impact and count them by means of scintillation counters or electrical resistance plates.

The foregoing are some of the experiments that could be performed in the early satellite vehicles with techniques already available. They would not call for large vehicles or raise extremely difficult engineering or operational problems. Probably a satellite weighing only 20 to 30 pounds would suffice for these experiments.

Undoubtedly the first successful launching of a satellite will inspire immediate talk of manned space stations and manned space flight. But anyone confronted with the practical problems must consider these only possibilities of the distant future. We have already noted how difficult it is even to launch a tiny satellite in a predictable orbit. A manned vehicle would multiply all the problems by many orders of magnitude. Consider, for instance, the single matter of the working components of the ship. In an unmanned "bird" we can afford to be content with less than complete perfection; if any of the components fail to work or to last long, we can try again. But in a manned vehicle every component, and the system as a whole, will have to operate with perfect reliability throughout the flight. Similarly, the weight problem alone compounds the difficulties many times. To project a vehicle big enough to carry men and the equipment they need for survival will call for a propulsion system far more powerful and efficient than we need for the simple satellite experiment.

Meanwhile there is excitement enough in the project immediately at hand. The National Academy of Sciences is working on the scientific experiments to be made, and has called on the Department of Defense for support in the design and launching of the rocket vehicle. The scientists and engineers engaged in the project have good reason to hope that some kind of orbiting vehicle will appear in the heavens on schedule.

THE COELACANTH

There are now 11 specimens of this curious fish, which until 1938 was thought to have been extinct for 70 million years. They provide prime evidence on the evolution of land animals

by Jacques Millot

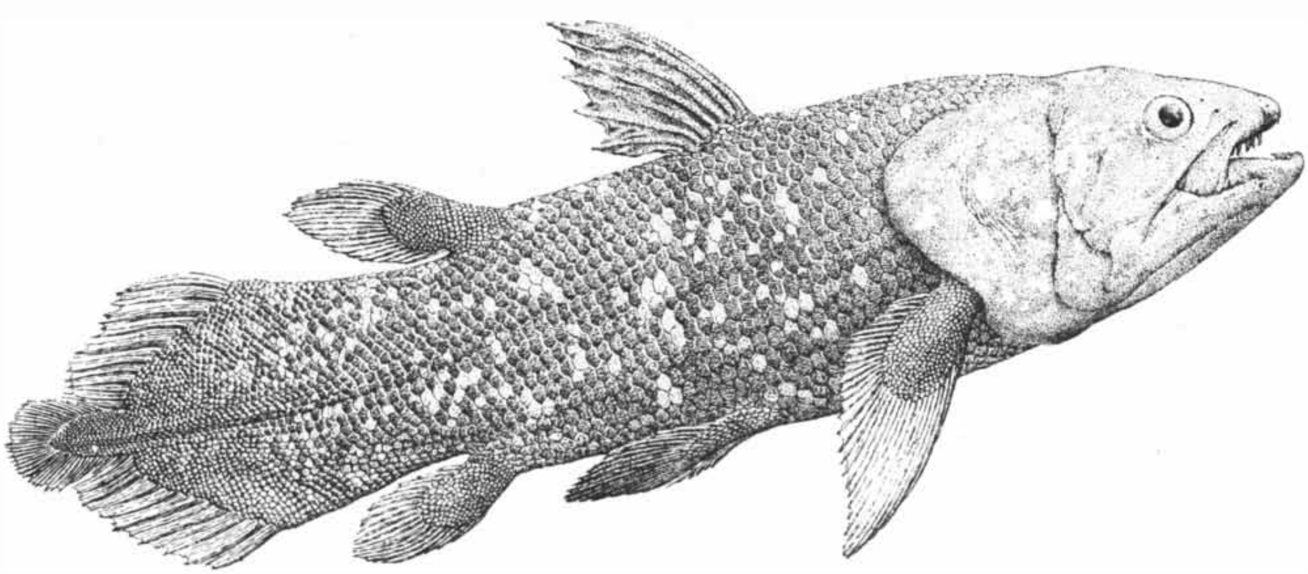
In 1938, off the east coast of South Africa near the mouth of the small Chalumna River, a fisherman brought up a strange fish. It came to the attention of the zoologist J. L. B. Smith, at Rhodes University College in Grahamstown, and he recognized the fish as an authentic coelacanth. The discovery revolutionized the zoological world. For the coelacanth was a member of a very ancient class of fishes which was supposed to have disappeared some 70 million years ago. This great group of fishes, called crossopterygians, flourished during that decisive era in the history of the earth when the first land animals evolved—when the fish, taking on legs and lungs, went forth to conquer the continents. The crossopterygians were distinguished by lobed fins which were the forerunners of the limbs of higher animals, and that fact alone makes them extraordinarily interesting.

The news that a representative of this supposedly extinct group was still in existence naturally created a great sensation everywhere. The coelacanth acquired a world-wide celebrity such as few animals have ever achieved. Zoologists became extremely eager to find other specimens in better condition, in order to investigate the anatomy and physiology of the fish. It was an unparalleled opportunity to study at first hand a living link from the ancient evolution of vertebrates.

For 14 years Smith and others searched without success in the Indian Ocean along the east coast of Africa. At last, in 1952, word came that a fisherman had pulled up a second coelacanth in the waters off Anjouan, an island in the French Comoro archipelago north of the Mozambique Channel. The South African Government provided Smith with an airplane to fetch it. Unfortunately this specimen was, like the preceding one, in such sad shape—mutilated and half decomposed—that no really useful study could be made of it.

The interested scientists decided that they must organize a methodical search, mobilizing all possible facilities to insure success. A system for catching, preserving and transporting the fish by air was therefore set up in the Comoro Islands by the Madagascar Institute of Scientific Research, aided by the local government. This organization has been rewarded by the capture of nine new coelacanths, all in good condition.

Thorough study of these fish is now in progress. Specialists of various countries



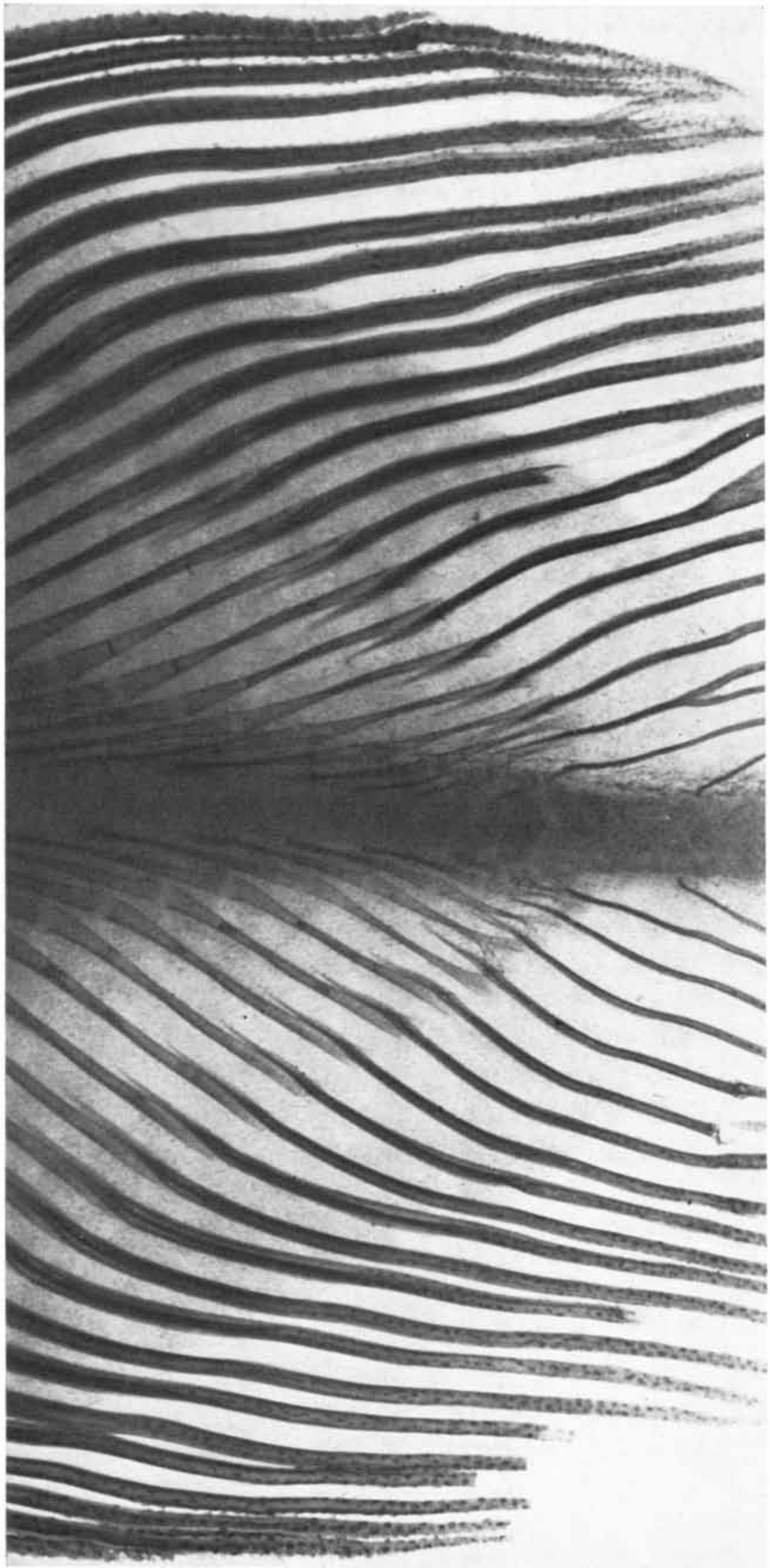
DRAWING of a coelacanth is based on specimens caught in the Comoro Islands. Its fins, with the exception of one on its back, are characteristically paddle-shaped. An adult coelacanth is between four and five-and-a-half feet long and weighs from 70 to 180 pounds.

are collaborating in a program which is centered in the laboratory of comparative anatomy of the National Museum of Natural History in Paris.

When I was a high-school student, we were taught that there were five major classes of vertebrates: the fishes, the amphibians, the reptiles, the birds and the mammals. This view is now out of date. The label "fish" covers a range of animals as diverse as those that live on land. For a zoologist the difference between, say, a lamprey and a carp is greater than between a frog and a man. It is more useful, therefore, to divide the vertebrates into two great groups: the fishes on the one hand and the "tetrapod" (four-limbed) animals of the land and air on the other. The fishes can be subdivided into four principal categories: the agnatha (without jaws), the placoderms (armored), the chondrichthyes (cartilaginous) and the osteichthyes (bony).

The agnatha were not only the earliest fishes but also the first vertebrates we know of. They sucked in food particles through round mouths. Lacking not only jaws but also paired fins, they probably swam clumsily, tadpole-fashion. In our time they are represented only by two degenerate descendants, the lampreys and the hagfishes, which lead a near-parasitic life [see "The Sea Lamprey," by Vernon C. Applegate and James W. Moffett; SCIENTIFIC AMERICAN, April]. At their apogee the agnatha apparently evolved into fish armored with bony plates. During the Devonian Period (some 400 million years ago), they gradually disappeared and were replaced by the placoderms, which retained the armor and acquired primitive jaws and paired fins. Then the placoderms in turn vanished as two new lines of fishes with jaws came into being—the cartilaginous and the bony fishes.

One of the great problems of evolution has been to find anatomical links between the fishes and their land-invading descendants, which emerged at the end of the Devonian epoch. Comparative anatomists have speculated for half a century on how the fin of the fish evolved into the forelimb of the frog, the forerunner of our own arm. It is hopeless to trace a connection if we look only at a modern fish. In the fish we know well—the goldfish of the aquarium, the trout of the dinner table—the fins are altogether different in structure and orientation from the limbs of a frog. For a long time evolutionists were troubled by this major gap between the fishes and the



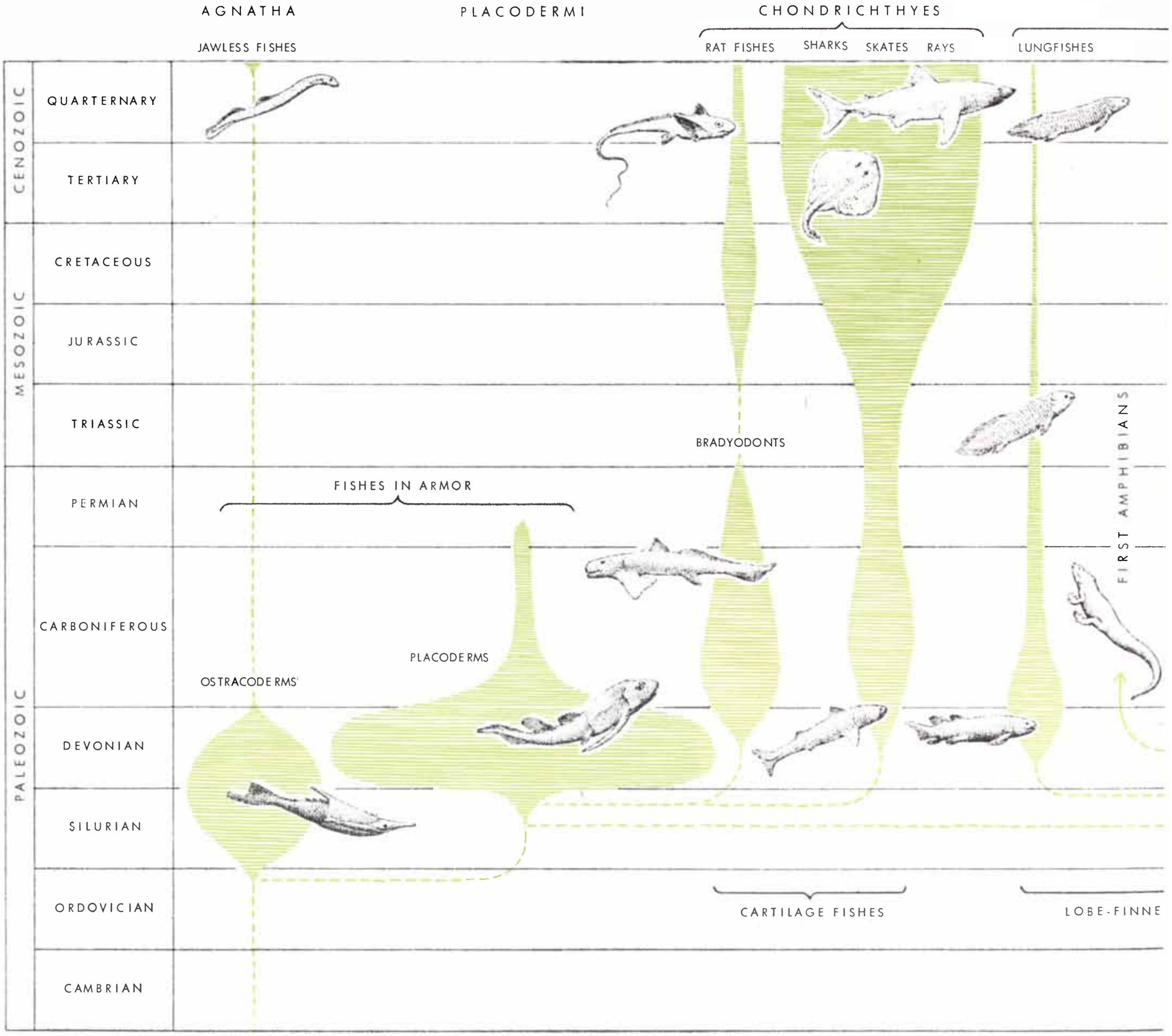
X-RAY PHOTOGRAPH represents a vertical section through the tail of a coelacanth. At the top and bottom are the fin rays. In the middle is a section of the fish's primitive spine.

amphibians. But the gap has now been bridged by studies of ancient fishes, and this is where the coelacanth comes in.

The fins of the crossopterygians are strikingly different from those of all other fishes. Instead of being attached to the main body directly, they are borne on a scaly stalk protruding from the body. The fin articulates through a single structure, just as the limbs of a tetrapod—toad, eagle, dog or man—hinge on a single bone, *e.g.*, the humerus of the arm and the femur of the leg. The fin of the crossopterygians can be thought of as a true little limb—the missing link between the typical fin of fishes and the limb of the other vertebrates. Furthermore, the skull of the crossopterygians is constructed along the same general lines as that of primitive amphibians. These striking resemblances have quite naturally led paleontologists to consider the crossopterygians as the pivotal group that brought forth amphibians and the land and air animals.

The crossopterygians are very ancient bony fishes which appeared some 400 million years ago at the start of the Devonian. They include two distinct lines of descent. One line is the coelacanths (whose name, from the Greek, means literally "hollow spine"). The other is called the rhipidistians.

It sometimes happens in a family that two brothers, while bearing a close resemblance to each other physically, have contrasting temperaments and aptitudes and lead quite divergent lives. The same sort of thing can be noted in the history of animal descents. The coelacanths and the rhipidistians offer a striking example. The rhipidistians were the bright boys of the crossopterygian family, resolutely turned toward progress. They foreshadowed the later vertebrates not only in their fins and skull structure but also in possessing internal nostrils—a develop-

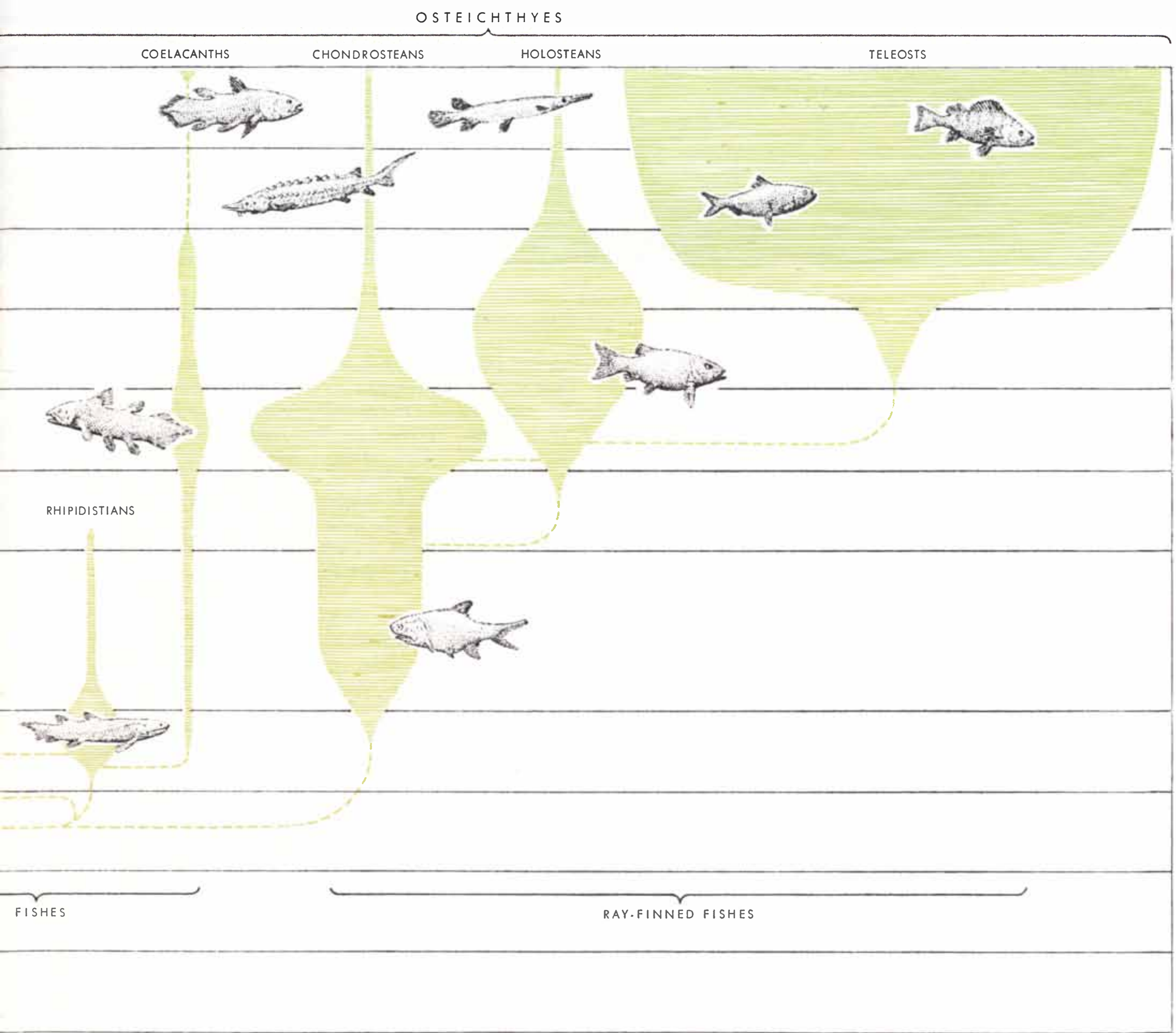


EVOLUTION OF FISHES is outlined in this chart. The vertical dimension of the chart is time, with the present at the top. The horizontal dimension of the colored areas indicates the relative abundance of each group at any one time. The dotted lines represent the

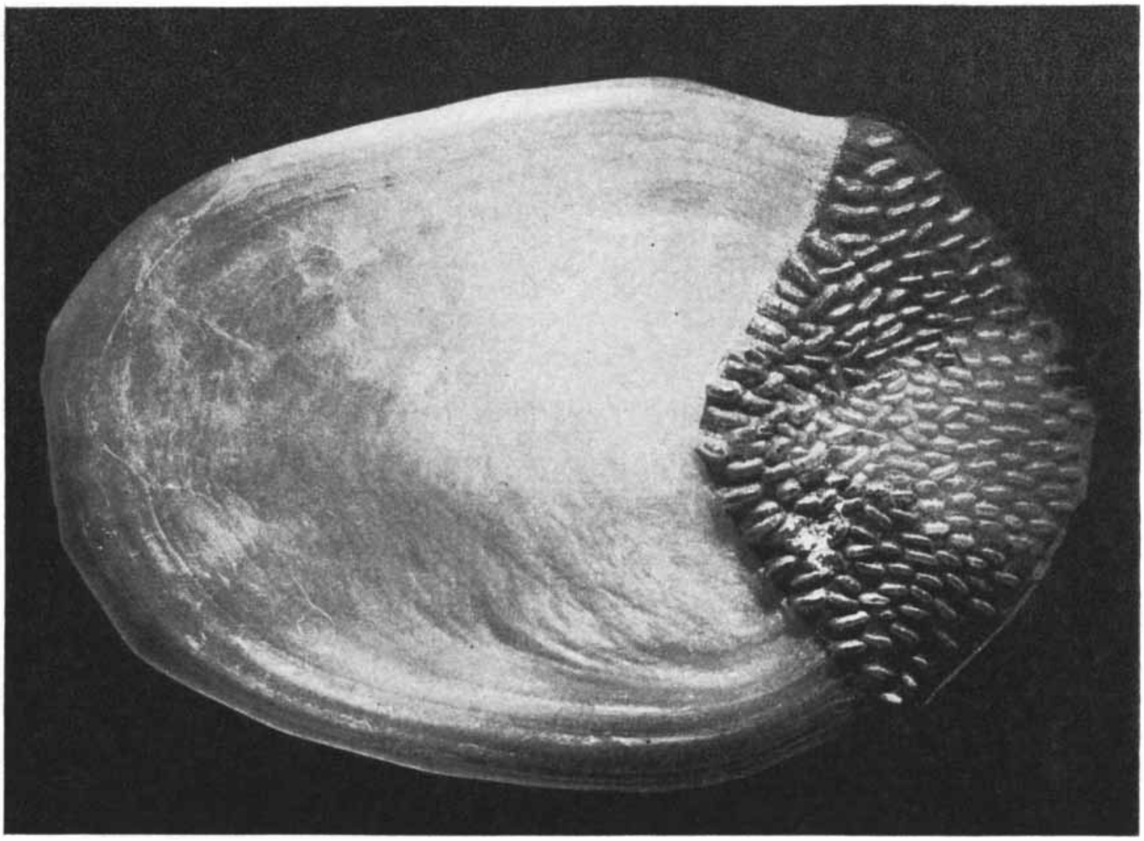
ment which seems to indicate that they possessed functional lungs and led an amphibian existence. Indeed, fossils of primitive amphibians are found beside them in many a geological deposit. The rhipidistians show a remarkable structural kinship to early amphibians found in deposits of late Devonian times in Greenland. They form a solid bridge between the fishes and the amphibians.

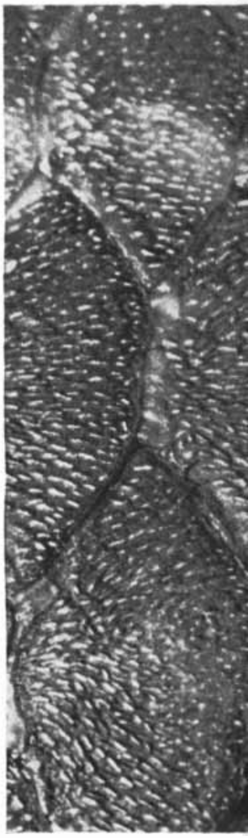
On the other hand, the coelacanths have shown themselves to be as stable and as obstinately conservative as their rhipidistian brothers were progressive. Throughout the hundreds of millions of years the coelacanths have kept the same form and structure. Here is one of the great mysteries of evolution—that of the unequal plasticity of living things. Why are certain organisms so labile while others apparently very like them retain their identity through the ages, no matter what vicissitudes they have to undergo? Whatever the reasons or the moral, the fact is that the unchanging coelacanths far outlived their rhipidistian brothers, for the latter disappeared by the end of the Devonian Period.

All of the coelacanths now captured belong to one species, named *Latimeria chalumnae* by Smith. They are good-sized fishes, between four and five-and-a-half feet long as adults and weighing from 70 to 180 pounds. The living coelacanths are a good deal larger than those previously found as fossils. Their body build calls to mind some of the big modern rock fishes, and their mode of life cannot be far different, though they live at greater depths. The coelacanth's flat, powerful tail is not distinctly differentiated from the rest of its body. Its body is entirely clothed in large, circular scales, whose size, exact shape and ornamentation vary with the region of the body. Alive the fish has a steely blue-gray color, flecked with



supposed evolutionary relationships of the groups. The typical species that illustrate the characteristics of each group are not drawn to the same scale. The chart was prepared with the assistance of Bobb Schaeffer of the American Museum of Natural History.





SINGE SCALE of a coelacanth is enlarged three times in the photograph at the left. At the left side of this photograph is the part of the scale that is overlaid with other scales. At the right side of the photograph is the exposed part of the scale, ornamented

light spots; after death its color changes rapidly, usually to chocolate brown.

Its fins at once identify the coelacanth as a crossopterygian. Six of its seven fins have a characteristic paddle shape and are borne on well-developed, scaly stalks [*see illustration on page 34*]. Each has about 30 fin rays. The seventh fin, on the forward part of its back, is fan-shaped and is attached directly to the back.

Coelacanth fossils have been found in many parts of the world—from Brazil to Spitsbergen, from Great Britain to Madagascar. But today the fish seems to be restricted to the waters washing the little Comoro archipelago, situated halfway between Madagascar and east Africa at the north entry to the Mozambique Channel. The first specimen, found off South Africa, must have been a wanderer from the Comoro area.

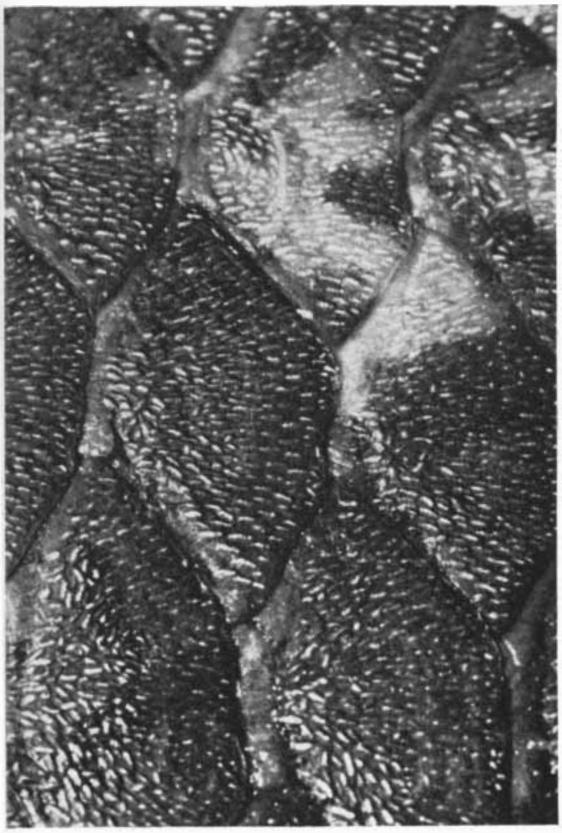
Although the local Comoro fishermen have been mobilized almost to a man and have been spurred on by sizable rewards, the catch of coelacanths is only three or four per year. The fishing is rather difficult: coelacanths live on the deep, rugged bottom and cannot be bagged with nets. Except for the first stray specimen, all have been caught at from 80 to 200 fathoms—the limit of the fishing lines. In all likelihood they go down to about 400 fathoms. Their eyes are phosphorescent, and they shy away sharply from the light. They survive only a few hours after being brought to the surface. One specimen, taken in perfect condition, was immediately placed in a submerged boat as an aquarium, but in spite of all the care lavished on it it died within a day, plainly through the combined effect of the decompression and the rise in temperature. Samples of water taken precisely where the fish were caught have shown temperatures of the order of 54 degrees Fahrenheit, as against the 79 degrees of surface waters.

The coelacanths are probably no great swimmers. They seem to be rather sedentary animals which live amidst basaltic rocks where they find shelter and lie in wait for their prey. Their powerful tail should enable them to hurl themselves at their victims with an irresistible pounce. Perhaps their stalked fins permit them to creep along the rocks like seals. But for the time being this is mere speculation. The only fish that was observed alive for any length of time was slow-moving (at the surface at least), but exhibited exceptional mobility of its fins. The pectoral fins, notably, can turn in just about all directions—nearly 180 degrees fore and aft as well as up and down. At the time of death the two fins may set themselves in opposite ways; the fish then presents an asymmetry highly disconcerting to an uninitiated observer.

The Mozambique coelacanths are carnivores feeding only on small fishes. They usually swallow their prey whole, and some of the little fishes have been found intact in the predator's stomach. For the most part the coelacanth's food fishes are believed to live at depths from 300 to 500 fathoms.

The discovery of the living coelacanths magnificently confirms, and amplifies, what paleontologists had deduced about the early vertebrates from their fossils. It gives ringing testimony to the remarkable powers for reading the past that mankind has developed through sophisticated modern paleontology. When we read archaeologists' conclusions about ancient life on our planet, pieced together from the most fragmentary evidence, their assertions must sometimes seem rash, and we wonder how much reliance can be placed on their picture. But now that we have a "living fossil," the coelacanth, to check their deductions, we can see that the paleontologists' reconstructions of the crossopterygian fishes are masterpieces of skill and insight.

The bringing to light of living coelacanths adds some 70 million years to



with tubercles. In the photograph at the right several scales are enlarged two times.

their estimated longevity. They are beyond compare the oldest "higher animals" on the earth. To appreciate their age, we must bear in mind that when they arrived the only other vertebrates in the world were a few strange fishes now long extinct; that in their heyday there was not yet the least sign of a reptile or an amphibian animal, to say nothing of a mammal or a bird. Compared with the coelacanths, the ancient and extinct dinosaurs lived only yesterday; the coelacanths are nearly 200 million years more ancient. And yet these astonishing fishes turn out to be still with us and still robust—by no means degenerate or tired of living.

What is even more remarkable is that in spite of drastic changes in the world environment, the coelacanths are still much the same organically as their ancestors. Their living organs yield many secrets of the past. As Smith has said, the coelacanths are incomparable "machines for reading time backward."

It has long been realized that the age-old evolution of animal organs is more or less reflected in the development of the embryo of a vertebrate animal today; biology students of my generation were suckled on the formula: "Ontogeny follows phylogeny"—the development of the individual repeats the development of the race. As Thomas Huxley used to say: "The individual must climb back to the top of his genealogical tree." The classic view is that in the course of a few weeks or months the young embryo retravels the entire evolutionary path traveled by his forefathers in the course of the ages. Whether this is strictly true has been much debated, but it is indisputable that the study of embryonic stages gives invaluable aid in reconstituting the ancestral stages.

Let us take the heart, for instance. In the very young embryo of a vertebrate animal, including man, the heart begins as a simple enlargement of the principal blood vessel. The enlarged section partitions itself into four chambers in a row. As the organ develops, the vessel coils back on itself S-fashion, and the two rear chambers fold over above or ahead of the forward ones. As a result the heart acquires a globular shape, with the auricle (consisting of the atrium and sinus) folded over the ventricle.

Now if this development truly repeats the evolution of the vertebrate heart, we should expect the coelacanth to have a more or less linear heart, with a sinus and atrium behind the ventricle. Dissections of the fish have verified the correctness of this prediction. The heart is not quite linear but has the shape of a flattened V. The atrium and venous sinus are behind the ventricle, with only the merest suggestion of an overlap. Altogether the form of the coelacanth's heart neatly matches a diagram, picturing what a primitive vertebrate's heart should be like, which was drawn some 30 years ago by the British zoologist Edwin S. Goodrich! Such confirmations are the compensation of men of science.

An equally striking finding emerges from examination of the coelacanth's pituitary gland. This tiny but important organ, situated just beneath the brain, originates in a curious manner in the embryo of a modern vertebrate. It develops from two separate bulbs: one coming from the floor of the cerebrum, the other from the back wall of the pharynx. In other words, one bulb develops from nerve tissue, the other from digestive tissue. In the course of the fetus' development, the pharyngeal bulb detaches itself completely from the digestive tube and joins the nerve bulb to form the pituitary, so that no indication of its origin in the pharynx remains. But in the coelacanth that connection persists: throughout the fish's life its pituitary gland is connected to the roof of the palate by a long tube, richly supplied with blood vessels and functioning in hormone production. Here again we have a telling illustration of an ancient stage in animal evolution.

Study of the coelacanth's nervous centers is especially interesting. Its brain is tiny and simple in construction; it occupies only a minute part of the fish's cranium, and is extremely small in proportion to the whole body. The brain of a 90-pound coelacanth weighs less than 50 grains—that is, no more than one 15,000th of the body weight. No present-day vertebrate that we know of has so small a brain in relation to its size. And yet the coelacanth's marked microcephalia has not prevented it from outclassing all other vertebrates in life's competition across the ages. Here, then, is food for thought: smallness of the nerve centers is in no way a hindrance to triumph in the struggle for life. Indeed, it would seem that other biological factors, such as fecundity and physiological adaptability, play a role far greater than intelligence in the survival of species. But it must be said that the coelacanthian brain, though tiny and simple, seems perfectly proportioned within itself. Its various elements seem to have remained in balance, none developing out of proportion to the others.

There are still a great many things to be learned from this uniquely instructive anatomy—from the fish's hollow spine extending far forward into the head; from its double respiratory system (both gills and lungs—now degenerate), which permitted the animal to evolve toward either an aquatic or a terrestrial life; from its unusually complex fins, which foreshadow our own limbs, and from its exceptionally rich musculature, which allows the fish to make precise and varied movements.

Detailed studies now in preparation will soon apprise the scientific world on all these points. In the meantime, research is continuing. It will throw light on the mode of life of these remarkable crossopterygians and will try to penetrate the secret of the adaptability which has enabled them to live through many geological eras under widely differing conditions without modifying their constitution. It will also try to penetrate their mode of reproduction and their stages of embryonic development, in which we can expect some real revelations about evolution.

Let us thank fortune for permitting the coelacanths to live on into our time. They open a window onto the past of the higher animals, including ourselves, and help us to reconstruct and to understand our history.

The Strange Case of the Blind Babies

During the past 15 years there has been a little-known epidemic of a form of blindness called retrolental fibroplasia. How its cause was discovered is an intricate tale of medical detection

by Theodore H. Ingalls

It was first noticed in Boston. In 1940 a Boston ophthalmologist, Theodore Terry, was abruptly confronted with a new disease which defied his skill to diagnose, let alone to treat. In the course of just a few months he was called to examine six cases of babies going blind from some obscure cause. Soon afterward the same mysterious disease began to be reported in other cities—Baltimore, New York, Chicago, Denver. All through the 1940s the toll mounted steadily, not only in the U. S. but also in Europe, until the number of infants stricken by blindness ran into the hundreds each year. And then, after much labor by groups of investigators in many countries, the mystery was solved, almost as suddenly as it had arisen.

To determine the causes of a new disease requires good detective work as well as precise scientific analysis. Hence it may not be amiss to commence this account of what might be entitled "The Tragedy of the Sightless Babies" by quoting Conan Doyle:

"The principal difficulty in the case, remarked Holmes in his didactic fashion, lay in the fact of there being too much evidence. What was vital was overlaid and hidden by what was irrelevant. Of all the facts which were presented to us we had to pick just those which we deemed to be essential, and then piece them together in their order so as to reconstruct this very remarkable chain of events."

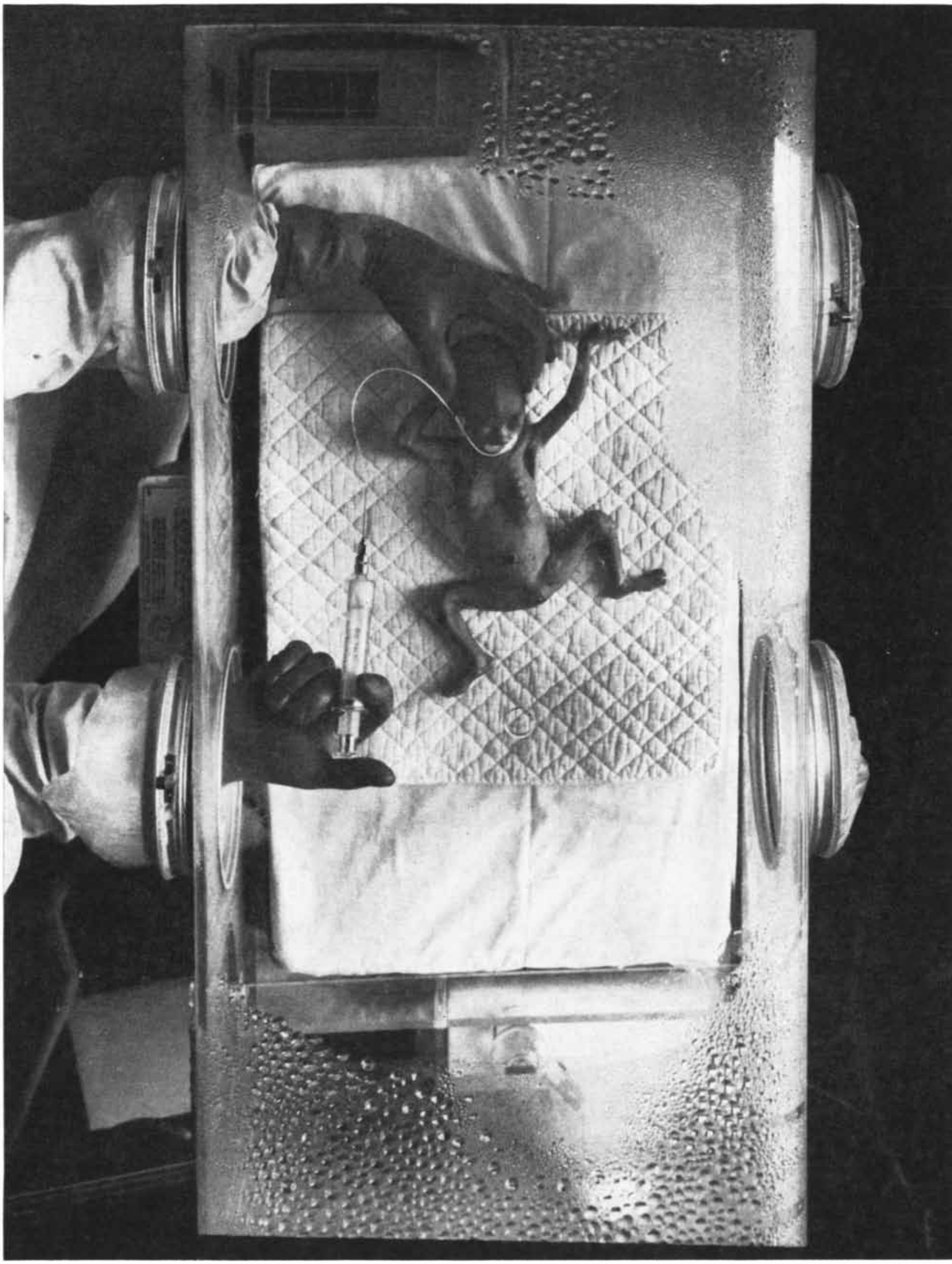
These words tell in a nutshell why it took 14 years to solve a problem that seems relatively simple in retrospect. Before I go further I should make clear that there was no single Sherlock Holmes here. At least 25 or 30 scientists—ophthalmologists, pediatricians, chemists, physiologists, pathologists, statisticians, epidemiologists—contributed the clues which gradually assembled the pieces of the puzzle into a recognizable pattern. Some of the scientists whose discoveries helped had been dead for many years; some were military researchers working for Hermann Goering's Nazi Air Force; some were men and women who gave all their time to this baffling problem; and some will be genuinely astonished if they happen to see their names in this article, so undramatic was their role in the gathering, analysis and eventual synthesis of seemingly conflicting data.

To go back to Dr. Terry: he found that the most characteristic feature of the disease which had blinded his six baby patients was a curtain of fibrous scar tissue behind the lens of the eye. Hence he named it retrolental fibroplasia—formation of fiber behind the lens. (William and Ella Owens in Baltimore later traced the steps by which the membrane of fibrous tissue developed in the eyes of stricken babies.) What might have caused the damage? Terry counted off many reasonable possibilities—premature exposure to light, for example—without once centering his suspicion on the actual culprit. He did, however, notice something that struck him as odd—and this was to become the first clue. All six children had been born prematurely.

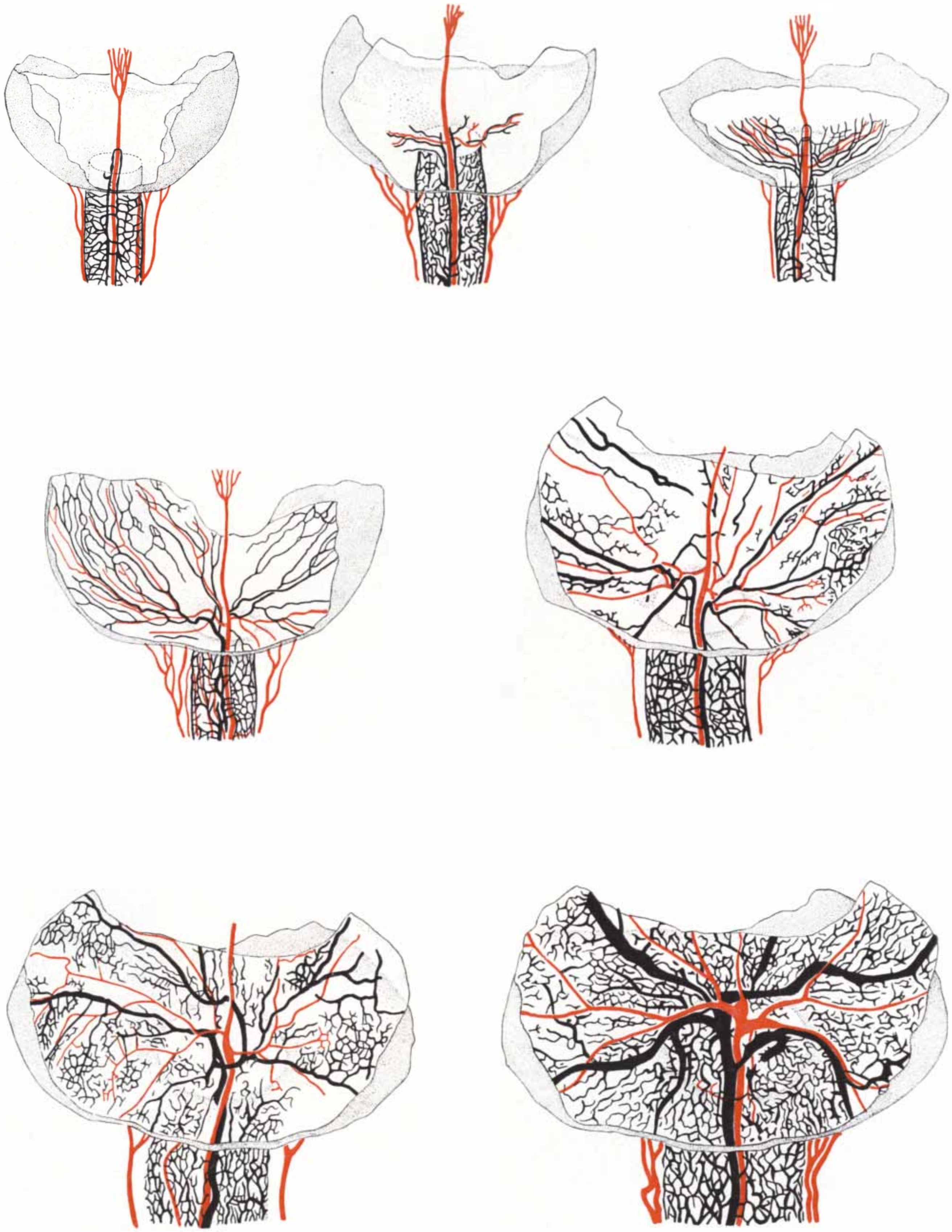
Terry set about with a high-power microscope and drawings by prism projection to study the developing eyes of kittens and baby opossums, especially the latter, for they crawl out of their mother's womb and fasten themselves onto her nipples long before their eyes are formed. He was tireless in preparing and analyzing his material, but he was not to know where his clue would lead, for he died before the epidemic or the investigation of the disease had really got under way.

A committee took over the research Terry had started. Merrill King examined babies who were stricken with the disease, and Everett Kinsey and Leona Zacharias began a statistical and epidemiological study. All the victims of retrolental fibroplasia were infants in the first few months of life. The epidemic had a definite beginning and an appalling climb. Among babies born in one of the Boston hospitals, for example, there were no cases in 1941, four in 1942, seven in 1943, nine in 1944 and 11 in 1945. In the State of New York, where an organized study of the epidemic was undertaken, thanks to the initiative and imagination of Edward Schlesinger in the State Department of Health, the number of cases rose steadily from 12 in 1941 and 1942 to more than 300 in 1951 and 1952. In certain U. S. cities during the late 1940s the chances were one or two in 10 that a markedly premature baby would go blind. And yet throughout the affair it was always a striking fact that the affliction tended to spare some hospitals, some states and even whole nations.

It was not until 1946 that the second solid clue to the mystery was recognized. Arlington Krause, the perspicacious pro-



PREMATURE INFANT lies in an incubator at the Pennsylvania Hospital in Philadelphia, one of 18 hospitals participating in the Cooperative Study of Retrolental Fibroplasia. When this photograph was made, the infant, which was some 26 weeks premature, was nine days old and weighed one pound, six ounces. Here the infant is fed a special formula by means of a syringe and a tube extending through its nose. The nurse holds the syringe through rubber ports in the side of the incubator, ordinarily closed.



BLOOD-VESSEL GROWTH in the eye of the human fetus was plotted by the Italian anatomist Riccardo Versari. The red vessels are arterial; the black, venous. These diagrams illustrate stages between the ages of three months (*top left*) and eight months (*bottom right*). Since the blood vessels that will nourish the retina develop during the fifth, sixth and seventh months, the vision of a premature infant is particularly vulnerable. Any severe injury to the growing capillaries at that time may well result in blindness.

fessor of ophthalmology at the University of Chicago, concluded from autopsies that retrolental fibroplasia was a "systemic disease." Don't look only at the eyes, he suggested; look at the brain and other tissues also. And look at the blood vessels. The blood vessels were implicated by Krause's descriptions of his microscopic studies and by a report of two New York ophthalmologists, Algernon B. Reese and Frank Payne, who found that premature infants with retrolental fibroplasia frequently had birthmarks on the skin. Krause's work, supported by the discovery of the capillary disturbance by Reese and Payne, suggested that some general physiological disorder, which would attack not only the eyes but also other organs, was responsible for the epidemic of blindness among babies.

This was the state of affairs when I began my own studies of the subject. I had come back from the Army to the Harvard Medical School and thrown in my lot with the late W. Lloyd Aycock for a joint review of the severe damage suffered by babies born to mothers who had had German measles during pregnancy. The observation that this mild infection of the mother might blight the eyes, ears, heart or brain of the developing embryo had given physicians a new view of the importance of supposedly insignificant disturbances of the mother during pregnancy.

While considering this subject, Aycock and I frequently discussed retrolental fibroplasia, for his own grandchild had developed the condition and had died in infancy with hydrocephalus. Impressed by Krause's idea of a systemic disease, I got in touch with Judson Smith, the obstetrician who had delivered Aycock's grandchild, and with the baby's pediatrician, my old office colleague Richard Tefft. The records of both physicians were revealing. Dr. Smith's notes indicated that the mother had had massive hemorrhages from a misplaced placenta during the seventh and eighth months of pregnancy and the baby had had to be delivered by Caesarean section. Dr. Tefft had found the baby so tense even in the first few days of life that he had done a spinal puncture. The fluid had proved to be bloody —not fresh blood but a "prune-juice-colored material which was obviously the result of an old intracranial hemorrhage." Tefft thought that this bleeding might have been due to a deficiency of oxygen in the blood.

Here, then, was a major clue. Was oxygen deficiency the cause of retrolental fibroplasia? Hemorrhage from a misplaced placenta might be expected to produce such a deficiency. I found evidence of oxygen deficiency in other cases of the disease. And Bertha Klien of Chicago demonstrated that growths found in the retinas of the blind babies were of a kind that lack of oxygen might promote. The oxygen question began to get attention from various investigators. But in the meantime other possible culprits were attracting suspicion—transfusions given to babies, deficiencies of vitamin A or vitamin E, and the like. Kinsey and Zacharias, studying the records of almost 100 cases, were impressed with the possibility that the rise of retrolental fibroplasia might be associated with the increasing tendency to prescribe iron and water-soluble vitamins for infants. Suspicion also fell on the use of anesthetics and sedatives in premature deliveries.

The survey by Kinsey and Zacharias included the fact that it had become a general practice to place premature babies in oxygen incubators immediately after birth. But no one, either then or before, could attach much significance to that. If oxygen was involved in retrolental fibroplasia at all, it was because of a lack of it, not a surplus. There seemed no reason for suspecting the giving of oxygen in the sleek, smoothly efficient new incubators that had come into wide use in hospitals in the 1940s.

The turning point in the mystery of retrolental fibroplasia came in 1950 and 1951. More and more studies, in the U. S., France, England and Australia, focused on the connection of the babies' blindness with oxygen supply. In July, 1950, I came back to the statistics of Kinsey and Zacharias to emphasize that, according to their study, babies who became blind had been kept under oxygen longer, on the average, than those who did not. I argued that the statistics seemed to show that the babies who developed retrolental fibroplasia were those who needed treatment for oxygen deficiency, as evidenced by the fact that they were kept under oxygen longer. It had not yet sunk in that the giving of oxygen might itself be the cause of the trouble. But that suggestion came not long afterward.

The first statement of it that I can find in the medical literature appeared in the French *Medical Press* for May, 1951. It was a simple observation by Marcel Lelong and his colleagues in Paris that there was reason to wonder whether "suroxygenation" (an excess of oxygen) might not be responsible for retrolental fibroplasia. I have no idea how the French pediatricians came to their inspired opinion. It had been known for many years, however, that oxygen could be toxic at high tensions. For instance, an Italian flyer named Pezzi had written in 1938 that breathing pure oxygen below an altitude of 26,000 feet produced "inflammation and burns of the respiratory tract." Other aviators, mountain climbers, balloonists and submariners had reported similar experiences.

Confirmation of Lelong's surmise gradually emerged in reports by investigators in other countries. That oxygen overdosage might be the culprit in retrolental fibroplasia had been suggested to Kate Campbell of Australia by colleagues who had visited England and the U. S. and had noticed that while oxygen was used freely in the U. S., in England it was used sparingly and there were few cases of the disease. Dr. Campbell examined the figures in Melbourne and found that among 123 premature babies kept in a high-oxygen atmosphere, 23 developed retrolental fibroplasia, whereas among 58 infants given moderate amounts of oxygen, only four were stricken with the disease.

If Americans were using oxygen freely, they were also among the first to sense the danger. As early as 1950 three Denver doctors—Harry Gordon, Lula Lubchenko and Ivan Hix—had begun to curtail drastically the administration of oxygen to "preemies." Even after Dr. Campbell's finding, however, the incrimination of oxygen was far from clinched, and it was not easy to decide how far to limit its use, especially for blue babies that became rosy when put into an oxygen tent.

Ironically, it was in England in 1951 that the most dramatic epidemic of retrolental fibroplasia broke out. In that year 20 babies became blind in the city of Manchester, where the use of oxygen "cots" had just been introduced in one of the large hospitals. The hospital thereafter gave oxygen only sparingly, and in the following two years no blindness developed.

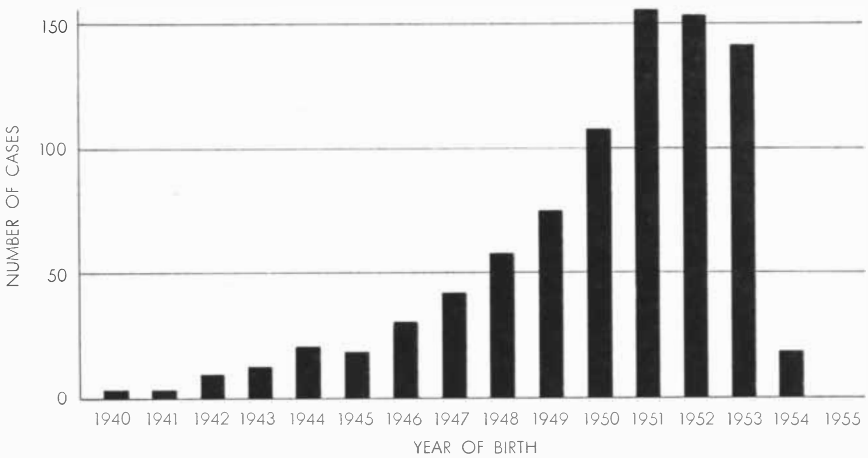
High oxygen tension, then, was pretty clearly the primary cause of the disease. Yet its infant victims showed unmistakable evidence of oxygen deficiency. Here was the great paradox of the whole strange affair. Somehow heavy administration of oxygen was bringing about a shortage of oxygen in the blood;

the babies were starving for oxygen in the midst of plenty. The treatment of premature infants with oxygen was creating the very deficiency it was designed to counteract!

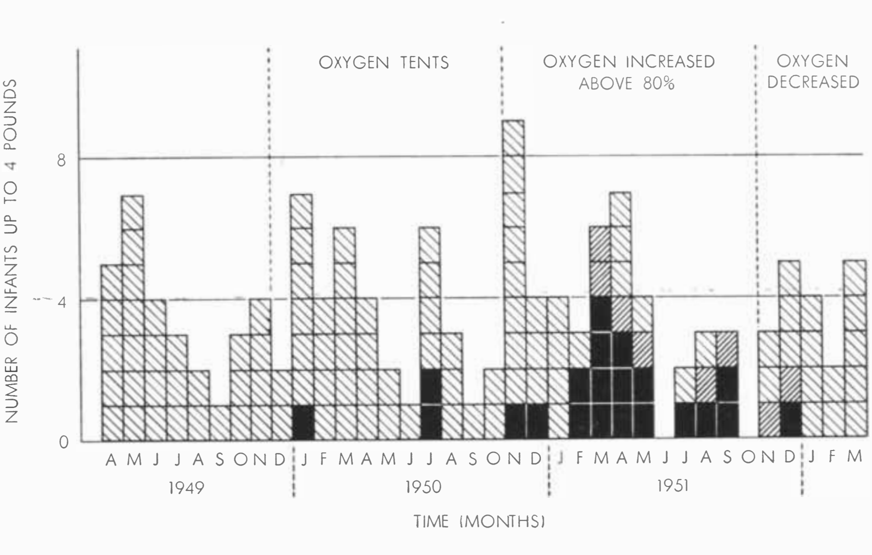
Why? How? This is not the place to set forth the details of the clinical observations, the pathological studies, the experiments on laboratory animals, that led to the final solution. Important contributions were made by Gordon, Lubchenko and P. D. Bruns in Denver; by Eirlys Jefferson and Mary Crosse in England; by A. Patz and his colleagues in Washington, and by T. S. Szewczyk in St. Louis. Some of the clues were dug up from reports of oxygen experiments made many years ago. Physiological studies carried out by John W. Bean at the University of Michigan were especially pertinent.

One of the last breaks in the case came during a luncheon conversation I had with an Air Force officer taking graduate training at Harvard University in the fall of 1954. We had been discussing oxygen toxicity, and he called to my attention that some interesting reports on this very subject, by German scientists who had worked for the *Luftwaffe*, had been translated and published by the Air Force in a volume entitled *German Aviation Medicine, World War II.* My colleagues and I lost no time looking it up, and two of its chapters gave us key pieces to the puzzle.

In the first, J. Pichotka described how long exposure to high concentrations of oxygen had so irritated the lungs of experimental animals that many of the tiny air sacs had degenerated. In the second, H. Becker-Freyseng reported that rabbits kept in an oxygen atmosphere for several days showed a steadily increasing deficiency of oxygen in their blood, leading to suffocation.



NUMBER OF CASES of retrolental fibroplasia reported in New York State from 1940 to 1955 is plotted in this chart. The epidemic reached its peak in 1951 and rapidly tapered off.



RISE AND FALL of blindness at St. Mary's Hospital in Manchester shows oxygen was the cause. Black marks severe cases; dark hatching, mild cases; light hatching, normal vision.

Two other pieces complete the picture and reveal the whole pattern. Many years ago, around 1900, an Italian anatomist named Riccardo Versari observed that it is during the fifth, sixth and seventh months that a human fetus develops the tiny blood vessels which will nourish the delicate retinas of its eyes. This means that a baby born in those months, ahead of its time, enters the world in a vulnerable condition from the standpoint of its future vision. Any injury which nips these tender shoots, which destroys the growing capillaries, will ultimately manifest its effect in blindness. And so we come at last to the final piece in the "very remarkable chain." Retrolental fibroplasia emerged in epidemic proportions when hospitals began to expose premature babies to very high oxygen atmosphere in efficient new incubators. Often the atmosphere used was more than 50 per cent oxygen (contrasted with 21 per cent in ordinary air).

As Becker-Freyseng succinctly put it: a too-rich oxygen atmosphere "acts simultaneously as a *poison* and as a *therapeutic agent*." The italics are his, but we can adopt them as well, for these few words tersely summarize the explanation of the tragedy of oxygen and the sightless babies.

This was the end of the trail as far as understanding the outbreak of retrolental fibroplasia was concerned. Once the hazard was fully recognized, the epidemic quickly subsided. Physicians and hospitals are now aware that when oxygen is administered, it should be balanced carefully to the infant's needs and capacities. The accepted ceiling is an atmosphere with no more than 40 per cent oxygen.

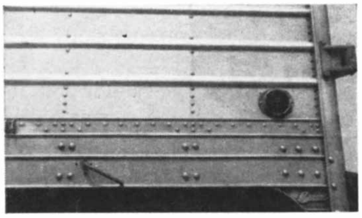
To be sure, oxygen deficiency and retrolental fibroplasia may arise from causes other than excessive exposure to oxygen. There have been a few recent cases of the disease in babies who received no oxygen treatment. But this is another problem. The chapter we have reviewed here is closed.

Yet the story may not be ended. Almost two centuries ago Joseph Priestley, the discoverer of "dephlogisticated air" (oxygen), conjectured prophetically that man might get in trouble if "this pure kind of air" became a "fashionable article in luxury." The tragic fulfillment of his conjecture during the past decade should put us on our guard. Experiments on animals suggest that adults are more vulnerable to excessive oxygen than infants. It is possible that adults have suffered oxygen injury without anyone having suspected it.

Kodak reports to laboratories on:

half-second butyrate on the road... how we became horticultural apothecaries... what darkroom craftsmanship can now accomplish... looking through the microscope with movie film and camera

Skin for aluminum



This is the freshly washed side of an aluminum truck trailer. The portion on the left had once been sprayed for demonstration with a clear lacquer made from *Eastman Half-Second Butyrate*, and the portion on the right left bare. Note the difference brought out by 16 months and 128,000 miles of weather, flying gravel, and road salt. There was also a dent that penetrated the lacquer but failed to start it peeling or chipping.

In summary, aluminum resists the elements till kingdom come, but a coat of Egyptian Lacquer Company's (South Kearny, N. J.) new Half-Second Butyrate-*based product helps to keep it clean and unpitted while waiting. Full information about* Eastman Half-Second Butyrate *is obtainable from Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).*

Orchid medicine

Medicine for people we don't sell, nor medicine for animals. Medicine for orchids, yes—the two aromatic salts, *o-Phenylphenol Sodium Salt* (*Pract.*) (Eastman P2896) and *8-Quinolinol Sulfate* (Eastman 1776). Only this past spring did we learn that we had it to sell. Letters began to drift in asking for descriptive literature on our orchid remedies. What could we answer? Of course we had no such literature, but could we deny that among our 3500-odd items there might be something to cure an ailing orchid?

(People are always assuming that because we sell a chemical we know all about its sundry uses and have hungry salesmen panting for an opening to demonstrate them all. This is a perfectly natural assumption that happens to be false with respect to Eastman Organic Chemicals. Unlike the entrepreneur who sells the sizzle instead of the steak, we sell the chemicals rather than the benefits they confer. But we do love to sell the chemicals.)

What we did was to track down the plant pathologist who had found these two particular compounds to be capable of making a fine distinction between the metabolic systems of orchids and those of certain bacteria and fungi that infest them. (Use in 1:2000 dilution by spray or immersion for 60 minutes or longer.) We checked with him on the identity of the compounds and then hung out our shingle as horticultural apothecaries with a limited line.

If any man thinks he can make a living by putting these compounds up under his own trademark and backing it with more helpful service to orchid growers than ours, more power to him and we hope he lets us quote on supplying the chemicals. They're among some 3500 available from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

Color prints while you wait

The day when you can ask one of the boys in the darkroom to bang out a few color prints before lunch has just about dawned.

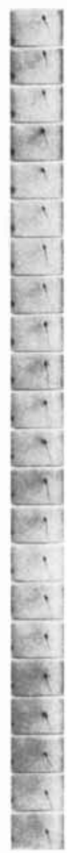
Just like reaching into the drawer for *Kodabromide Paper*, they can now reach for a new paper bearing the name *Kodak Color Print Material*. It comes in *Type R* for making prints directly from Kodachrome or Ektachrome transparencies and *Type C* for color negatives such as are obtained with *Kodak Ektacolor* or *Kodacolor Film*.

There is, frankly, still a little more to it than making black-and-white prints. There are quite a few more processing steps, and the instructions for them must be followed rather carefully. When the directions read 75 F for the developing bath, they don't mean 76 F.

Because the acceptability of a color balance is influenced by an intricate set of psychological, physical, and chemical factors, there is plenty of room for creative craftsmanship in the selection of filter combination, lamp voltage, and exposure. The more painstaking the craftsmanship, the more pleasing the results are likely to be. On the other hand, it is possible to slack off on the craftsmanship a bit and still get color prints on paper that convey more information than even the best monochrome could ever give.

If you use color photography in your business, we would deem it an honor to have you among the first on board. For a more precise idea of what's involved in the use of Kodak Color Print Material, *write Eastman Kodak Company, Professional Color Sales Division, Rochester 4, N. Y.*

Cinephotomicrography



That motion pictures made through the microscope might have much value both as an investigative technique and as an aid to scientific communication and instruction doubtless occurred to thoughtful men in earliest nickelodeon days, if not before. Certainly the art has been widely and effectively practiced and improved since then, but how many laborers in the various vineyards have had too many other important and more difficult matters meriting their attention to give thought to what cinephotomicrography could do for them?

Therefore, with no loftier motive than moving a little merchandise, it may be that by publishing a new revision of the booklet, "Motion Pictures Through the Microscope," we shall accomplish the greater good of a seed dropped in the right place at the right time.

The booklet speaks of how to use a motion-picture camera to alter the apparent rate of events on a microscope stage, making them many thousandfold faster or four times slower, as desired; of the details of aligning camera with microscope; of illumination, exposure, color rendition, the defeat of vibration, and a hundred other petty points that distinguish exasperation from proud achievement.

A copy of "Motion Pictures Through the Microscope" (Kodak Pamphlet N-2) is obtainable without charge from Eastman Kodak Company, Sales Service Division, Rochester 4, N. Y.

Cinephotomicrograph by E. J. Farris.

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

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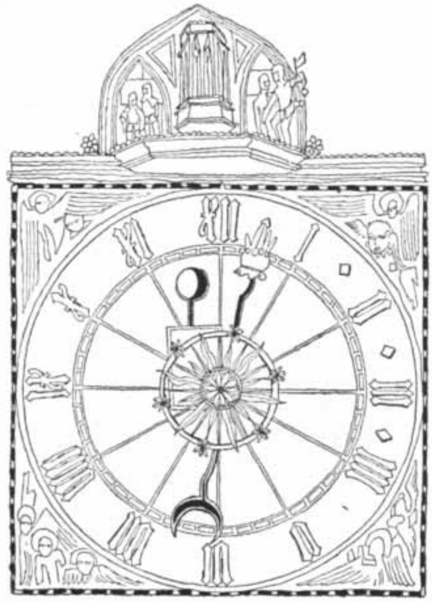
SCIENCE AND



Nobel Prizes

The Nobel awards in science, each worth a record $36,720 this year, went to one Swedish and three U. S. investigators.

Hugo Theorell, head of the biochemistry department of the Nobel Medical Institute in Sweden, won the medicine prize for his work on enzymes. He separated, purified and identified the various enzymes by which living cells carry out oxidation or breathing reactions. After he had crystallized the first of these, the so-called yellow breathing enzyme, he split it into two parts, each biologically inactive, and then recombined the parts, forming the potent enzyme again. This was the first time that any enzyme had been separated into its two components—coenzyme and apoenzyme. Theorell went on to identify a whole spectrum of breathing enzymes—red, pink, green, colorless. He was also the first to prepare a pure sample of myoglobin, the red coloring substance in the muscles.

The physics prize was divided between Willis E. Lamb and Polykarp Kusch for their independent but related measurements of electron energies with radio waves under I. I. Rabi at Columbia University. Lamb, together with Robert C. Retherford, used microwave radiation to determine precisely the amount of energy required to shift the electron in a hydrogen atom between two very nearly equal energy states. Kusch, by observing the behavior of beams of various atoms in a field of radio waves, was able to measure the magnetic strength of an electron with great accuracy. Both results differed from the values predicted by P. A. M. Dirac's theory of the electron. (Dirac had earlier won the Nobel prize for the theory.) The discrepancy touched off a ferment in theoretical physics out of which emerged the new quantum field theory.

Vincent du Vigneaud, chairman of the department of biochemistry at Cornell Medical College, received the Nobel chemistry award for his studies of two hormones of the pituitary gland known as oxytocin and vasopressin. Du Vigneaud was the first to isolate individual hormones from the secretions of the rear half of the pituitary, an undertaking requiring 10 years and the glands of some 100,000 cattle. Having found that two distinct substances were involved, he proceeded to determine their chemical structure. Both are polypeptides, or strings of amino acids. Oxytocin, which du Vigneaud succeeded in synthesizing, is the first polypeptide hormone to be produced artificially. It causes contractions of the uterus during childbirth and releases the mother's milk from the breast. Vasopressin, which raises blood pressure and decreases the kidney's urine production, is given to diabetics.

Antiproton

Only a few months after it was first turned on, the giant Bevatron at the University of California paid off one of the biggest bets its designers had made on it. The $9.5-million accelerator materialized the long-sought antiproton. The existence of this particle, with the mass of a proton but carrying a unit of negative rather than positive charge, had been taken virtually for granted for more than a quarter of a century. But it could not be produced until the Bevatron's energy of 6.2 billion electron volts became available to experimenters.

It was in 1928 that the British physicist P. A. M. Dirac first suggested that anti-particles could be created out of energy. He predicted that when an anti-particle encountered its corresponding particle, the two would combine in a reaction which released the energy of formation and annihilated both particles. In 1932 the prediction was strikingly borne out by the discovery of the anti-electron, or positron. Since then physicists have been heavily committed to the idea that the antiproton also must exist. Its appearance, at long last, was greeted with a universal sigh of relief.

To make antiprotons the physicists at the University of California Radiation Laboratory bombard copper atoms with the 6.2 Bev proton beam from the Bevatron. The theory is that when a proton collides with a neutron in a copper nucleus, about two Bev of energy disappear, and in their place appears a proton-antiproton pair.

The crux of the experiment is to separate and detect the antiprotons before they encounter protons and are annihilated. A magnetic field separates the negative products of the bombardment from the positive and neutral fragments. The negative beam contains a few antiprotons and about 50,000 times as many pi mesons. Since the deflection in a magnetic field depends on momentum, a fast pi meson will be bent at the same angle as a slower antiproton. To distinguish between the two, the particles' time of flight is measured between two counters spaced 40 feet apart. The "slow" antiprotons take one twenty-millionth of a second to negotiate this distance; the mesons, much less. When the discovery was announced last month, more than 50 of the slow particles had been picked up in the counters.

As a further check, the experimenters also try to detect the final fate of the antiprotons. After the beam has spent most of its energy, it is sent into a large counter set up to detect energy bursts of two Bev. Such bursts could come only from an annihilation, since the particles themselves have much less energy. Eventually the scientists hope to get pictures of antiproton tracks in cloud chambers or photographic emulsions.

The experiments are being done by Owen Chamberlain, Emilio Segrè, Clyde Wiegand and Thomas Ypsilantis, assisted by Herbert Steiner. Edward J. Lofgren is the physicist in charge of all work with the Bevatron.

Red-Shift Law Amended?

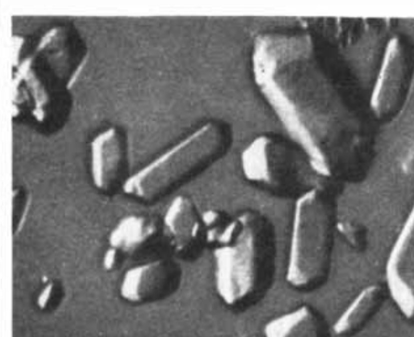
The "law" of the red shift is one of the main reasons why the 200-inch telescope on Palomar Mountain was built. The displacement of light from distant galaxies toward the red, indicating that the galaxies are moving away from us, has been the basis of the theory of the expanding universe. Since the red shift increases with distance, the speed of the galaxies also is believed to increase with distance. Does this law of the increasing red shift hold indefinitely into space? The 200-inch telescope has now given what seems to be an exciting answer. Out at the limits reached by the telescope the red shift apparently is not increasing in proportion to distance; in other words, the acceleration of galaxies is slowing down.

At the recent meeting of the National Academy of Sciences at the California Institute of Technology a group of astronomers reported that this was their conclusion on the basis of measurements of the spectral displacement of light from 26 extremely distant clusters of nebulae, ranging up to one billion light-years away. The measurements were made by N. U. Mayall of the Lick Observatory and M. L. Humason of the Mount Wilson and Palomar Observatories. They were announced by A. R. Sandage of Mount Wilson and Palomar. He cautioned that the results were not yet "conclusively established."

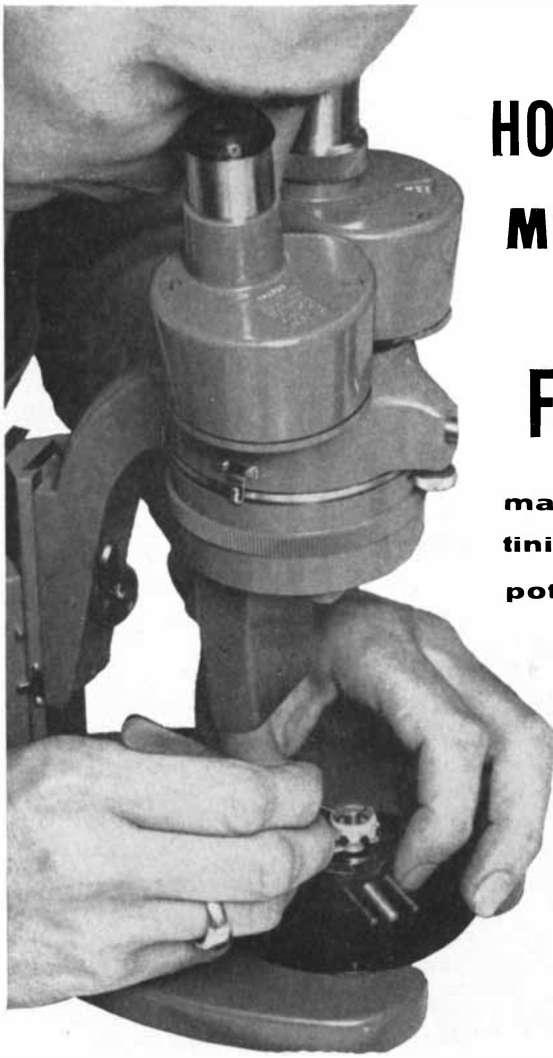
Polio Virus Crystallized

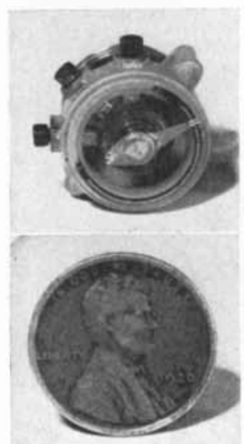
The first animal virus, one of the polio viruses, has been crystallized. The difficult chemical feat was performed by C. E. Schwerdt and F. L. Schaffer of the Virus Laboratory at the University of California. Until now the only viruses prepared in crystalline form have been plant viruses.

The California biochemists prepared an extremely pure and concentrated sample of one of the Type II strains of polio virus, extracting four 100,000ths of an ounce of material from some four gallons of infected monkey kidney tis-



POLIO VIRUS CRYSTALS are photographed under the light microscope. They average one thousandth of an inch in length.





sue. They placed their tiny sample in a vessel with some weak salt and acid solution, cooled the mixture to a few degrees above freezing and gently rocked the container overnight. In the morning they found that about 40 per cent of the sample had turned into small crystals which were easily seen under an optical microscope.

The crystals average about one thousandth of an inch in length and look like rectangular boxes with pyramids at either end. Each contains almost a billion virus particles. That the crystals are made of virus is proved by the fact that the material is infective when dissolved.

Schwerdt and Schaffer, reporting their work at the meeting of the National Academy of Sciences in Pasadena, said it emphasizes the "basic similarities between animal and plant viruses." They believe that other small animal viruses also can be crystallized. This development would provide researchers with samples of infective material known to be almost perfectly pure and exactly reproducible.

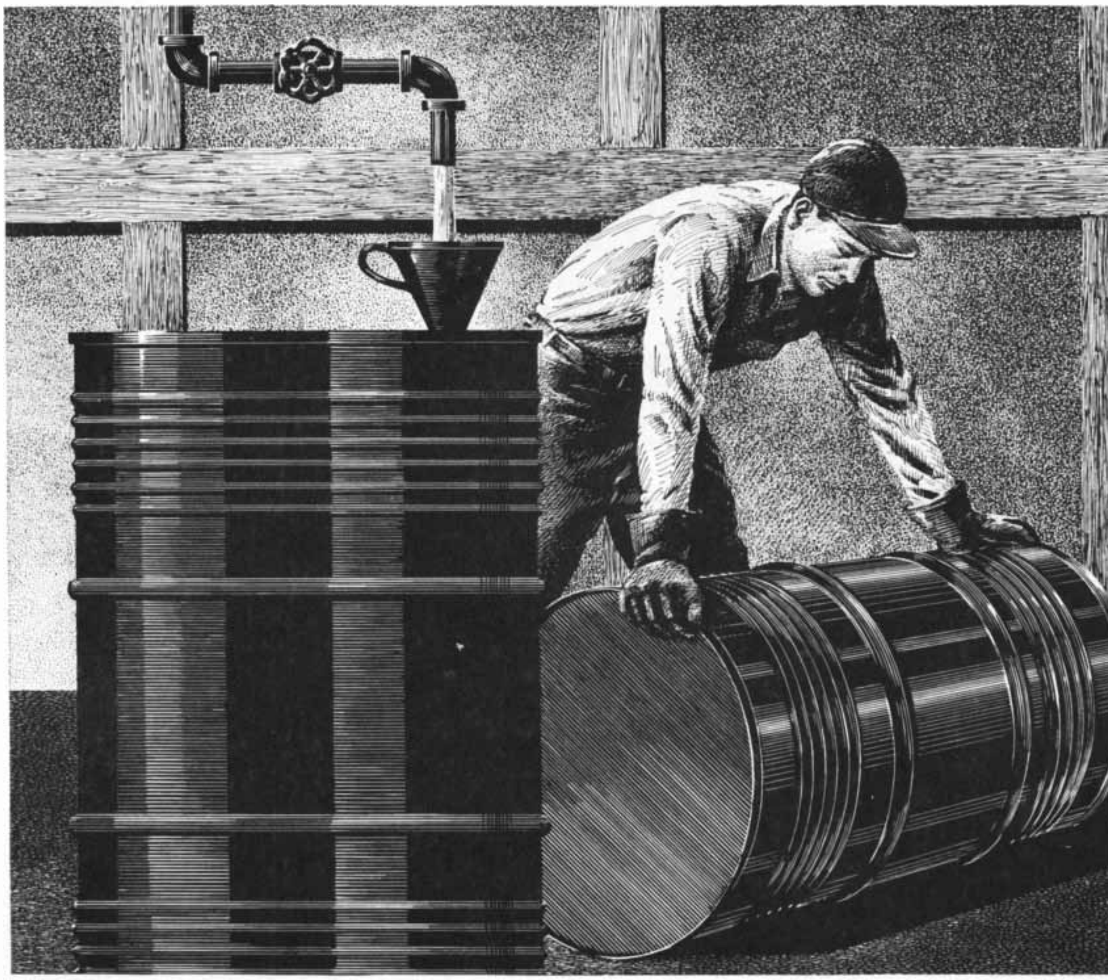
Synthetic's Success

A year ago chemists of the Goodrich-Gulf Chemical Company and the Firestone Tire and Rubber Company announced they had artificially synthesized the natural rubber molecule. Natural (hevea) rubber, as had long been known, consists of a rather simple hydrocarbon compound called isoprene linked in a certain way to form long chainlike molecules. The strength and wearing quality of natural rubber depend largely on its peculiar molecular pattern.

The first tires of the man-made "natural" rubber have now been road-tested. Reports to a recent meeting of the American Chemical Society's Rubber Chemistry Division said that it performed as well as natural rubber. GR-S, the wartime synthetic rubber, predominates in today's automobile tires, but generous proportions of natural rubber must be mixed with it in heavy-duty tires because GR-S does not stand heating well.

Safer Streptomycin

A new form of streptomycin, which appears to eliminate some bad side effects of the drug, has been developed in Germany. In its common form streptomycin is tacked onto a sulfate group. Chemists at the drug firm of Chemie Grunenthal in Stolberg have substituted the B-vitamin pantothenic



acid for the sulfate. When small amounts of the new drug, streptomycin pantothenate, are mixed with ordinary streptomycin sulfate, the combination is an effective antibiotic and avoids damage to the eighth cranial nerve, responsible for the deafness and dizziness that often accompanies use of streptomycin.

Henry Welch, a Food and Drug Administration antibiotic specialist, summed up the significance of the new drug by saying: "If it performs the way the Germans say it does, it may affect the entire method of treating tuberculosis in the U. S."

Basic Research Institute

An anonymous donor has given the University of California $2,750,000 to set up an Institute for Basic Research in Science, modeled along the lines of the Institute for Advanced Study at Princeton. The nameless philanthropist asked that the new institute dedicate itself "to the encouragement of creative thought." He specified that its chief purpose is "to discover and encourage the work of individuals of great talent and promise."

The annual budget will start at $100,000 and is expected to be doubled soon. The institute plans to concentrate at first on about 10 research projects which might have a hard time getting funds from any other source.

New AEC Commissioner

President Eisenhower last month filled a long-standing vacancy in the five-man Atomic Energy Commission by appointing Harold S. Vance, 65, chairman of the executive committee of the Studebaker-Packard Corporation. Earlier in the year the President had nominated Allen Whitfield of Iowa for the post, but Whitfield withdrew while the Joint Congressional Atomic Energy Commission was investigating his political and business background.

Vance began as a mechanic and rose through the Studebaker ranks, becoming chairman of the company's board of directors in 1935 and succeeding Paul Hoffman as its president in 1948.

Satellite Business

The artificial satellite project [*see article on page 29*] has been made official by executive orders and signed contracts. The various major responsibilities as outlined by the Defense Department are as follows:

The Navy will be executive agent of

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IN CANADA: SUN OIL COMPANY, LTD., TORONTO AND MONTREAL the program, which has been named Project Vanguard. Chief of Naval Research Rear Admiral F. R. Furth is general supervisor, and John P. Hagen is director.

The satellites themselves are in the hands of the National Academy of Sciences and National Science Foundation.

The Glenn L. Martin Company of Baltimore has a $2 million contract to build the three-stage rockets which will project the satellites to their orbits. Martin builds the Navy's Viking rockets.

The General Electric Company will furnish the rocket motor for the first stage. Reportedly it has already been built and tested in the Army's Hermes rocket.

Electron Mirror

For the conventional electron microscope specimens have to be sliced extremely thin, otherwise they are opaque to the not very penetrating electron beam. The fact that electrons are so easily reflected is the key to a new and entirely different kind of electron microscope described in the current issue of the *Journal of Applied Physics*.

The author of the article, Ludwig Mayer of General Mills, Inc., calls the new instrument an electron mirror microscope, because it portrays on a fluorescent screen the pattern of electrons reflected from the surface of the specimen. At this stage of development, he says, it has the resolving power of a light microscope. Potentially it could show details as fine as those an electron-emission microscope can resolve.

The electron mirror microscope actually shows any irregularities of the electric potential at the surface of the specimen. Thus it pictures such purely electrical properties of the specimen as surface charge and conductivity as well as its geometrical profile. The image that appears on the screen is a kind of electron-optical schlieren diagram and has to be interpreted carefully.

Anesthesia and the Aged

"He's never been the same since his operation." P. D. Bedford, a noted physician of Oxford, England, had heard that said about too many elderly patients. He therefore investigated the cases of 1,193 persons who had undergone surgery after they reached the age of 50, and he reports in *The Lancet* that the trouble seems to lie in the anesthesia connected with the operation.

The minds of 10 per cent of these aged persons had been affected to some

degree. Most had become untidy, forgetful, unable to concentrate as intensely as before. Two professional men—a history don and a surgeon—had been forced to abandon their work. Twenty-nine had become mental patients.

Dr. Bedford warns that the aging brain may be sensitive even to brief periods without sufficient oxygen. In an editorial endorsement of his article, *The Lancet* advises that in the case of an elderly patient "general anesthesia should be brief, light, devoid of nitrous oxide and accompanied by generous oxygen intake."

Gorilla Gastronomy

Bushman, the famous Chicago gorilla, died on New Year's Day, 1951, at the Lincoln Park Zoo. A seven-month illness had shrunk his muscular frame to a mere 500 pounds. He left no family, for never in his 22 years had he mated.

Three hours after Bushman died, two University of Chicago physicians and a zoo veterinarian began an exhaustive autopsy on his still warm corpse. Why, they wondered, do gorillas fare so poorly in captivity compared with other apes? Zoo gorillas never breed, and they age much more rapidly than wild gorillas.

Bushman, at an age when he should have been in his physical prime, showed unmistakable signs of senility. His heart, blood vessels and spinal cord had degenerated. His testicles were atrophied. Yet his muscles seemed still strong, and his hair had not turned gray.

After long study Paul E. Steiner, Theodore B. Rasmussen and the veterinary, Lester E. Fisher, reported in a recent issue of the A. M. A. *Archives of Pathology* that Bushman's decline was due to improper diet. He seemed to have a nutritional disorder akin to beriberi, which accounted for a partial paralysis of both legs and one arm. There was additional evidence of a deficiency of B vitamins and possibly vitamin E.

Bushman had eaten each day 22 pounds of fresh fruit, vegetables and whole wheat raisin bread, plus three quarts of milk, some water and multiple vitamins. On this ample caloric intake he had reached a weight of 550 pounds and at one time got so chubby that the cream was skimmed from his milk. Chimpanzees thrive on this sort of food. Evidently a gorilla needs some other nutrient of which physiologists are not yet aware. This idea is supported by the fact that a 700-mile area in Africa where chimpanzees abound is totally devoid of wild gorillas.

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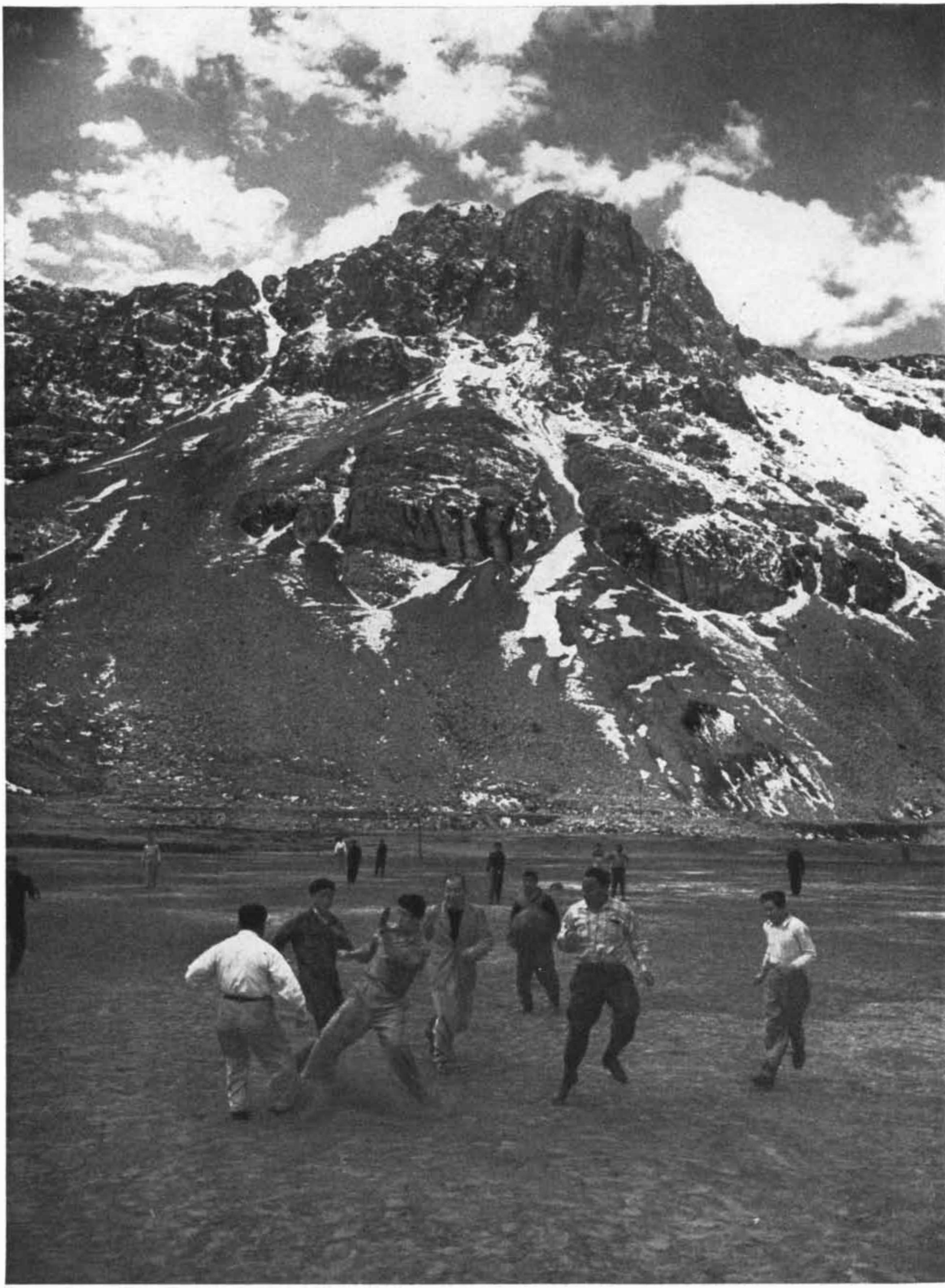


PERUVIAN MINERS play soccer near Morococha, the altitude of which is near 15,000 feet. At this height (pressure eight pounds per square inch) men who are accustomed to living at sea level (pressure about 14 pounds) are exhausted by climbing a few steps.

LIFE AT HIGH ALTITUDES

As man extends the vertical dimension of his environment, he reflects on the role of oxygen in his physiology. Here the matter is discussed in terms of men who pass their lives in the thin air over 10,000 feet

by George W. Gray

Respiration presents a striking example of the close dependence of life on non-life. It is not only man and the animals that breathe, but also (except for certain primitive organisms) every plant down to microbial forms—all must have oxygen, the breath of life, to burn their fuel and release the energy needed to sustain their living processes. The ultimate source of this oxygen is the vast supply which presses from all sides in the atmosphere.

Air symbolizes lightness, but the earth has five million billion tons of it. Distributed over the surface of our planet, this weight exerts a pressure of about 14 pounds to the square inch at sea level. Our lungs, blood, heart and other organs are adjusted to receive and utilize the amount of oxygen which the accustomed pressure delivers to them. All the factors in respiration are set to operate at this load. It is inevitable, therefore, that when a person ascends or descends from the level to which he is habituated, his internal equilibrium is affected by the changing pressure.

Studies made in balloons and airplanes, and more recently in altitude chambers, show that for the first mile of ascent only minor adaptations can be detected. With continuing rise the efforts of the system to adjust become appreciable, and as high altitudes are reached critical changes may ensue. Three levels of behavior have been observed, marking three stages in the body's response to the anoxia, or oxygen want. The thresholds vary from person to person, but in general they follow a well-defined pattern.

1. The *reaction threshold*, the altitude at which the body's effort to compensate for decreasing pressure begins to be noticeable, ranges from about 6,000 to 10,000 feet. The pulse quickens; the spleen launches its reserves of red cells into the blood stream; the tiny muscles controlling capillaries relax, allowing more blood to reach the tissue cells. While adjustments of such kinds are operating to get the maximum of oxygen into the system, other mechanisms are economizing its use, seeking to conserve the gas for vital functions. At around 10,000 feet it usually becomes difficult for the body to make further adaptations, and from then on anoxia openly disturbs the life processes.

2. The *disturbance threshold* ranges from 10,000 to about 16,500 feet. Muscles now are slow to react; sight becomes fuzzy; hearing, taste, smell and the other senses are dulled; the faculties of decision, attention, judgment and insight weaken, showing symptoms like those of alcohol intoxication. Compensatory mechanisms strive to make up for the scarcity of oxygen, and they may succeed in restoring functions to near normal. But if the ascent continues the needs of the body become critical.

3. The *critical threshold*, like that of the other two, varies with the individual and may be reached anywhere between 16,500 and 26,000 feet. Vision darkens; the heart pounds; muscles refuse to move. Some individuals lose consciousness; others go into convulsions; the ultimate crisis is death. A dramatic example of the effects of a sudden rise to high altitude was given in 1875, when the French aeronauts Gaston Tissandier, H. T. Sivel, and J. E. Crocé-Spinelli made their famous ascent in the free balloon *Zenith*. Tissandier recorded his feelings on the way up. "I had taken care to keep absolutely still, without suspecting that I had already perhaps lost the use of my limbs," he wrote. "At about 7,500 meters (24,600 feet) the torpor which overcomes one is extraordinary. Body and mind become feebler little by little. There is no suffering. On the contrary, one feels an inner joy. There is no thought of the dangerous position; one rises and is glad to be rising. I soon felt myself so weak that I could not even turn my head to look at my companions. I wished to take hold of the oxygen tube, but found I could not move my arms. My mind was still clear, however, and I watched the aneroid barometer with my eyes fixed on the needle, which soon pointed to 290 millimeters, and then to 280. I wished to call out that now we were at 8,000 meters (26,200 feet), but my tongue was paralyzed. I shut my eyes, fell down powerless, and lost all further memory."

The *Zenith* continued to rise, and the barometer recorded a maximum of 27,950 feet. The balloon then lost gas and began to sink. When it reached the ground both Sivel and Crocé-Spinelli were dead—but Tissandier was sitting up! He had revived when the descent brought him to a level of adequate oxygen—and apparently is the first person to return from critical anoxia with a record of its subjective symptoms.

Oxygen starvation underlies many illnesses which medical science calls by other names, and of the body's three primary requirements—air, water and food—the most quickly felt lack is that of oxygen. Aeronautics, with its swift transition to levels of low pressure, has dramatized the relation of the living body to the inanimate air, and has given a fresh emphasis to the importance of knowledge in this area. There is a whole new clinical field known as aviation medicine, with specialized research equipment such as altitude chambers, oxygen masks and now even space suits—and in a number of institutions the body's capacity for adaptation to low

MOROCOCHA STATION of the Institute of Andean Biology has a laboratory fully equipped for physiological studies at 14,900 feet.

SAN NICOLAS STATION of the Institute is a small building for occasional studies of miners who work nearby at 16,500 feet.

oxygen pressure is being intensively investigated. Most of these research centers are at sea level and many are branches of military aeronautical establishments, but the world's truly unique outpost of high-altitude study is a civilian establishment in Peru—the Institute of Andean Biology. It is a division of the four-centuries-old University of San Marcos, and was founded in 1928 at the proposal of Carlos Monge, professor of clinical medicine in the San Marcos Faculty of Medicine. Monge is director and administrative head of the Institute, and Alberto Hurtado, professor of pathological physiology, is director of research. The following account is based on a visit to the Institute and interviews with Hurtado.

High-Altitude Man

Peru offers strategic advantages for the study of high-altitude effects. Here, as in Chile, the Andes rise precipitously almost out of the ocean, and within a few miles of the coast one can mount from sea level to heights of 14,000 to 20,000 feet. Because of this peculiar topography there have been several expeditions of research scientists from other countries, and prominent among them was the visit of the British-American group of 1921-22. This expedition was led by the distinguished British physiologist Joseph Barcroft and it included representatives from the universities of Cambridge, Edinburgh and Harvard, the Massachusetts General Hospital of Boston, the Presbyterian Hospital of New York and the Rockefeller Institute for Medical Research. The Central Railway of Peru, the chief artery of transport between the seacoast and the mining centers on the mountains, placed a baggage car at the disposal of the visitors, and the car served as a mobile laboratory for their studies at the various heights they occupied during the two months of their stay in Peru. This was one of the historic projects in high-altitude research. Its findings threw new light on many problems of anoxia, and the official report of the expedition, which Barcroft published in the *Transactions* of the Royal Society in 1923, attracted wide attention in scientific circles. "It became a text of absorbing interest to members of our Faculty of Medicine in Lima, particularly to those concerned with human physiology," said Hurtado. "I was a student in the United States, in the third year of my medical course at Harvard, when this publication appeared."

The fact that eminent biologists had traveled halfway around the world to study anoxia in their Peruvian Andes was like a shot in the arm to the small group of budding physiologists in Lima. It pointed up the fact that Lima students of high-altitude physiology did not need to travel outside their own country, for here, almost on their doorstep, was a research setup all ready and waiting. More than four million Peruvians lived at elevations between 6,000 and 13,000 feet; and another 165,000 dwelt above 13,000 feet, including a few hundreds in mines above 15,000 feet. There was therefore at hand ample opportunity to observe how the human body reacts, not only temporarily in persons recently ascended from sea level, but in whole populations who were born, reared and had lived to maturity and old age under continuous exposure to low oxygen pressure.

"Professor Barcroft and his associates gave little attention to study of the mountaineers," said Hurtado. "To be sure, they did report a few incidental observations regarding the natives' anatomical and physiological characteristics, but these studies were an almost insignificant part of their program. The primary subjects of their investigations were themselves, and it was their own pulse rates, blood counts, vital capacities and other respiratory factors that the expedition members recorded at various stages of their ascent from sea level up to more than 14,000 feet. The assumption seemed to be that man at sea level was the normal human being."

Yet to most Peruvians, sea-level conditions are the rare exception. Over the centuries, countless millions have lived their entire lives working at heavy labor in the mines and on the slopes, without ever experiencing the "normal" atmospheric pressure of 14 pounds to the square inch. Surely here is a phenomenon deserving of study and offering a promise of interesting results. It was this sort of thinking that prompted the establishment of the Institute of Andean Biology.

"In our research there is no slighting of the man accustomed to sea-level conditions, who doubtless represents the majority of the world's population," explained Hurtado. "But equally we do not ignore the well-acclimated man accustomed to the low pressure of the mountain heights, who surely represents the maximum of adaptation to anoxic conditions. We study them both. We have measured the breathing performance, blood content and blood circulation of high-altitude men in our mountain stations, and then have brought the same individuals down to sea level and repeated the measurements there. Similarly, we have studied sea-level men in

Lima, and then have taken them to Morococha and measured the same properties and capacities at 14,900 feet. Finally we have compared the reactions of high-altitude men with those of sea-level men at both elevations—and have found some striking contrasts."

The findings are of interest to lay people as well as scientists, but before taking them up it may be helpful to look briefly at the Institute, its stations and equipment.

From 490 to 16,500 Feet

The Institute of Andean Biology has three laboratories. One is at Lima, seven miles from the Pacific shoreline, which at its elevation of only 490 feet may be considered sea level; a second laboratory is at Huancayo, in the western range of the Andes some 300 miles southeast from Lima, at an altitude of 10,700 feet; while the third is at Morococha, 90 miles due east from the capital and at 14,900 feet altitude. In addition to its main station, Morococha has a branch at the nearby mining camp of San Nicolas for observations at 16,500 feet. Nor are these mountain laboratories isolated outposts. Huancayo is a teeming city of 27,000 occupied primarily with farming, cattle raising and other agricultural pursuits; Morococha is a mining town with some 8,000 residents; and although San Nicolas is rated as a camp, it has a permanent population of 800, workers in the nearby Volcán Mines. The Institute thus is organized to make laboratory studies over the altitude range from sea level up to more than three miles, with ample human material at each site to serve as subjects for the research.

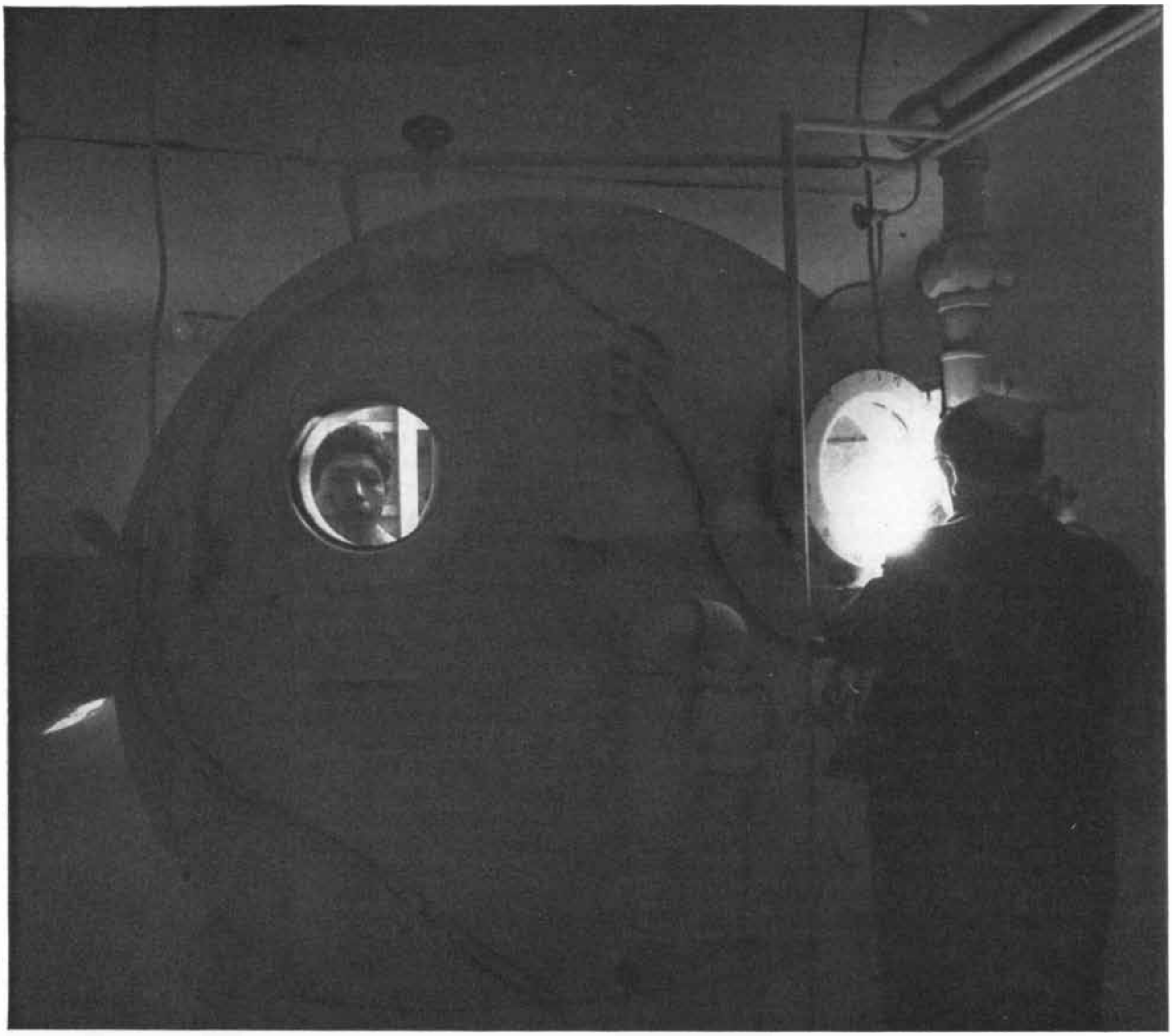
Staff members live in Lima or its suburbs. They go to the mountain stations for periods of observation, and bring the records of their high-altitude studies down to Lima for analysis. Each trip up and back means a new experience in adaptation, which varies with the individual; once Dr. Hurtado lost 32 pounds during a year of intermittent stay in Morococha.

The Lima laboratory is housed in one wing of the Loayza Hospital, a large infirmary operated in association with the Faculty of Medicine. The laboratory has a complete assembly of apparatus for the study of respiratory, circulatory and metabolic changes, and as Hurtado escorted us through its many rooms, introducing his staff associates and telling briefly of their work, he pointed to instrument after instrument. There was a large treadmill, used to measure the work capacity of a subject, a Barclay flame photometer, a high-sensitivity galvanometer, a Millikan oxymeter, an ergometer and many another tool of this specialized research. Much of the equipment was the gift of the Rockefeller Foundation, which also provided fellowships for the postgraduate training of 11 of the 20-man staff.

Recently assistance has come from other sources. There is an X-ray installation for studying the size of the heart, lungs and other internal organs, and an altitude chamber for which a special room has been built—both here on indefinite loan from the U. S. Air Force.

At the end of our laboratory tour, we entered a small room in which a man

VIEW FROM THE MOROCOCHA STATION shows Andean peaks rising above the town of Morococha. Morococha is 90 miles east of Lima. It has a population of 8,000. The Institute also has a station at Huancayo, 300 miles southeast of Lima at 10,700 feet.



ALTITUDE CHAMBER at the Morococha station is used to investigate the effects of stratospheric atmospheres on men who are already accustomed to life at high altitudes. At the left an experimental subject looks through an observation window in the chamber.

was seated. He was small of stature, copper-colored, with jet-black hair and deep-set eyes. He got up hastily and bowed. "This is a man from Morococha," the scientist explained, "a native who had lived there all his life until he lost his adaptation and became distressingly ill, with dizziness, nausea and fatigue. It is a condition which occasionally strikes high-altitude dwellers and it was first systematically studied back in 1928 by Dr. Monge—a chronic *soroche* or mountain sickness, known as Monge's disease. Apparently the illness is a result of the blood's overproduction of red cells, which means of course an overabundance of hemoglobin, the oxygen-carrying pigment. At sea level a normal person in good health has from 15 to 16 grams of hemoglobin in each 100 cubic centimeters of blood, at the altitude of Morococha the average is 19 to 20 grams, but this man had 26 grams per 100 cc. when we measured him last week at the peak of his illness. That is about the highest hemoglobin content I have ever observed—it's what a man theoretically would need at 20,000 feet."

Hurtado had brought the mountaineer down to Lima both to relieve his acute condition and to study him. The man's blood had thinned and was now close to the sea-level average, his headache and other symptoms had disappeared and he was fast becoming a completely adapted sea-level man.

This tour of the Lima laboratory was on a Saturday, and arrangements were made for a trip to Morococha the following week. "There are other visitors from the United States," said the research director, "and we'll make a party of it and call for you at 8 a.m. in our station wagon."

The drive up the mountain was a weird and unforgettable experience. Leaving the faint haze that perpetually envelops Lima in the Peruvian midwinter of July, we passed through clouds and sunshine up a paved road that continuously curved as it climbed. The Central Railway of Peru paralleled our course, first on one side of the highway and then, crossing under, on the other. The trains short-cut through 80 tunnels on the way up, but our station wagon, breathing through its humming supercharger, wound around cliffs and over precipices, chugged through the mountain towns of Chosica, Matucana, San

TREADMILL at the Morococha station is used to study metabolism during exercise. Here pulse, respiration rate, oxygen uptake and carbon dioxide output of subject are analyzed.

Mateo and Casapalca, past sloping terraces of potato plantings and diminutive cornfields, now threading deep gorges, sometimes clinging to a narrow shelf of a perpendicular palisade, but always climbing. At one place we were stopped by a red flag, and as we waited we saw a bulldozer a hundred feet above us nuzzling loose rocks over the side of the cliff. Some of them were as big as our car and 50 times heavier. One gigantic chunk, crashing down, bounced over the road into a eucalyptus grove and hurtled down the slope. Just before noon we reached Morococha.

Morococha

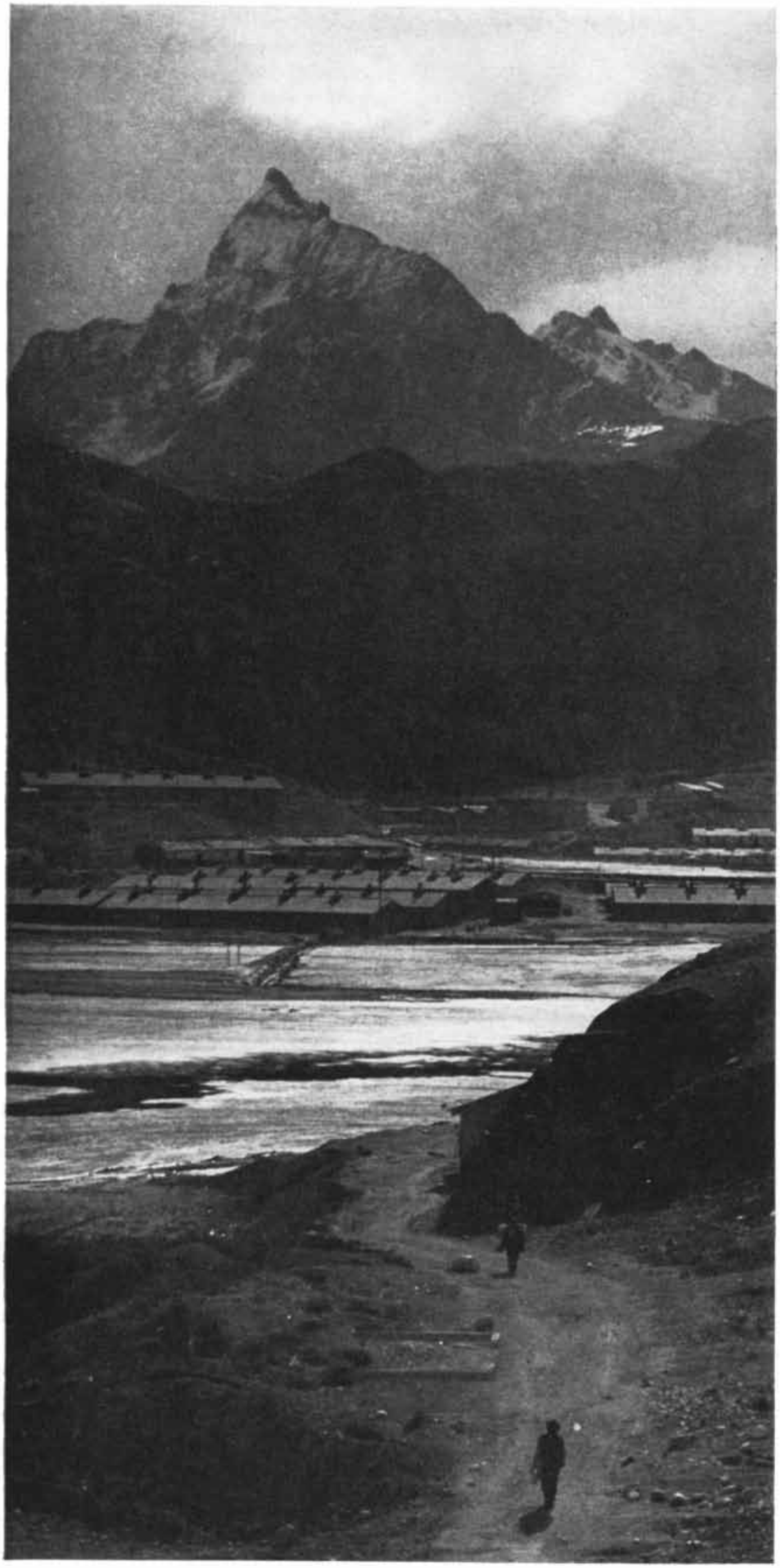
"Don't smoke," cautioned Hurtado, as the nervous visitor fingered his cigarette pack in a reflex of indecision and restlessness. He had dropped into an armchair in the common room of the laboratory and was plainly ill at ease—as were we all after that 90-mile drive up to this rocky cleft in the Andes. Outside the window the snow-clad peak of Yanasinga towered another 1,000 feet above Morococha's 14,900, reminding us that there were yet greater heights and still thinner rations of air.

The Indian woman who keeps house for the staff brought a tray of orange juice. Each of us took a glass, and Hurtado handed out aspirin tablets. We were still limp from the exertion of climbing out of the car, climbing up the half-dozen steps to the laboratory entrance and stumbling to our chairs. But, as we rested, the feelings of lightheadedness, weakness and clumsiness gradually abated, and when lunch was announced everybody responded with appetites that did it full justice. After the meal all felt ready for a guided tour of the place. But we stepped gingerly as we were shown from room to room; and seeing the bluish tinge which colored the lips of our companions we could not keep from wondering how many grams of hemoglobin per 100 cubic centimeters were pounding through our veins.

The Morococha laboratory occupies a two-story stone building erected with funds provided by the Peruvian government. It is thoroughly modern, and, thanks to the proximity of the power plant of the Cerro de Pasco copper mines, has electricity and running water as well as heat and the usual conveniences. The first floor is mainly occupied with research equipment, the second has dormitory quarters for 10 persons, and there are also three beds on the research floor. The laboratory duplicates most of the apparatus seen in Lima, for the same kind of measurements have to be taken here. There is even an altitude chamber, a twin of the one we had inspected at Lima, also on loan from the U. S. Air Force. The altitude chamber is able to simulate pressures up to those of the stratosphere, and it is being used to see how persons acclimatized to 14,900 feet react when subject to the conditions of still higher levels.

The most amazing sight of our three hours at Morococha was a group of residents playing soccer. While we sea-level tenderfeet were laboring over every step and panting at the slightest extra exertion, these men of Morococha were running and shouting, kicking the ball, chasing it, evading and pursuing one another, continuously in motion—and with no sign of discomfort.

"We have made actual measurements of the Morocochans' endurance under heavy exercise," said Hurtado, "and their capacity for physical exercise is prodigious. In one study, 10 volunteers from the Peruvian Navy served as our control group. The treadmill was set to move 363 feet per minute up an 11-percent grade, and the test was to see how long each man could climb before reaching exhaustion. The experiment was begun in the Lima laboratory. It was the altitude to which the sailors were accustomed, but most of them had to give up after 30 minutes of climbing—although one man kept going a full hour. Then we shifted to Morococha, allowed



COPPER MINES near Morococha maintain its high-altitude population. Electric power generated for the mines makes possible the operation of extensive equipment in the laboratory.

the sailors a month to get adapted, and found that there they were able to walk the mill only four minutes, on the average. By way of comparison, we next tested five engineers, natives of the U. S., who were employed at the mines and had been living at Morococha from two to five years. They did better than the sailors—but six to eight minutes was the limit of their endurance. Finally we tested a group of men who had lived on the mountain from birth—and most of them stayed with the moving treadmill about an hour; one kept climbing 96 minutes."

The high-altitude men thus not only outdid the sea-level men at 14,900 feet, but they were able to turn out more work at their accustomed mountain level than the sailors were at their accustomed sea level. And they did it, as the measurements showed, with a number of surprising differences—a proportionately smaller consumption of oxygen, less production of lactic acid and a lower oxygen debt.

"This astonishing ability to scrimp on oxygen use, to reduce lactic-acid production and to get along with less oxygen debt, constitutes an extraordinary degree of adaptation," said Hurtado. "The biological processes of respiration are conditioned at every turn by a purely physical phenomenon—the behavior of gases—and we want to know how it is that at high altitude the Morococha native is apparently better able than his sea-level cousin to accommodate himself to the gas laws."

The Rule of the Gas Laws

The gas laws, which Hurtado mentioned as controlling respiration, are indeed basic to our subject. Oxygen must get from the atmosphere to tissue cells deep within the body, where the gas is needed to burn sugar and other fuels. At the same time carbon dioxide gas, a waste product of this burning, must be eliminated from the tissue cells and discharged into the atmosphere. The gas laws ordain that a gas will move only from a place of higher pressure (or tension) to one of lower. In order, then, to maintain the two-way transport of the breathing process, it is necessary that the oxygen tension be progressively lower as one moves from the atmosphere in toward the tissue cells—and that, conversely, the carbon dioxide tension be progressively lower as one moves from the tissue cells to the outer air.

The atmospheric pressure of 14 pounds to the square inch at sea level is measured by the barometer, in which a column of mercury rises in an evacuated glass tube to the height of 760 mm. When the barometer is carried to higher altitudes, the column of mercury in the tube descends, and at the elevation of Morococha it stands at only 442 mm., which corresponds to a pressure of slightly more than 8 pounds to the square inch.

But oxygen comprises only about 21 per cent of the mixture which makes up air; the major constituent of course is nitrogen, and air also contains a small inclusion of carbon dioxide and usually some water vapor in addition to traces of rare gases. According to the gas laws, each constituent exerts a fraction of the total pressure proportional to its part of the mixture. This means that of the 760 mm. measured at sea level, oxygen is responsible for only 21 per cent of the pressure, or about 158 mm.; the rest being provided by the weight of the nitrogen and other gases. Thus, although the whole air at its total pressure of 760 mm. is inhaled, it is only the partial pressure of the oxygen that counts in pushing the indispensable gas into the tiny air pockets, or alveoli, of the lungs, where the blood threads its way through delicate capillaries to throw off the unwanted carbon dioxide and take on the precious oxygen. The partial pressures of the incoming air from the atmosphere, the outgoing air from the lungs, and the gases within the alveoli were found at sea level to be as tabulated on this page.

	INCOMING AIR	OUTGOING AIR	ALVEOLAR AIR
OXYGEN	158.25 mm.	116.2 mm.	102.5 mm.
CARBON DIOXIDE	.30 mm.	28.5 mm.	40.0 mm.
NITROGEN	596.45 mm.	568.3 mm.	570.5 mm.
WATER VAPOR	5.00 mm.	47.0 mm.	47.0 mm.
TOTAL PRESSURE	760.00 mm.	760.00 mm.	760.00 mm.

PARTIAL PRESSURE of principal gases inhaled and exhaled at sea level are given in this chart. The pressure of gases in the alveoli, or air sacs, of the lungs is also tabulated.

The tabulation shows at once the wherefore of the two-way traffic. The pressure of carbon dioxide in the alveoli is so much greater than that in the incoming air, that the carbon dioxide will fairly rush to get out. But in the case of oxygen, the difference is in the opposite direction. The pressure of oxygen in the alveoli is so much lower than that of the oxygen in the incoming air, that the latter will stream into these inner air pockets to diffuse from there through the thin walls into the blood. And this diffusion is able to proceed because the amount of oxygen in the incoming blood is such that its tension is lower than that of the oxygen in the alveoli.

Suppose now we transfer the sea-level man to Morococha. There the total pressure of the atmosphere is 442 mm. and the partial pressure of atmospheric oxygen only 93. This partial pressure on the mountain is lower than that of oxygen in the alveolar air at sea level, as shown in our table, and a man suddenly lifted from Lima to Morococha—if it could be done in the twinkling of an eye—would assuredly be in acute distress, with the oxygen pressure within his lungs greater than that of the outer atmospheric oxygen. Actually, of course, a progressive adjustment takes place as one ascends the mountain, and by the time the sea-level man has reached Morococha his alveolar oxygen has attained the partial pressure of 50 mm., which Hurtado finds is normal for that elevation. But in a very swift ascent, such as the balloonists Tissandier, Sivel and Crocé-Spinelli experienced in the *Zenith*, it might be that the atmospheric pressure decreased so much faster than the alveolar pressure in the lungs of the passengers, that there was an actual reversal of the differential.

The point is that the gas laws rule, and the body brings into play mechanisms which keep the oxygen moving continually inward to the tissue cells. One of the body's resources in promoting this inward traffic is the chemical affinity of hemoglobin, the pigment of the red blood cells. There is a mutual attraction between the atoms of oxygen and the molecules of hemoglobin, and they readily join to form a compound known as oxyhemoglobin. So an early defensive move of the body is to release additional red cells into the blood, each cell packed with hundreds of millions of molecules of hemoglobin. The number of oxygen carriers thus is increased, thereby enhancing the probability of picking up oxygen from the alveolar air. A second stratagem in the man newly arrived from sea level is the acceleration of the heart's contractions, which speeds up the flow of blood. The tissue cells thus receive more blood per second, and this blood is richer in its hemoglobin content. There is still a third adjustment, and that is an increase in the volume of air taken into the lungs and expired in a given time. This deeper breathing results in a small but significant rise of the oxygen tension over the level imposed by the diminished atmospheric pressure.

"The native of Morococha also has this increased pulmonary ventilation—that is, his lungs take in a greater volume of air than is normal at sea level," said Hurtado, "but there is no increase in the rate of heart contractions nor in the amount of blood pumped beyond the limits which are considered normal. In this way, he is able to preserve his heart from undue strain. There are other characteristics in the native. His adjustments are more deep-seated and profound than those of the émigré from sea level. The significance of our research is not limited to high-altitude physiology, for anoxia is associated with many illnesses which occur at sea level. The knowledge that we gain of the efficient adaptive mechanisms which enable the high-altitude man to compensate for anoxia may be useful from a clinical point of view. There is thus a practical incentive for our study of these people whose bodies, from their birth and even before, have been molded by the heights."

Molded by the Heights

The native of Morococha appears to be built for life on the mountain. His most obvious bodily endowment for coping with low atmospheric pressure is a large chest occupied by a larger than normal pair of lungs. Barcroft was impressed by this during his Peruvian expedition, and wrote in 1923 that "the native of five feet three inches has the chest of a man of six feet." Hurtado has made a systematic study of chest dimensions both in Lima and in Morococha, measuring them externally as well as in X-ray photographs. He found that the high-altitude native has a markedly larger lung area; and while his chest has a vertical diameter smaller than that of the Lima resident, its diameter from back to front and also from left to right is greater, giving it a rounder shape and larger volume.

These measurements take on added significance when we consider the smaller stature and lighter weight of the native. Hurtado finds that the mean height of Morocochans is 157 centimeters (five feet, 1.8 inches), to compare with 169 cm. (five feet, 5.4 inches) for residents of Lima. The ratio of weight to height is also lower; a fat person is a rarity among the high-altitude natives. John H. Lawrence of the University of California, who spent several weeks in research at the Institute in 1950, made a study of the body-fat constant, using an isotope of hydrogen as the tracer. He found that Morocochans averaged only 17.7 per cent of fat in their body weight, to compare with 24 per cent for Lima. This higher proportion of lean to fat seems important from the point of view of acclimatization. Hurtado has suggested that it may explain, in part at least, some of the metabolic differences which he and his associates have observed in the natives during physical activity—for less fat means "a decreased pack load."

Not only are the lungs proportionately larger, but the hearts of high-altitude natives are also, thus providing the blood with a more powerful pump. And there is a difference too in the source of the extra red cells which the body pours into the bloodstream. In the sea-level men moving to high altitude the source is the spleen, which serves as a temporary storage center for reserves of red cells; but in the high-altitude native it is the bone marrow, the tissue which makes red cells, that launches the additional oxygen carriers into the circulation—and it turns them out in enormous numbers daily. Studies at the Institute show that red cells die at about the same rate at which they are produced, and thus the circulation is never clogged with too many—a condition that exists chronically in the disease known as polycythemia, which is occasionally found among sea-level people.

"A lowering of oxygen tension in the blood seems to stimulate the bone marrow to an increased output of red cells, and we are trying to find the means by which it does this," said Hurtado. "Another problem is the changed behavior of hemoglobin at high altitude. Its affinity for oxygen is not as strong in Morococha as it is in Lima, and this we believe is a compensatory mechanism which enables the red cells to let go their oxygen more readily when they reach the tissue cells where the oxygen is needed. Just how this weakening of the bond between the gas and the pigment is brought about we do not know. It may be that the molecular structure of hemoglobin is different at high altitudes. We plan to investigate that possibility, both with the ultracentrifuge and with the analytical method of electrophoresis."

It is under the stress of physical work, when muscles are called into action by violent exercise, that the differences between the adaptation of sea-level man and that of high-altitude man become most conspicuous. For a muscle to act it must burn sugar, which means that it must have oxygen, and this demand is of course superimposed on the normal, constant, continuous oxygen consumption of the body at rest.

"When at rest," explained Hurtado, "there is no difference between the high-altitude man and the sea-level man in their consumption of oxygen. But at high physical activity, such as one must do to climb our treadmill, the high-altitude man shows his superiority. He can do heavier work, as we have seen, and he can keep at it longer. Moreover, this greater activity is accompanied by less production of lactic acid.

"His decreased production of lactic acid takes on special significance when we remember that lactic acid is formed when the need for oxygen is not satisfied in the active muscle. The accumulation of lactic acid produces, or at least accompanies, fatigue. Unless oxygen is available to oxidize the acid, the muscle eventually enters into a state of rigor, followed by exhaustion. It was natural to suppose that the accumulation of lactic acid would be accelerated at high altitude, where oxygen is in short supply and at low pressure.

"But such is not the case, and the first to report this was H. T. Edwards of the Harvard Fatigue Laboratory. He was a member of the International High Altitude Expedition which studied anoxic reactions at various levels in the Chilean Andes in 1935. In these investigations Dr. Edwards noticed that the production of lactic acid in himself and other members of the expedition was not excessively high, but on the contrary was approximately the same as at sea level. This was surprising. However, the subjects of his study also showed a marked decrease in their ability to exercise at high altitude, and so the low lactic-acid values were interpreted as a consequence of low work output. But our findings at Morococha are fundamentally different, because in the native mountaineers the decreased production of lactate is associated with a greater actual performance of work than the control group was able to accomplish, even at sea level."

DIRECTOR of the Institute for Andean Biology is Carlos Monge (*right*). Alberto Hurtado (*left*), professor of pathological physiology in the Institute, is its director of research.

During violent exercise, muscles may operate for many seconds or even minutes without adequate oxygen. It is estimated that in a 100-yard sprint occupying a few seconds the runner's oxygen requirement may be more than six liters, whereas the maximum consumption possible is not over four liters per minute. In this emergency situation the muscles operate with a minimum of oxygen, "go in debt" for what they lack, and replenish their stores when the burst of activity is over. The recovery period during which an oxygen debt is being repaid may last 80 minutes or more—and the amount of the debt is determined by measuring the oxygen used during that period and then subtracting from it the quantity used during a rest period of equal length.

Here again the high-altitude man has an advantage. Researchers at the Institute of Andean Biology have found that the oxygen debt, proportioned to body weight, is about 15 per cent less in Morococha natives than in sedentary people in Lima. Measurements made of Lima athletes give them an intermediate position between the two extremes.

"Now all these differences must have a bearing on adaptation," Hurtado reasons. "The fact that at high altitude the acclimatized man has a greater capacity for exercise, and that he accomplishes this with less expenditure of energy, with a decreased lactate production, and with less oxygen debt, suggests the existence of compensatory mechanisms at the level of the muscles and other tissues. That is to say, it is not only the breathing apparatus and the circulatory system that have made readjustments to the lowered oxygen supply. In addition, we believe, the tissue cells to which the blood delivers the oxygen also participate in the acclimatization. Indeed, it would be strange if this were not so. It would be strange if the body, in order to adapt itself to a condition of oxygen shortage, should modify, as we have seen, some of the processes for acquiring oxygen at the lung level and also for its transport to the tissues, and then leave unchanged the unloading and utilization of this gas where it is finally used."

The search for adaptation at the tissue level is a primary interest of the Institute's program at present, and results are beginning to appear.

For example, there is a form of hemoglobin known as myoglobin, which is found in muscles and had been thought to serve as an agency for storing oxygen. Some years ago R. T. Clark, an investigator at the School of Aviation Medicine at Randolph Field in Texas, observed that rats which were made to exercise while living at low oxygen pressure in an altitude chamber built up extra supplies of myoglobin in their muscles. Following this clue, Tulio Velasquez of the Institute staff took a score of rabbits to Morococha, left them free to exercise, and then at fortnightly intervals made biochemical analyses of muscular tissues. After four months he found a sharp rise in the content of myoglobin, which was most marked in skeletal muscle, less in white muscle and least in heart muscle. "We are now investigating myoglobin in native animals," said Hurtado. "Physiologists believe that one of its functions may relate to the quick loading and unloading of oxygen—a facility that should be extremely useful to muscles called on to function at high altitude. If an increase of the substance is definitely confirmed in our high-altitude animals, it will be evidence of a tissue compensatory process."

Van R. Potter, professor of oncology at the McArdle Memorial Laboratory for Cancer Research at the University of Wisconsin, visited the Institute at the invitation of Hurtado and spent four months in tissue studies. Potter worked with two groups of guinea pigs, one born and reared at sea level, the other at 14,000 feet. He studied muscle tissue in the two sets of animals, and focused his inquiry on the activity of succinoxidase, an enzyme system which contributes to the utilization of oxygen. The tests showed a higher activity in the Morococha animals than in those living at sea level, and this activity, Potter says, "is believed to reflect an increased amount of enzyme per unit weight of tissue." After Potter's return to Wisconsin, Donald W. Tappan of the same faculty went to Peru, where he has confirmed and extended the finding. Collaborating with them has been Baltazar Reynafarji of the Institute staff.

In addition to searching for tissue changes at the chemical level, Hurtado and his group have looked for possible changes in the number, size and structure of the blood capillaries which thread among the tissue cells. In guinea pigs they have found that animals born and reared at high altitude have many more capillaries per muscle fiber than those raised at sea level, and these studies are now being extended to human material. The Cerro de Pasco Copper Corporation maintains a hospital at Morococha, and from the amputations and operations performed there specimens of muscle and other tissues are available for analysis.

"Then it would seem, from all these superior adaptations, that the natives of Morococha are endowed with bodies designed by heredity to operate under the low-pressure conditions which meet them at birth. Is that your conclusion?" Hurtado was asked.

"No," he answered. "I don't think we are dealing with a new physiology related to a race especially fit for life at high altitudes and different from the one which corresponds to the sea-level man. I believe these characteristics represent only compensatory modifications imposed by the environment on a common physiological pattern. As Barcroft has pointed out, acclimatization to high altitudes is made up of a series of integrated adaptations. But there is a difference between the adaptation of the native and that of the newcomer. My personal opinion is this: The tolerance to high altitude acquired by a newcomer is based mainly on respiratory, circulatory and hematological changes, while the natural acclimatization which is present in a man born and raised on the heights is chiefly in tissue adjustments. And it is these deep-rooted adjustments that we are now trying to determine."

An International Center of Research

In addition to Drs. Potter and Tappan, several other investigators from the U. S. have studied physiological problems at the Institute. The visit of Dr. Lawrence of the University of California was mentioned earlier; he has a special interest in polycythemia, and wanted to compare the blood composition and other characteristics of high-altitude natives with those of victims of the disease. Donald Gregg of the Walter Reed Hospital spent three months at the Institute, investigating the physiology of the blood circulation. F. G. Steggerda of the University of Illinois was another recent research visitor; he experimented on himself to study gastrointestinal gases at high altitudes.

Both the U. S. Air Force and the U. S. Public Health Service have called on Institute members to explore certain problems of high-altitude physiology. A group from the Air Force School of Aviation Medicine has spent some time at Morococha studying problems of anoxia from the point of view of aviation.

"Our idea is to make this Peruvian institution an international outpost of science," said Hurtado, "and we are happy that so many investigators in the United States have already recognized the advantages which our unique site and completely modern facilities offer."

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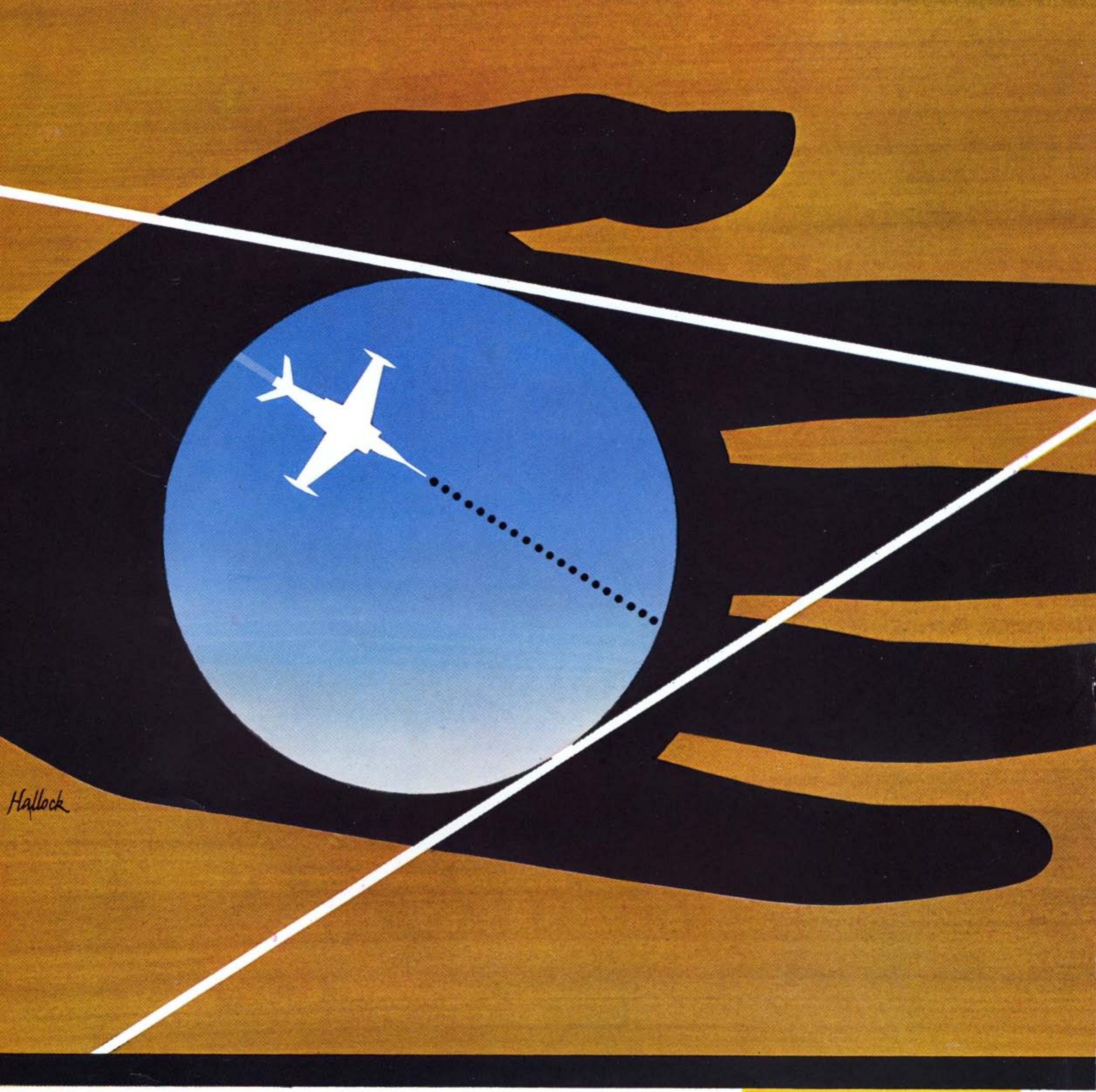
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Isaac Newton

This inward, quarrelsome man, who often forgot to eat his meals, invented the calculus and laid the foundations of mechanics and optics—all in 18 "golden" months after graduating from college

by I. Bernard Cohen

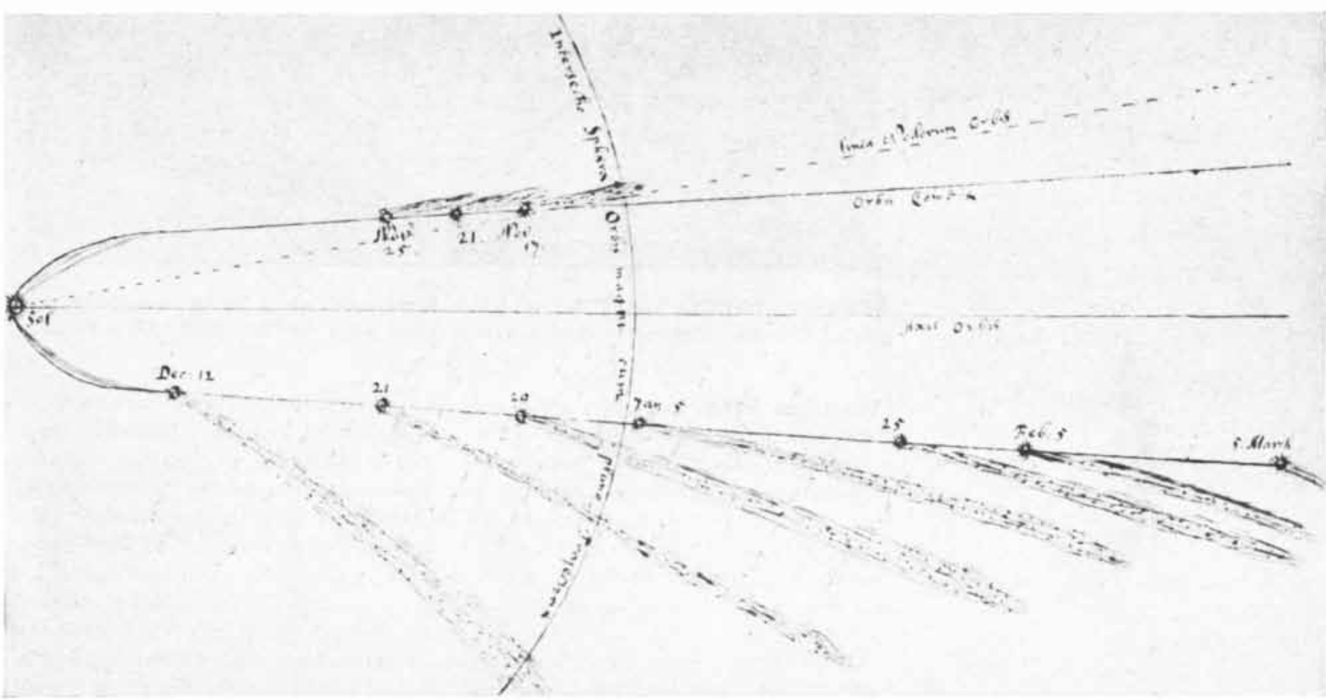
The mind and personality of Isaac Newton challenge any historian. Newton was a strange, solitary figure, and the wellsprings of his behavior were hidden even from his contemporaries. A biographer of his time compared Newton to the River Nile, whose great powers were known but whose source had not been discovered. Nevertheless, the few facts we have about his early life do allow some speculation about Newton's character and development.

He was born prematurely, a physical weakling. It is said that he had to wear a "bolster" to support his neck during his first months, that no one expected him to live. Newton later was fond of saying that his mother had said he was so tiny at birth that he could have been put into a quart mug.

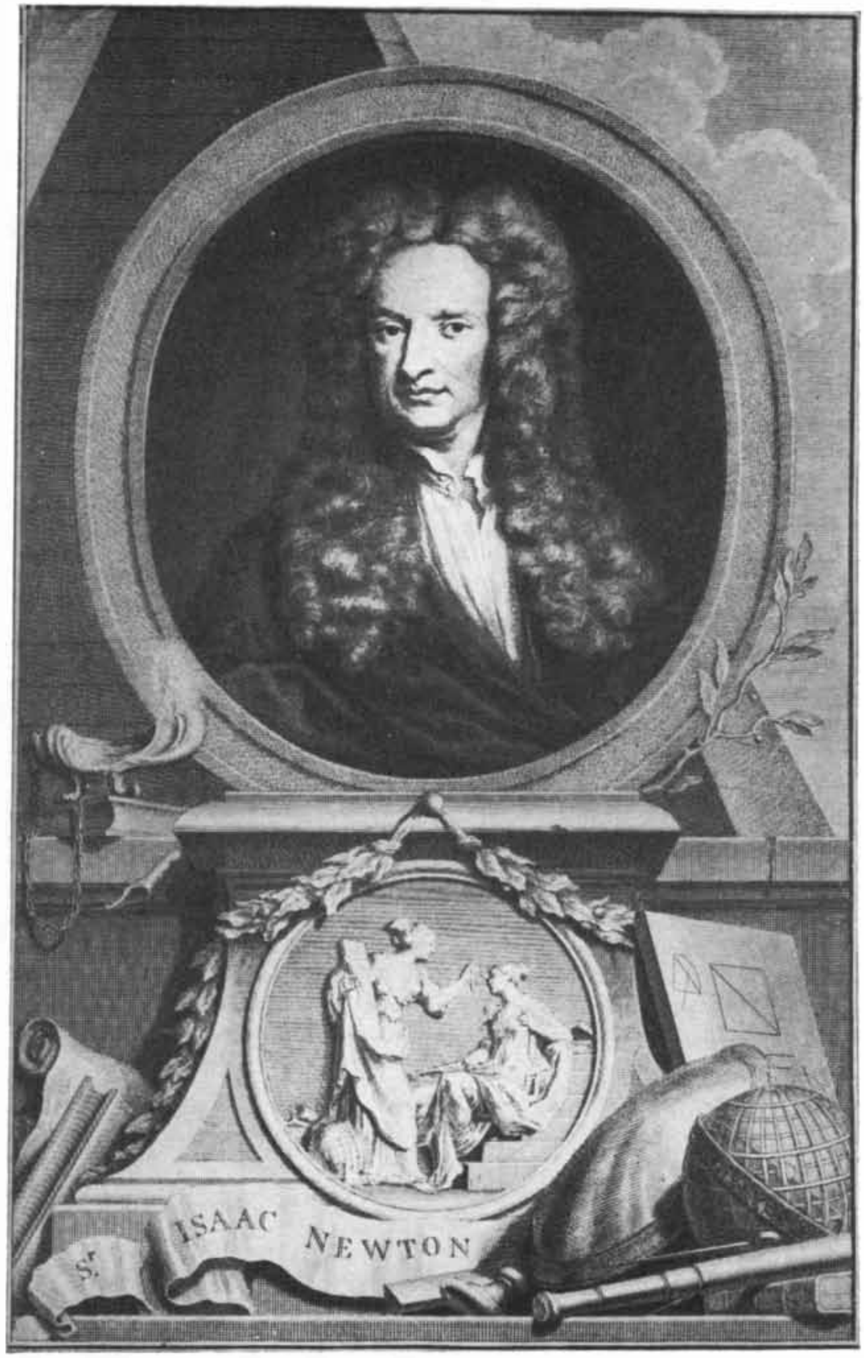
Newton's father died three months before he was born. When the boy was less than two years old, his mother remarried, and he was turned over to his aged grandmother. He lived on an isolated farm, deprived of parental care and love, without the friendly companionship and rivalry of brothers and sisters. The late Louis T. More, author of the best-known modern biography of the man, held that much of Newton's "inwardness" could be attributed to his lonely and unhappy childhood.

Born in 1642, Newton grew up in an era when England was still tasting the "terrors of a protracted and bitter civil war." Raiding and plundering parties were common. His grandmother was "suspected of sympathy to the royal forces." In the face of these real terrors and "the frights of his imagination," he could not have received much comfort from his grandmother or the hired laborers on the farm. Naturally enough, as More observed, the boy turned to "the solace of lonely meditation" and developed a strong habit of self-absorption. A girl who knew him in his youth described him as a "sober, silent, thinking lad" who "was never known scarce to play with the boys abroad, at their silly amusements."

He evidently overcame his physical weakness by the time he reached school age, for a schoolmate reported that Newton challenged a bully who had



ORBIT of Halley's comet in its appearance of 1682 was bound into the first edition of the *Principia*. Newton pointed out that comets as well as planets are subject to the inverse square law of gravitation. This hand-drawn picture was made by an unknown draftsman.



NEWTON'S "SILENT FACE," behind which Wordsworth saw a "mind voyaging strange seas of thought," appears in this engraving based on a painting by Godfrey Kneller.

kicked him in the belly to a fight and "beat him till he would fight no more"—winning out because he had "more spirit and resolution." The bully stood high in the class, and Newton was so determined "to beat him also at his books" that "by hard work he finally succeeded, and then gradually rose to be the first in the school."

When Newton was 14, his mother took the boy back into her home, her second husband having died. She conceived the idea of making him a farmer, but the experiment proved an unqualified failure. Newton found farming totally distasteful. Instead of attending properly to his chores, he would read, make wooden models with his knife, or dream. Fortunately for science, his mother gave up the attempt and allowed him to prepare for Cambridge University.

At the age of 18, Newton entered Trinity College. In his early years at the University he was not outstanding in any way. Then he came under the influence of Isaac Barrow, a professor of mathematics and an extraordinary man. He was an able mathematician, a classicist, an astronomer and an authority in the field of optics. Barrow was one of the first to recognize Newton's genius. Soon after his student had taken a degree, Barrow resigned his professorship so that Newton might have it. Thus at 26 Newton was established in an academic post of distinction and was free to pursue his epoch-making studies.

He had already sown the seeds of his revolutionary contributions to three distinct fields of scientific inquiry: mathematics, celestial mechanics and physical optics. After his graduation from the University he had returned to his home at Woolsthorpe for 18 months of work which can fairly be described as the most fruitful 18 months in all the history of the creative imagination. Newton's subsequent life in science consisted to a large degree in the elaboration of the great discoveries made during those "golden" months. What Newton did at Woolsthorpe is best stated in his words:

"In the beginning of the year 1665 I found the method for approximating series and the rule for reducing any dignity [power] of any binomial to such a series [*i.e.*, the binomial theorem]. The same year in May I found the method of tangents of Gregory and Slusius, and in November [discovered] the direct method of Fluxions [*i.e.*, the elements of the differential calculus], and the next year in January had the Theory of Colours, and in May following I had entrance into the inverse method of Fluxions [*i.e.*, integral calculus], and in the same year I began to think of gravity extending to the orb of the Moon . . . and having thereby compared the force requisite to keep the Moon in her orb with the force of gravity at the surface of the earth, and found them to answer pretty nearly. . . ."

As a by-product of his analysis of light and colors, which he had shyly kept to himself, Newton invented a reflecting telescope, to free telescopes from the chromatic aberration of refracting lenses. He made a small version of his new telescope for the Royal Society of London, and was shortly elected, at the age of 30, as a Fellow of the Royal Society, the highest scientific honor in England.

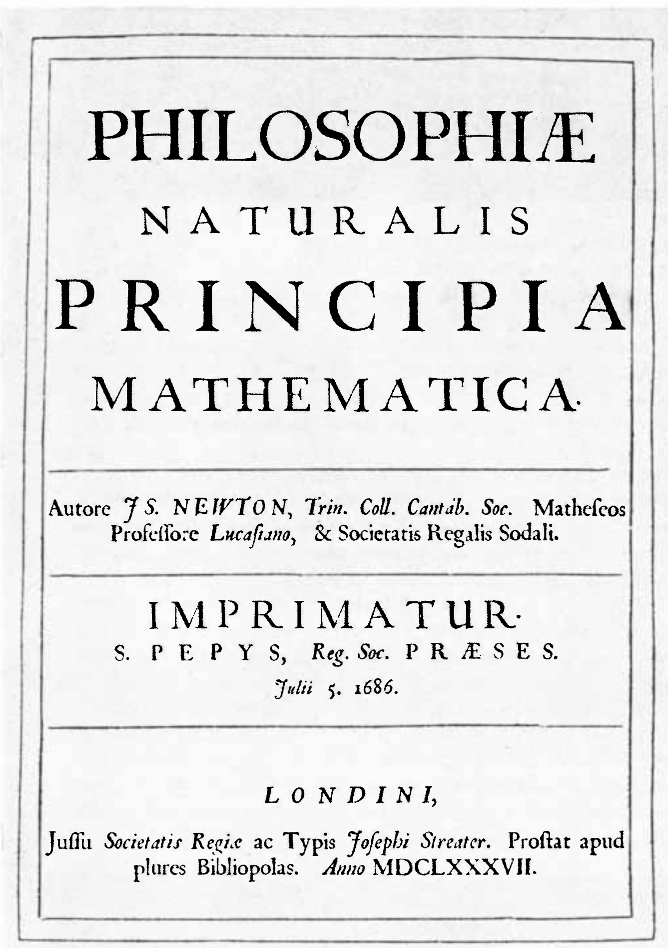
Newton was understandably overwhelmed by his sudden public recognition. He had been loath to announce his discoveries, but within a week after his election to the Society he asked permission to communicate an account of the "philosophical discovery" which had induced him "to the making of the said telescope." With a disarming lack of false modesty, he said that in his judgment he had made "the oddest, if not the most considerable detection, which hath hitherto been made in the operations of nature."

Newton's letter to the Royal Society, "containing his new theory of light and colours," was sent to London on February 6, 1672. This paper can claim a number of "firsts." It was Newton's initial publication; it founded the science of spectroscopy, and it marked the beginning of a sound analysis of color phenomena. Briefly, what Newton showed is that a prism separates white light into its component colors, associated with specific indices of refraction, and that a second prism can recombine the dispersed light and render it white again. These magnificent experiments provided a new departure for the formulation of theories about the nature of color. Yet the paper did not win for Newton the universal applause that he had sought. The Royal Society was bombarded with letters disputing Newton's conclusions. Some of the objectors were unimportant, but others were men of stature: Christian Huygens, Robert Hooke. With astonishing patience, Newton wrote careful letters answering each objection. But he won over only one of his opponents—the French Jesuit Father Pardies.

The controversy had an acid effect on Newton's personality. He vowed that he would publish no further discoveries. As he wrote later to Leibnitz: "I was so persecuted with discussions arising from the publication of my theory of light, that I blamed my own imprudence for parting with so substantial a blessing as my quiet to run after a shadow." And yet he did later continue to publish; he wanted the applause of the scientific world. This ambivalence was not overlooked by Newton's enemies. The astronomer John Flamsteed, who broke with Newton, described him as "insidious, ambitious, and excessively covetous of praise, and impatient of contradiction. . . . I believe him to be a good man at the bottom; but, through his nature, suspicious."

At Cambridge Newton was the very model of an absent-minded professor. His amanuensis, Humphrey Newton (no relative), wrote that he never knew Newton "to take any recreation or pastime either in riding out to take the air, walking, bowling, or any other exercise whatever, thinking all hours lost that was not spent in his studies." He often worked until two or three o'clock in the morning, ate sparingly and sometimes forgot to eat altogether. When reminded that he had not eaten, he would go to the table and "eat a bite or two standing." Newton rarely dined in the college hall; when he did, he was apt to appear "with shoes down at heels, stockings untied, surplice on, and his head scarcely combed." It was said that he often delivered his lectures to an empty hall, apparently with as much satisfaction as if the room had been full of students.

After the controversy, Newton withdrew from the public eye as a scientist. He served the University as its representative in Parliament and worked away in private at chemistry and alchemy, theology, physics and mathematics. He became acquainted with Leibnitz, but refused to give his great contemporary any exact information about his discoveries in mathematics. Today it is gen-



PHILOSOPHIÆ NATURALIS PRINCIPIA MATHEMATICA.

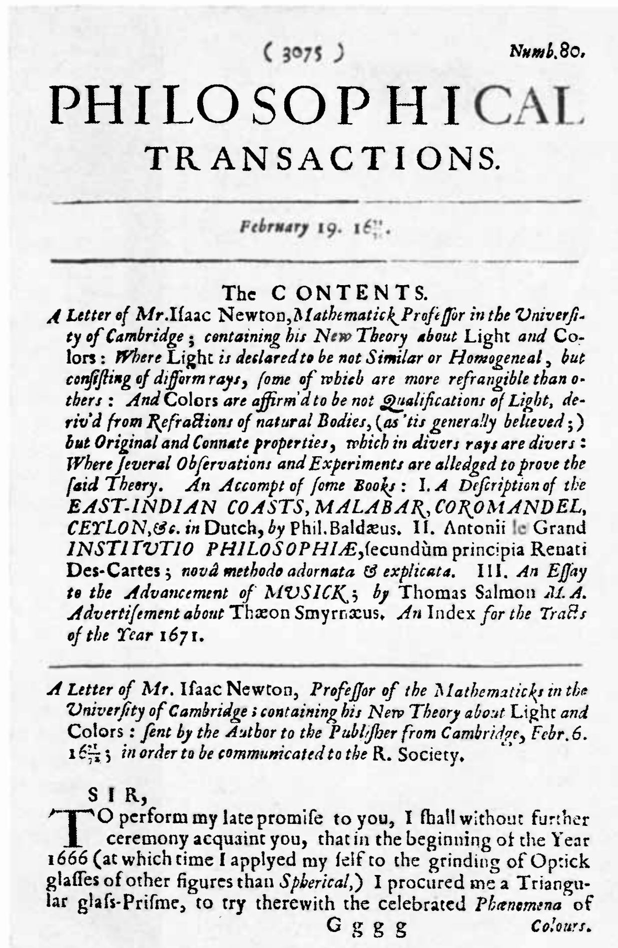
Autore J S. NEWTON, *Trin. Coll. Cantab. Soc.* Mathefeos Profeffore *Lucafiano*, & Societatis Regalis Sodali.

IMPRIMATUR. S. PEPYS, *Reg. Soc.* PRÆSES. *Julii* 5. 1686.

LONDINI,

Juffu *Societatis Regiæ* ac Typis *Jofephi Streater.* Proftat apud plures Bibliopolas. *Anno* MDCLXXXVII.

TITLE PAGE of the *Principia* described Newton as Lucasian professor of mathematics at Cambridge. The "imprimatur" was signed by the diarist Samuel Pepys, who was then the president of the Royal Society.



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PHILOSOPHICAL TRANSACTIONS.

February 19. 16$\frac{71}{72}$.

The CONTENTS.

*A Letter of Mr.*Ifaac Newton,*Mathematick Profeffor in the Univerfity of Cambridge; containing his New Theory about* Light *and* Colors: *Where* Light *is declared to be not Similar or Homogeneal, but confifting of difform rays, fome of which are more refrangible than others: And* Colors *are affirm'd to be not Qualifications of Light, deriv'd from Refractions of natural Bodies, (as 'tis generally believed;) but Original and Connate properties, which in divers rays are divers: Where feveral Obfervations and Experiments are alledged to prove the faid Theory. An Accompt of fome Books:* I. *A Defcription of the EAST-INDIAN COASTS, MALABAR, COROMANDEL, CEYLON, &c. in* Dutch, *by* Phil. Baldæus. II. Antonii le Grand *INSTITUTIO PHILOSOPHIÆ*, fecundùm principia Renati Des-Cartes; *novâ methodo adornata & explicata.* III. *An Effay to the Advancement of MUSICK; by* Thomas Salmon *M. A. Advertifement about* Thæon Smyrnæus. *An* Index *for the Tracts of the Year* 1671.

A Letter of Mr. Ifaac Newton, *Profeffor of the Mathematicks in the Univerfity of Cambridge; containing his New Theory about* Light *and* Colors: *fent by the Author to the Publifher from Cambridge, Febr.* 6. 16$\frac{71}{72}$; *in order to be communicated to the* R. Society.

SIR,

To perform my late promife to you, I fhall without further ceremony acquaint you, that in the beginning of the Year 1666 (at which time I applyed my felf to the grinding of Optick glaffes of other figures than *Spherical,*) I procured me a Triangular glafs-Prifme, to try therewith the celebrated *Phænomena* of

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NEWTON'S first communication to the Royal Society announced his discovery that white light is a mixture of many colors which can be separated by a prism and then recombined.

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erally agreed that the calculus was discovered more or less independently by both Newton and Leibnitz, but the two men and their partisans quarreled acrimoniously over priority, and Newton accused Leibnitz of plagiarism. Newton conceived a jealous proprietary interest in every subject he studied, and almost every achievement of his creative life was accompanied by some quarrel.

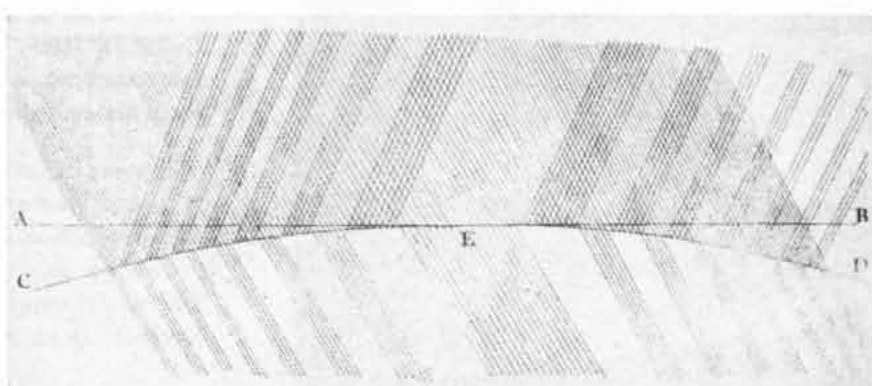
In 1684 came the famous visit to Newton by the astronomer Edmund Halley. He had a problem concerning the gravitational attraction between the sun and the planets. Halley and Hooke had concluded from Johannes Kepler's accounting of planetary motions that the force of attraction must vary inversely with the square of the distance between a planet and the sun. But they had been unable to prove their idea. "What," Halley asked Newton, "would be the curve described by the planets on the supposition that gravity diminished as the square of the distance?" Newton answered without hesitation: "An ellipse." How did he know that? "Why," replied Newton, "I have calculated it." These four words informed Halley that Newton had worked out one of the most fundamental laws of the universe—the law of gravity. Halley wanted to see the calculations at once, but Newton could not find his notes. He promised to write out the theorems and proofs. Under Halley's insistent urging he completed a manuscript for the Royal Society. Thus was born the *Philosophiae Naturalis Principia Mathematica*, known ever since simply as the *Principia*.

Just before its publication a crisis arose when Hooke laid claim to the inverse-square law. Newton threatened to withdraw the climactic chapters of his work, but Halley mollified him and the great classic went to press intact. Halley's credit in this enterprise is enormous. He not only got Newton to write the work but also saw it through the press and paid the costs of publication, although he was not a wealthy man.

The *Principia* is divided into three "books." In the first Newton laid down his three laws of motion and explored the consequences of various laws of force. In the second he explored motion in various types of fluids; here he was somewhat less successful, and much of his work had to be revised in the succeeding decades. In the third he discussed universal gravitation and showed how a single law of force explains at once the falling of bodies on the earth, the motion of our moon or of Jupiter's satellites, the motions of planets and the phenomenon of tides.

One of the most vexing problems for Newton was to find a rigorous proof that a sphere acts gravitationally as if all its mass were concentrated at its center. Without this theorem, the whole theory of gravitation would rest on intuition rather than precise calculation. For instance, in the simple case of an apple falling to the ground—the occasion of the central idea of gravitation according to Newton's own account—what is the "distance between" the earth and the apple? Here the calculus came into play. Newton considered the earth as a collection of tiny volumes of matter, each attracting the apple according to the inverse-square law of gravitation. Then he summed up the individual forces and showed that the result was the same as if the earth were a point mass, as if all the matter of the earth were shrunk into a tiny region at its center.

Newton suffered some kind of "nervous breakdown" after the completion of the *Principia*. He complained that



NEWTON'S RINGS are explained in this diagram from the *Opticks*. The lines AB and CD represent the plane and convex surfaces of a pair of lenses which Newton pressed together to obtain the well-known pattern of colored rings. His interpretation of the result was that moving light corpuscles (*slanted lines*) are put into alternate "fits" of reflection and refraction by passing through the varying thicknesses of the air space between the lenses.

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he could not sleep, and said that he lacked the "former consistency of his mind." He wrote angry letters to friends and then apologized; he protested bitterly to John Locke, for example, that the philosopher had attempted to "embroil him with women."

In 1696 Newton abandoned the academic life for the position of Warden, later Master, of the Mint. Honors for his scientific achievements continued to come to him: he was knighted in 1705 and served many years as president of the Royal Society. But the last quarter century of his life produced no major contributions to science. Some say that his creative genius had simply burned out. Others argue that after having founded the science of physical optics, invented the calculus and shown the mechanism of the universe, there just wasn't anything left for him to do in the realm of science.

Although he made no important discoveries, Newton's last years were not barren of ideas. Now famous and honored, he felt secure enough to offer many public speculations on scientific problems. He suggested various possible hypotheses as to the "cause" of gravitation and speculated on the nature of the "aether," the size of the constituent units of matter, the forces of electricity and magnetism, the cause of muscular response to the "commands of the will," the origins of sensation, the creation of the world, the ultimate destiny of man. In the century after Newton physical experimenters followed up many of his bold speculations.

Newton is often described as the inaugurator of the "Age of Reason." Alexander Pope expressed the sentiment of his time in the famous lines:

Nature and Nature's laws lay hid in night:
God said, Let Newton be! and all was light.

But the late Lord Keynes called attention to another side of Newton: his quest for an answer to the riddle of existence, his intense interest in alchemy, occult philosophy and religious studies, his unorthodox theological views. Anyone who reads the nonscientific writings of Newton, or even the speculations he published in the *Opticks* toward the end of his life, will not be wholly satisfied with Pope's famous couplet. He will, perhaps, prefer the summary by William Wordsworth, who wrote of Newton:

. . . with his prism and silent face,
. . . a mind forever
Voyaging through strange seas of thought, alone.

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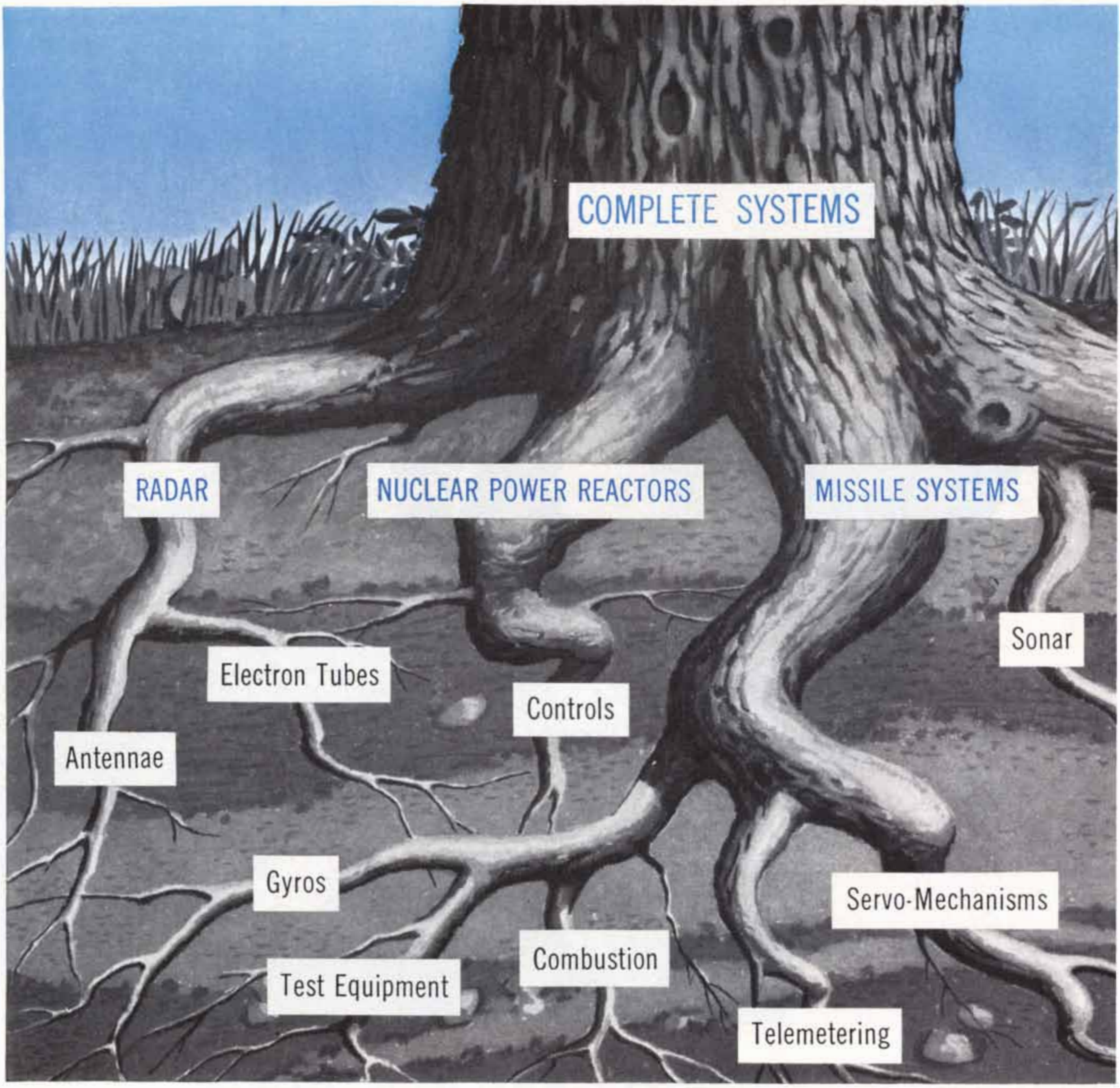

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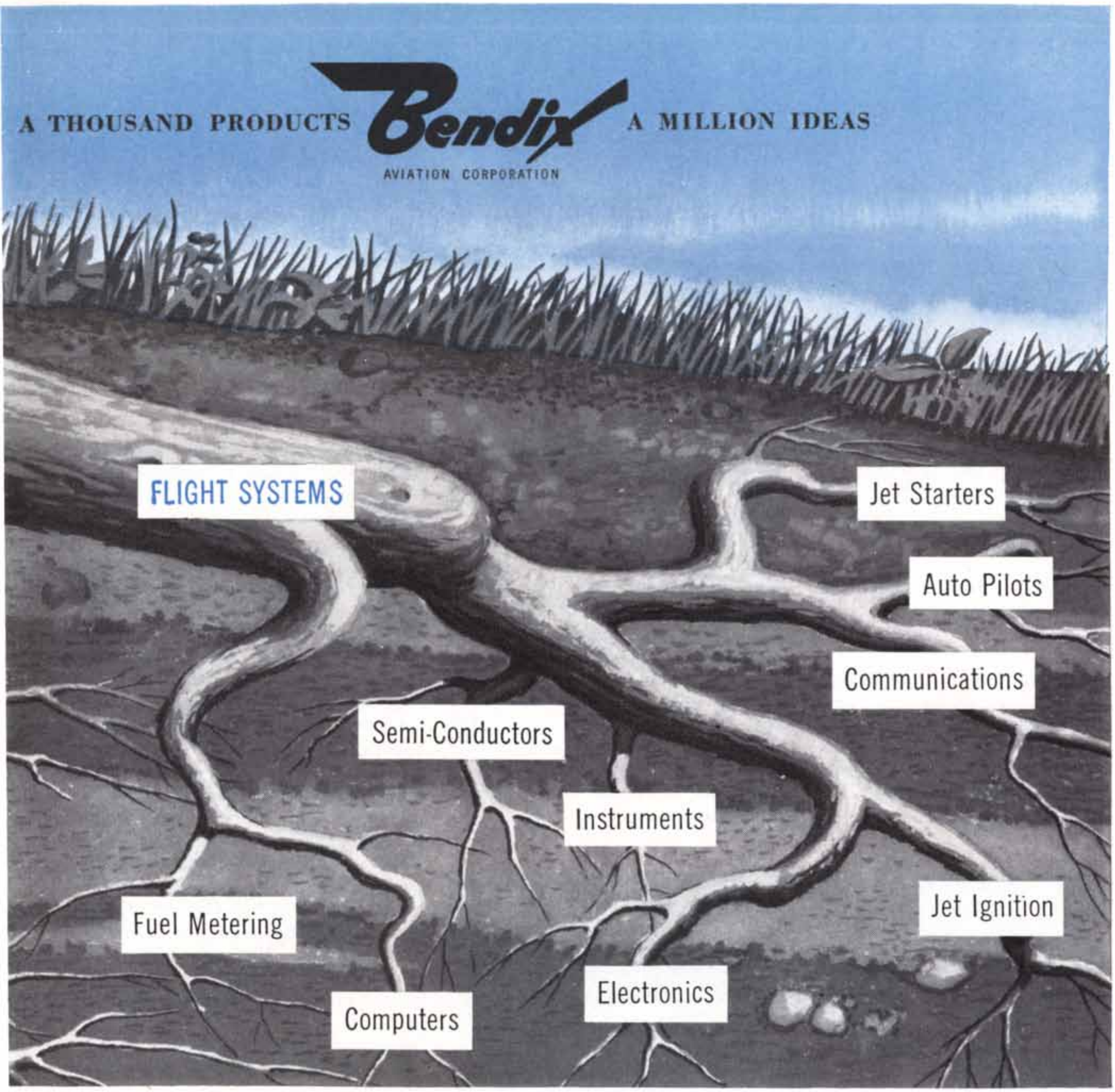

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A Model of the Nucleus

As an aid to understanding the atomic nucleus, physicists visualize it in terms of simplified models. A surprisingly fruitful approach is to regard it as a cloudy crystal ball

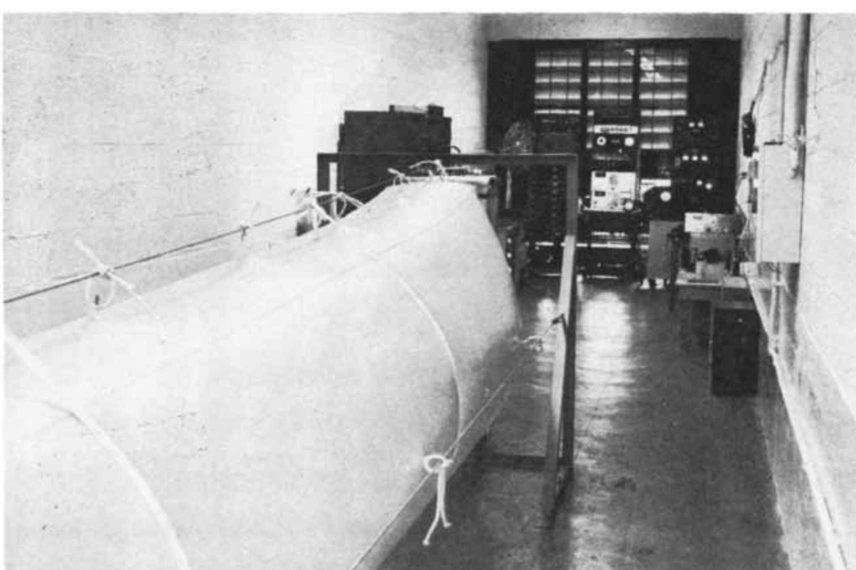
by Victor F. Weisskopf and E. P. Rosenbaum

Modern physics is frequently accused of deserting the real world for abstract mathematics. Instead of attempting to explain nature in terms of what we can see and feel, the impeachment runs, theoretical physicists offer only an arid set of equations whose physical meaning they will not even think about, let alone interpret to the vulgar.

The reproach is not deserved. Nearly every physical theory begins with some model by which the physicist seeks to interpret it. It is true that as a theory grows more sophisticated the model tends to lose its connection with everyday experience. But the physicist never ceases to be conscious of the fact that his equations represent an endeavor to account for the behavior of a real, physical universe.

The field of nuclear physics is still an unfamiliar territory; hence model-building is a major occupation of its investigators. In the nucleus of the atom we are dealing with an entirely new kind of matter: an unimaginably dense material composed of protons and neutrons, collectively called nucleons. How these parts interact, what law governs the enormous force they exert on each other—these are still mysteries. Therefore we cannot yet make use of the elegant mathematical methods of quantum mechanics, which have so successfully explained the properties of ordinary matter, involving only electrons. Until the force acting inside the nucleus is as well understood as the electrostatic force that acts on the atomic electrons outside, the equations for nuclear matter cannot be written. And so, to help organize the facts learned by experiments in nuclear physics laboratories, and to guide the imagination toward useful insights, nuclear physicists have recourse to various simple, intuitive models picturing a hypothetical structure of the nucleus.

Every model we build is an effort to make sense of some particular class of experimental results. In our attempts to get at the invisible world of the nucleus we are in the position of the three blind men examining an elephant: different experiments bring out different aspects of the subject. Hence our different models are not mutually exclusive. As we shall see, they can often be combined to give a more complete understanding.

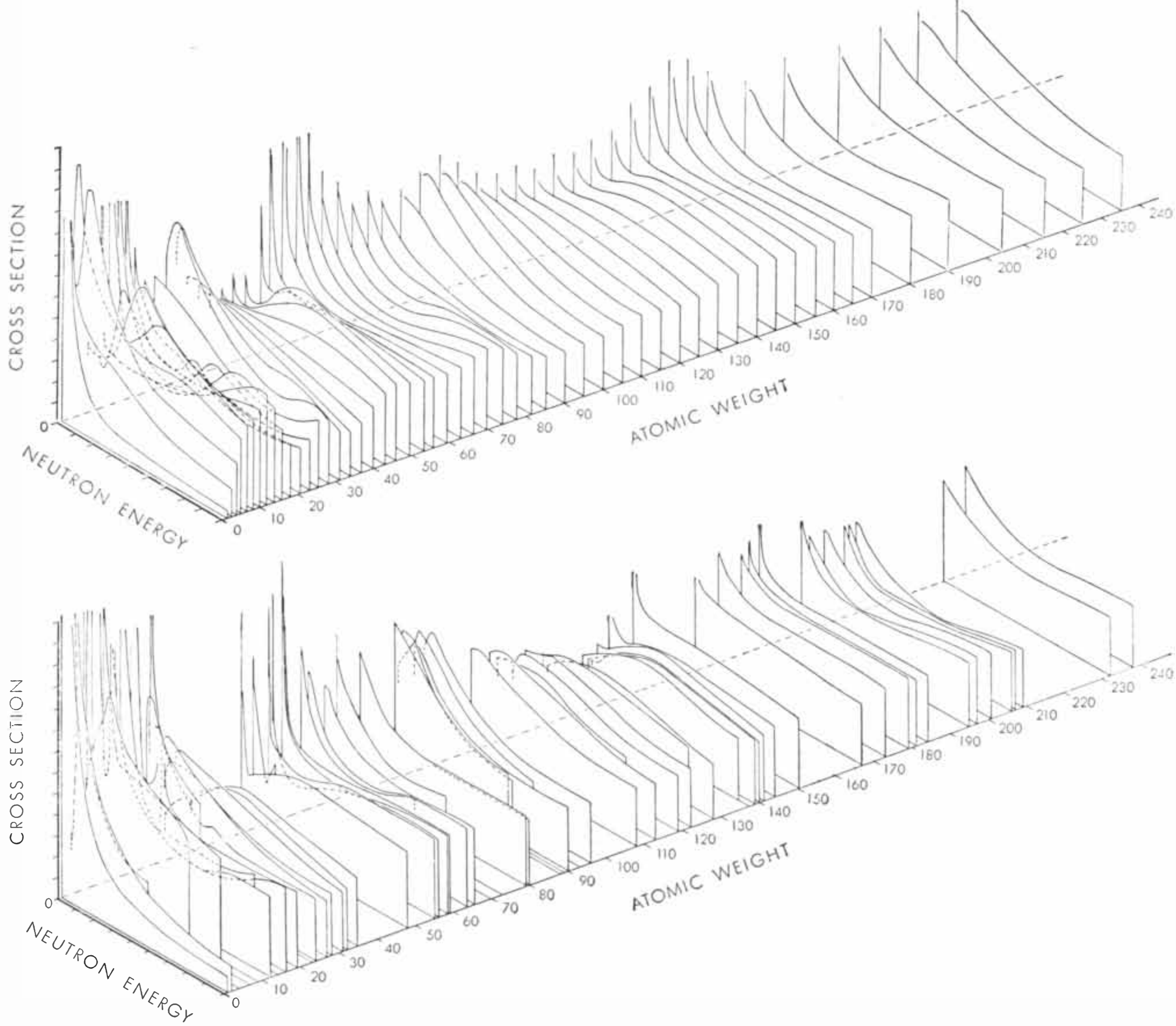


CROSS-SECTION EXPERIMENT using slow neutrons from the reactor at Brookhaven National Laboratory is depicted in this photograph. Bursts of neutrons from the pile pass through the target material (*not shown*) and then into the long helium-filled balloon in the left foreground. A scintillation counter immediately behind the balloon detects the incoming neutrons, separating them as to energy by their time of arrival. The helium path is provided because nitrogen atoms in air absorb neutrons and would weaken the beam.

We shall describe here a very simple model of the nucleus which has been surprisingly successful in predicting some quite complex behavior. It sidesteps the question as to how the individual nucleons may interact, concentrating instead on what might be called the gross structure of nuclear matter. To understand how the model works we should first know something about the specific experiments it was designed to illuminate.

The experiments have to do with bombardment of the nucleus with neutrons. These uncharged particles can easily enter the nucleus, because they are not resisted by the electrostatic force of the nucleus' positive charge.

Consider a simple, fundamental experiment. A sheet of iron about a quarter



NEUTRON CROSS SECTIONS of all the elements as predicted by the cloudy-crystal-ball model are shown at the top. The actual values found by experiment appear below. The graphs are three-dimensional, with atomic weight increasing horizontally to the right, the energy of the probing neutrons increasing in the direction from the plane of the page out toward the reader, and the cross section increasing vertically upward. The range of neutron energies shown extends from zero to about three million electron volts.

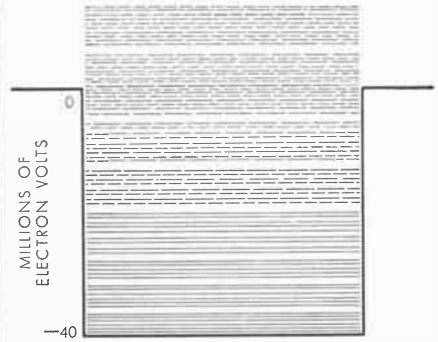
of an inch thick is exposed to a stream of neutrons flowing at a certain known rate, in particles per second, with all the particles moving at about the same speed. Some of the neutrons will pass straight through the thin sheet of iron. Some will be deflected by collisions with nuclei of iron atoms. Some will be captured, or absorbed, by nuclei. Behind the sheet a detector counts the number of neutrons that have passed straight through (those that are deflected miss the detector). Subtracting the number of neutrons that hit the detector from the number that entered the sheet, we get the number scattered or absorbed.

All these neutrons have collided with iron nuclei (assuming that the sheet is pure iron). Hence the percentage of neutrons scattered or absorbed tells us what fraction of the cross-sectional area hit by the beam is effectively covered by nuclei. We know, from the weight of the iron, the number of atoms in this area. Thus we can calculate the area of interception represented by each nucleus. This area is called the scattering and absorption cross section of the iron nucleus for neutrons of the given speed.

When the experiment is performed with fairly energetic neutrons (about 15 million electron volts), the cross sections of various nuclei turn out to obey a rather simple law. Each nucleus has an effective area about equal to that of a circle whose radius is found by the formula: 1.4 times the cube root of the atomic weight times 10^{-13} centimeters. The length unit 10^{-13} centimeters has informally been given the name "fermi," after the late Enrico Fermi. The atomic weights of the natural elements range from one to 238, so the cross-section radii range in length from 1.4 fermis to about 9 fermis.

Experiments with other types of bombarding particles, such as protons, yield the same result, when we make corrections for the effects of electrostatic force in their case. It appears that the cross section actually is a physical area.

Now we can describe the foregoing experiment in other terms, considering the neutron not as a particle but as a wave. We translate particle language into wave language by means of these two definitions: (1) the amplitude, or strength, of a wave at any point indicates the probability of finding a particle at that point—a strong wave means a high probability; (2) the frequency of a wave measures the energy of its parti-



WELL PICTURE of the nucleus with discrete energy levels is diagrammed schematically. Solid horizontal lines represent orbits which are normally filled; dotted lines are orbits which are not occupied unless a nucleon acquired more than its normal energy. Levels above the top of the well indicate that a nucleon may have more than 40 million electron volts of motion-energy and still revolve in an orbit within the nucleus.

cle—high frequency (short wavelength) means a fast particle, low frequency (long wavelength), a slow particle.

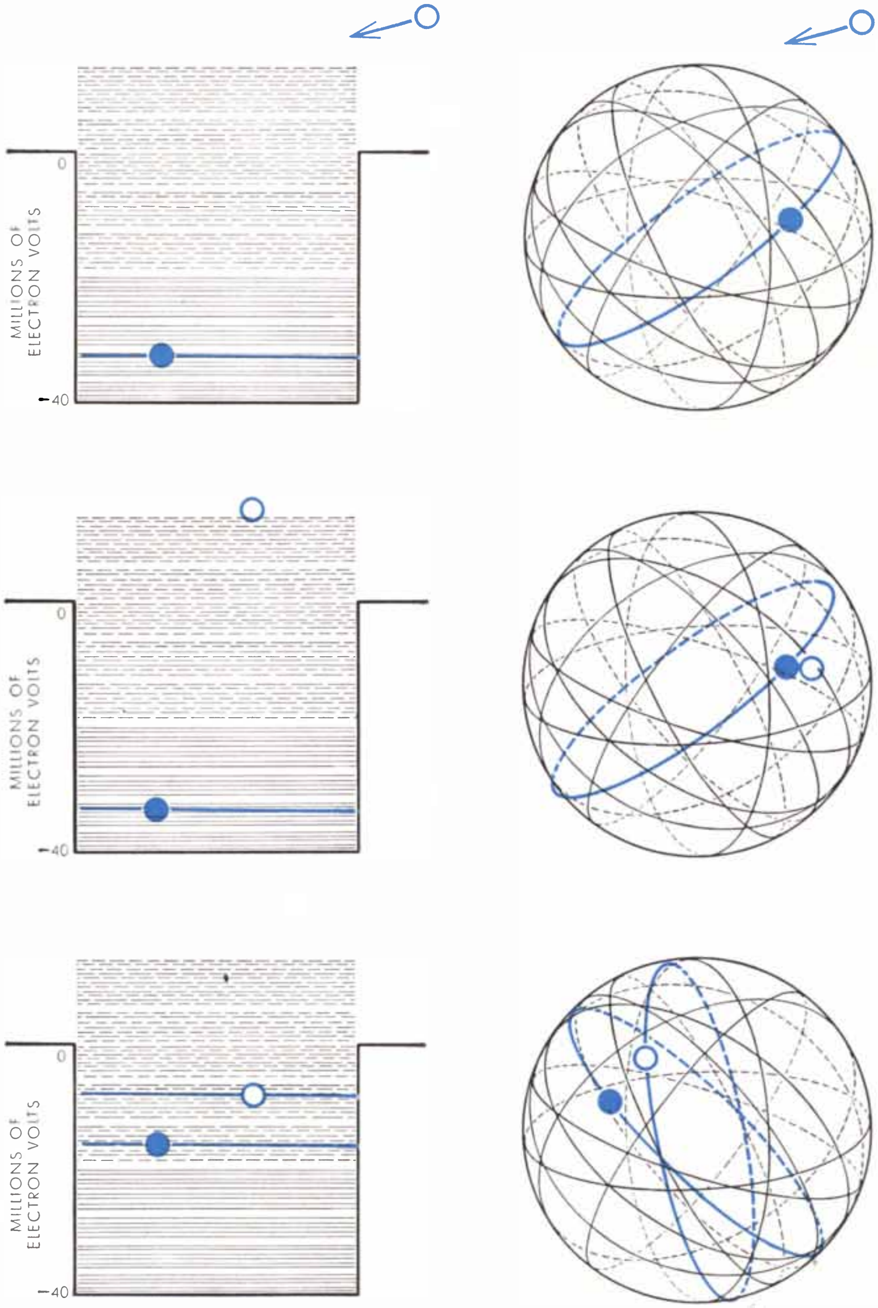
In wave terms the cross-section experiment might read as follows: A sheet of iron is placed in a monochromatic (single-frequency) beam of short-wave neutrons. (An energy of 15 Mev corresponds to a wavelength of about six fermis.) The scattering and absorption of neutrons is measured by the dimming of the brightness of the beam in its passage through the sheet. In these terms, for neutrons of the specified wavelength the iron nucleus acts as an opaque ball with a radius of 1.4 fermis. It blocks a portion of the neutron "light" beam and casts sharp shadows.

This wave description is very useful in interpreting the experiment. It suggests an optical model.

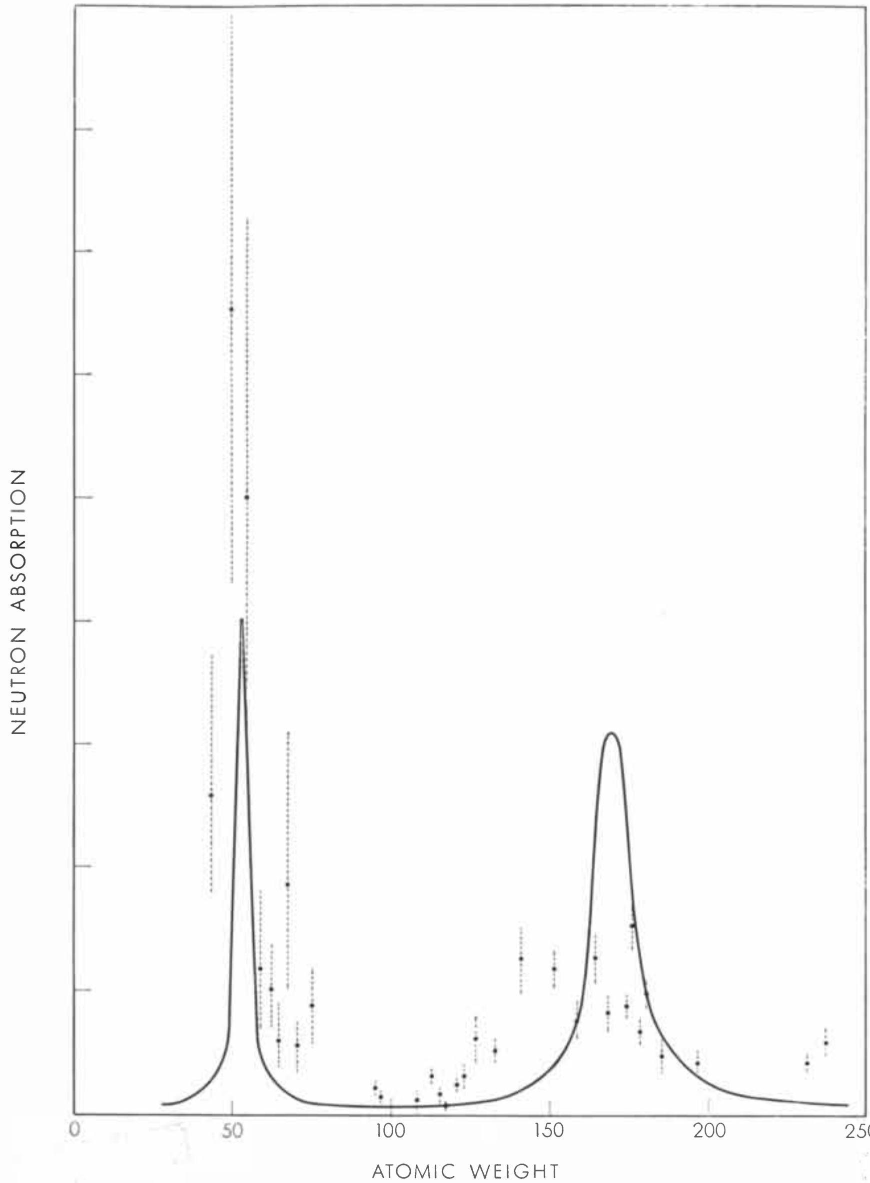
Thinking in optical terms, we are at once led to suspect that the results of cross-section experiments should depend on the wavelength of the neutrons used. For one thing, a beam whose wavelength is considerably longer than the nuclear radius will not cast sharp shadows, just as a long water wave washing around a small rock will not cast any appreciable "shadow" of calm water behind it. Yet the rock will cut off a little of the water wave's energy. If a harbor were dotted with separate small, exposed rocks, one could compute how much energy they would extract from incoming waves. In much the same way we can figure out how much energy an assembly of opaque nuclei should subtract from a long-wave neutron beam. When this computation is compared with actual measurements, however, it is found to be far off. The nuclei do not block nearly as much energy as they would be expected to. In fact, they act as though they were almost transparent to the waves! Nuclear matter, regarded as optical material, is opaque to short-wave neutrons but becomes more and more transparent as the wavelength of the neutrons increases. As observed in the "light" of slow neutrons, the nucleus looks like a cloudy crystal ball.

Let us see how this model helps us to understand the phenomena observed in experiments.

A beam of light passing through a group of semitransparent glass balls would, of course, be dimmed. Some



NEUTRON ABSORPTION is illustrated in these drawings. Left-hand diagrams show energies, right-hand diagrams, locations in space. At the top, a bombarding neutron (*open dot*) approaches the nucleus. Solid dot represents the nucleon destined to be hit, colored lines, its orbit. Middle diagrams show particles just before impact, when no energy has been exchanged. In the final result (*bottom*) the neutron has lost energy, dropping into a vacant orbit, and the target nucleon has picked up the energy, jumping to a higher orbit. The energy transaction is possible only if both particles find vacant positions. Cloudiness, or tendency to absorption, increases with the energy of the bombarding neutron because high-energy impacts put both particles into the upper, sparsely populated orbit region, while low-energy impacts leave them in the lower region where they are less likely to find vacancies.



STRONG ABSORPTION for nuclei of atomic weights near 55 and 155 is predicted by the optical model. The solid curve shows the absorption called for by the theory, the dots represent experimental observations. Dashed lines indicate the limits of experimental error.

light would be lost because of bending of rays out of the beam, the amount depending on the index of refraction of the glass. Some would be lost by absorption within the balls, the amount depending on the glass's coefficient of absorption, or cloudiness. If the index of refraction and the absorption coefficient are known, we can calculate by optical theory the amount of dimming for balls of any size and spacing.

By means of certain experiments it is possible to estimate the refraction index and the absorption coefficient of nuclear matter. We can then predict how strongly a neutron beam of any given wavelength, or energy, will be dimmed by a group of nuclei of any given size. The results of such a calculation are shown in the upper graph on page 85. The panels with curved upper edges indicate the theoretical cross sections of the elements (indicated by atomic weight) for neutrons of various energies ranging from zero to about three Mev. Each panel represents an atom of a certain size, and the curve of the top edge plots the predicted variation of the nucleus' cross section with increasing energy of the neutron beam. The height of each point on the curve stands for the size of the total cross section (scattering and absorption) for that energy.

The pattern is not simple. Usually the cross section decreases with increasing energy (shorter wavelength) of the neutron "light," but in some cases it rises along part of the range and there is a hump in the middle of the curve. And as we look along the sequence of the elements, we can see that there are groups of elements, around atomic weight 40 and again between 100 and 140, whose cross section for low-energy neutrons is small rather than large.

If the actual measurements of cross sections were to match this intricate and peculiar theoretical pattern, we could certainly feel that it was no accident. The measurements have been made (by many independent experimenters), the curves have been plotted, and the agreement between the pattern based on the measurements and the pattern based on the theoretical predictions is astonishing. The results of the measurements are shown in the lower graph on page 85. These curves match almost exactly many of the detailed and complex variations in the theoretical curves.

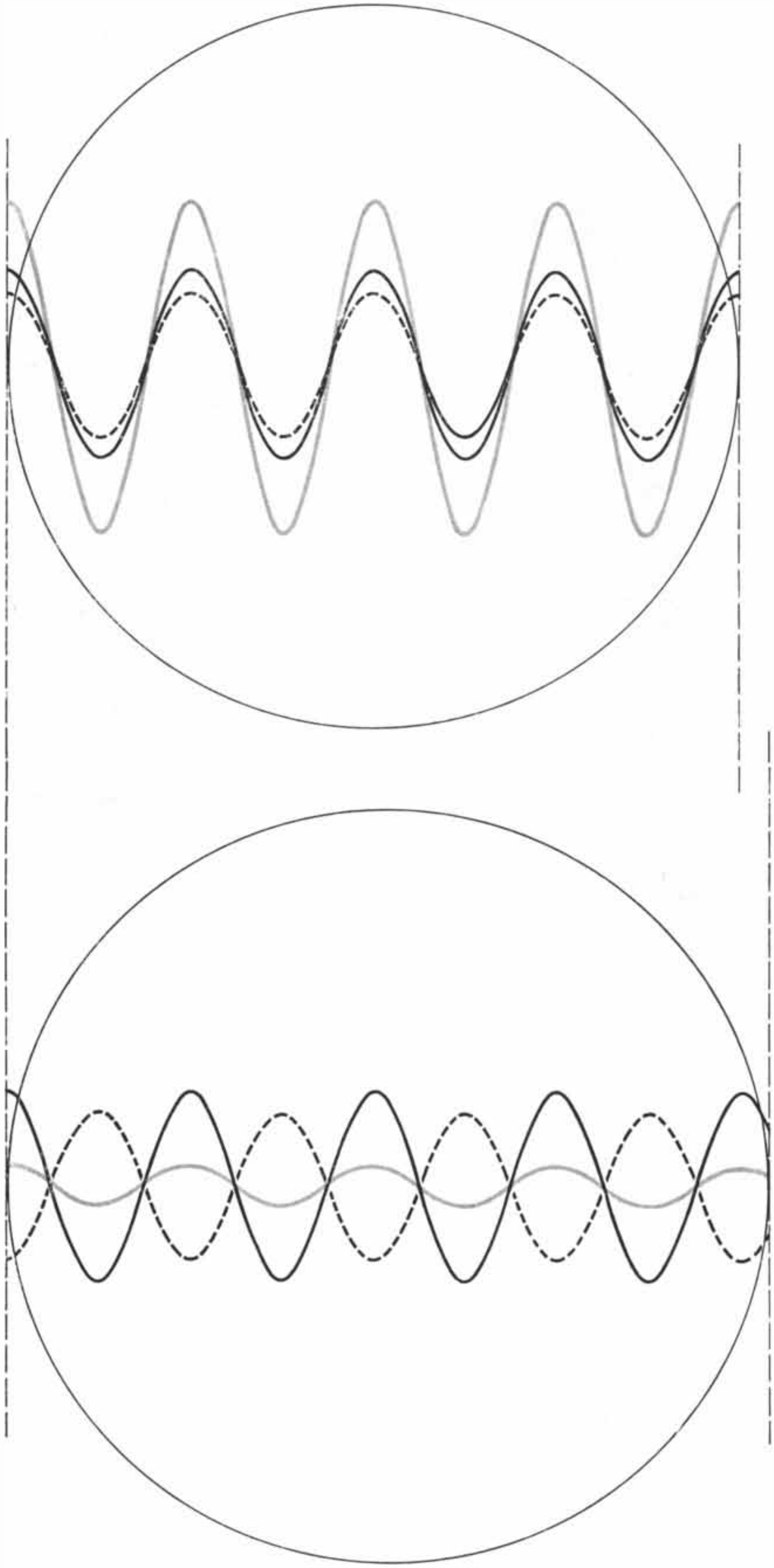
Evidently the cloudy crystal ball model is a highly useful way of picturing nuclear matter. But the model suggests some new puzzles. To say that the nucleus is semitransparent implies that part of the wave energy that passes through it emerges intrinsically unaltered. The emerging wave may be changed in direction but not in wavelength. Now in particle terms this means that some of the neutrons entering the nucleus get out again with their energy unchanged, which is surprising indeed in view of what we know about the strong interactions among nucleons. It is true that the force fields of the nucleons act only over an extremely short range—less than three or four fermis—but a bombarding neutron that gets into the nucleus surely comes within these fields. How can it pass through without interacting with the particles in the nucleus and exchanging energy?

For help in resolving this paradox we can turn to the shell model of the nucleus [see "The Structure of the Nucleus," by Maria G. Mayer; Scientific American, March, 1951]. In brief, this model says that the protons and neutrons inside the nucleus are arranged in a system of orbits, or shells, as the electrons outside the nucleus are. Each orbit corresponds to a specific level of energy, and a nuclear particle can pass from one to another only by an abrupt "quantum jump." Furthermore, the famous Pauli exclusion principle applies to the nucleons as to electrons. Each nuclear orbit can contain only two particles, spinning in opposite directions.

Now these occupancy rules imply "social" behavior on the part of the nucleons. Any individual particle occupies the orbit that it does because others are filled. In some sense it "knows" the over-all situation and stays in its proper niche. To put it another way, the force on an individual nucleon is a group force stemming from the entire ensemble of its neighbors acting as a single body. So, also, neutrons entering the nucleus from the outside are confronted with a single force exerted by the entire population of resident nucleons. Many of the incoming neutrons respond only to this force, failing to interact with individual nucleons. It is as if an individual entered a room full of dancers. He might try to cross the floor, in which case he would bump into some of the dancers or perhaps even be grabbed by a partner. But on the other hand he might skirt the group and emerge from the other side of the room without having lost or gained any momentum. So a neutron, swung away from individual contacts by the group force of the nucleus, may pass through it as if it were transparent.

Now to complete the picture of the energy conditions within the nucleus we shall forget cloudy crystal balls and shells for a moment and resort to still another model. In considering the energy states of the nucleons, it is convenient to think of them as having negative energy. That is, we arbitrarily choose zero as the top of the energy scale within the nucleus and represent the lower energy states by negative numbers, just as we can speak of temperatures below zero. In the nuclear case the reason for doing this is to indicate that energy must be added to a nucleon to pull it free of the other nucleons' force fields and raise it to the isolated, motionless state of zero energy. The nucleons are analogous to the water in a well, which has negative potential energy, with respect to ground level, because work must be done to raise the water to that level. We take a well, then, as a model of the nucleus.

It is a "potential" well—a well simply representing the fact that various levels of negative potential energy exist in the nucleus. These levels correspond to the orbits that can be occupied by the nucleons [*see diagram on page 86*]. Note that the well is "square," with sharp corners at the top, *i.e.*, no sloping edge. This reflects an assumption that a particle just outside the nucleus feels no force while one just inside feels the full amount. A particle is either completely in or completely out of the well. As for the well's depth, experiments indicate that it takes about 40 Mev of energy to lift a particle out of the nucleus from the lowest level.



TOTAL WAVE MOTION inside nucleus is strong (*gray curve in top diagram*) when incoming wave (*solid black curve*) and reflected wave (*broken curve*) reinforce each other. If nuclear radius is wrong length (*bottom*) individual waves interfere giving small total.

This well model is a precise counterpart of the cloudy crystal ball. The depth of the well is the measure of the nucleus' index of refraction, or the crystal ball's effect as a single body upon a neutron passing through it—an effect which may change the neutron's direction but not its energy. When we say that the crystal ball is transparent to the neutron, it is the same as saying that the neutron has not fallen into the well, because it has been acted on by the potential (single-body force) of the well as a whole. When we say that the ball is cloudy, we mean there is a finite probability that the neutron will be absorbed by the nucleus, or, in terms of energy, will fall into the well (exchange energy with individual nucleons). This probability is the coefficient of absorption. In other words, the cloudiness of the nucleus is determined only by absorption, not by scattering.

The crystal-ball concept pictures the nucleus in terms of waves; the potential-well model considers it in terms of particles. Both pictures are consistent with and supplement each other, when we examine the energy transactions in the nucleus.

Let us return to the cloudy crystal ball and try to discover what further investigations it may suggest.

We have observed that the cloudiness (absorption) of the crystal ball depends on the energy of the neutron "light" that attempts to pass through it. The lower the energy of the neutron beam, the more transparent the nucleus becomes. But this is not the whole story. Remembering that the neutrons behave as waves, we realize that, from a theoretical point of view, nuclei of certain sizes should be opaque even to neutrons of low energy. We should expect a "resonance" effect to operate under certain circumstances. These circumstances are the creation of a "standing wave" within the nucleus. Every physics student knows that when sunlight passes through a water drop, part of its energy is reflected back into the drop from the far boundary. Such reflection occurs whenever waves encounter a boundary between one medium and another, and the boundary of an atomic nucleus should be no exception. Now if a drop (or nucleus) is just the right size to allow the incoming waves and the reflected waves to reinforce each other, they will form what is known as a standing wave. This contains so much energy that even a poor absorber will soak up a considerable amount of it. Thus a nucleus in which a standing wave is set up should absorb strongly a low-energy wavelength to which most other nuclei are transparent.

We know what the size of the drop (or nucleus) must be in relation to the wavelength in order to have a standing wave. It has been calculated that a standing wave will occur whenever the radius of the body is an odd multiple of the wavelength divided by four. We know that the wavelength of the neutrons entering a nucleus is 4.4 fermis. Dividing by four, we get 1.1 fermis. Any nucleus whose radius is an odd multiple of this distance—*e.g.*, 3.3, 5.5, 7.7—should exhibit strong absorption of neutrons of the 4.4-fermi wavelength; in other words, it should be cloudy.

The elements with these radii are those of atomic weight 11, 55 and 155. Several experimenters have tested the prediction by measuring the cross sections of nuclei in the neighborhood of those atomic weights, and they have found that the 55 nucleus definitely is cloudy to the slow neutrons; that 11 probably is, and that nuclei near 155 also show the predicted absorption effect when corrections are made for the fact that their shape is not spherical.

Thus the cloudy crystal ball model not only accounts surprisingly well for a number of previously known experimental results but has also predicted new ones. It must reflect an important aspect of the real nucleus.

Many theoretical physicists are now trying to refine and extend the model. One problem is to determine whether the nucleus has a sharply defined surface as far as its optical properties are concerned, or whether it begins thinly and gradually becomes denser toward the center. The square-well concept assumes that it has a sharp boundary. By rounding off the corners of the well—*i.e.*, varying the values for the index of refraction near the surface—one might derive cross-section curves which would agree with the measurements even more closely than the theoretical set shown here.

It should be emphasized that the cloudy crystal ball represents only gross properties of nuclear matter. Calculations based on the model yield only average values. The model cannot account for the detailed variations in a nucleus' cross-section curves—the fine structure of ups and downs that appears in a chart of actual measurements. Yet despite its coarseness, in fact, because of it, the optical model can be expected to yield further valuable insights into the ultimate nature of matter.

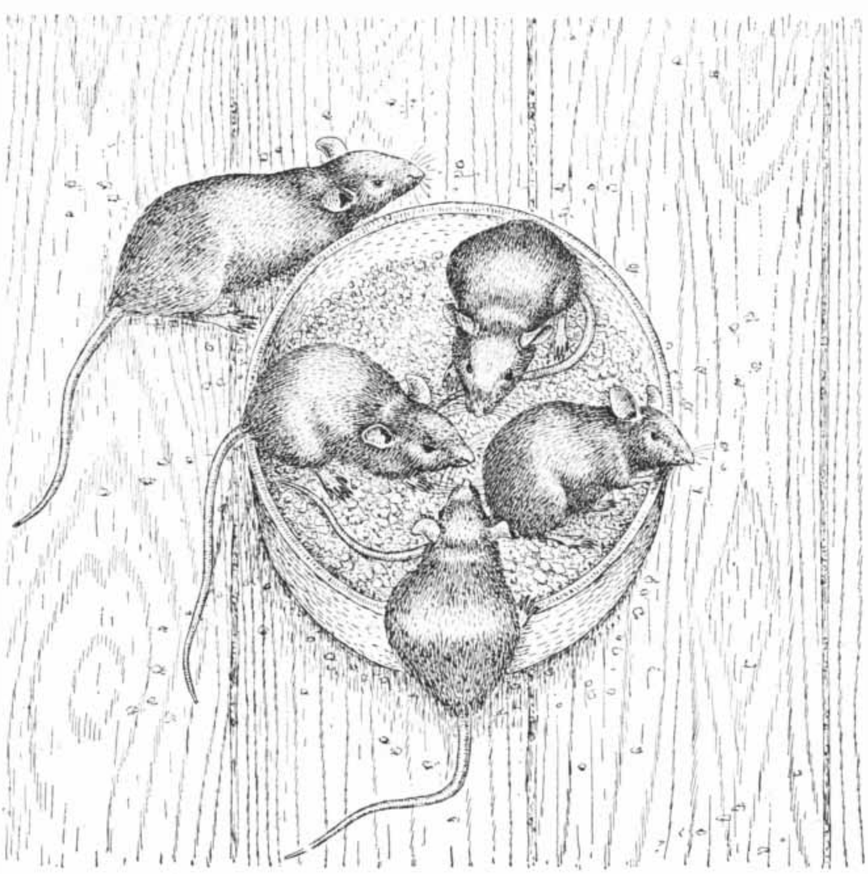
Populations of House Mice

What controls the abundance of animals? Here the question is approached by way of a small pest which has the experimental advantages of an accessible habitat and rapid multiplication

by Robert L. Strecker

"The proper study of mankind," wrote Alexander Pope, "is man." He might equally have said that a very proper study of man is mankind, considering mankind as a population. Studies of human populations as such tell us many things about what kind of creature man is. This is also true of other animals. The survival, behavior and success of any living organism depend to a considerable degree on its characteristics as a population.

No animal voluntarily lives in a social vacuum. It must congregate with others of its own kind, even if only to propagate; if by some chance an individual gets isolated from its kind, that is the end of the line. Plainly, then, a primary need of every kind of animal is to maintain itself as a population. There are laws of population development, just as there are laws governing all other mass phenomena in nature. Consequently we can learn something about any animal, including man, by studying populations in general, whether they be yeast cells, insects, mice or elephants.

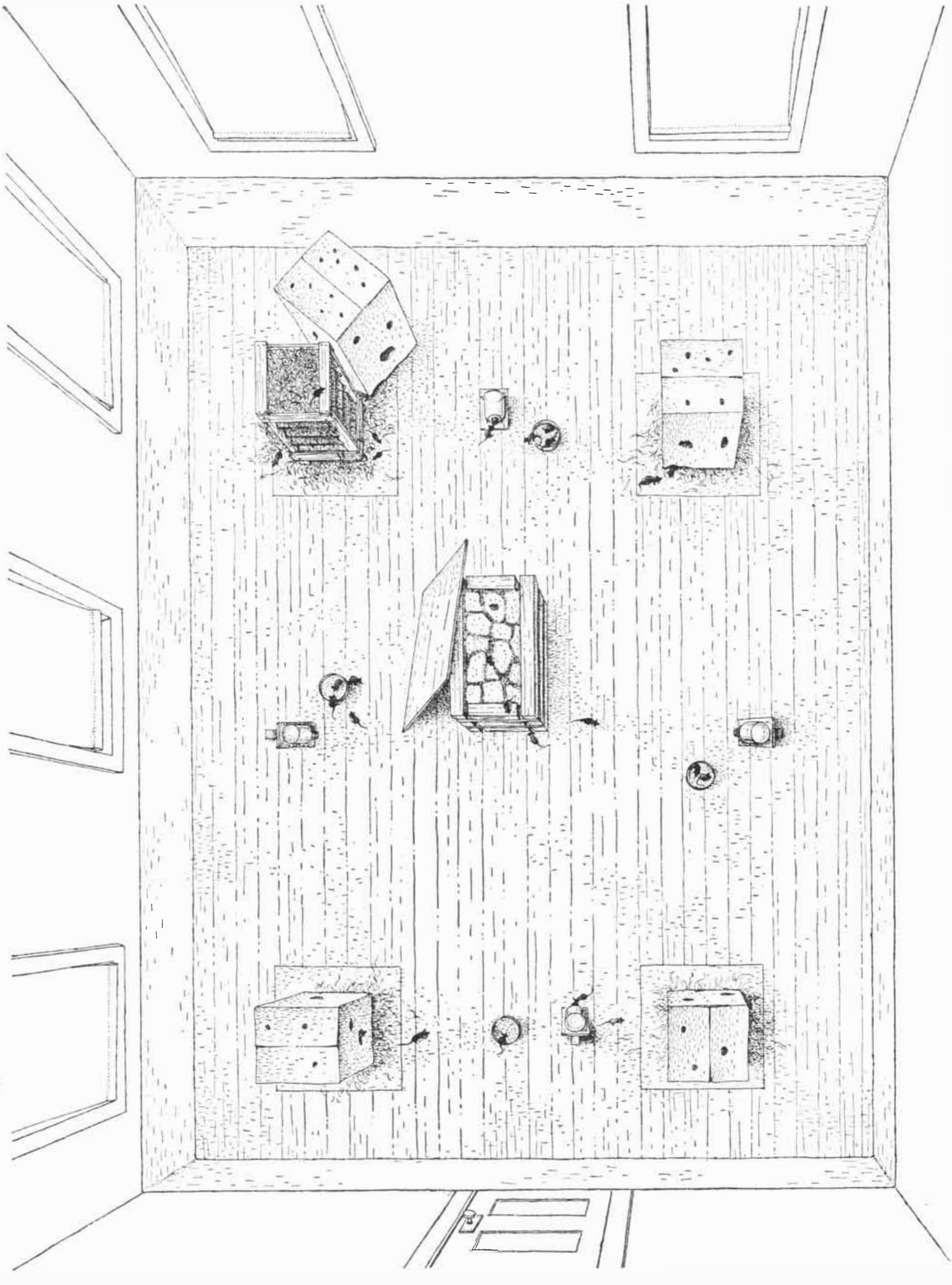


POPULATION OF HOUSE MICE in the principal experiment described by this article was given a total of 250 grams of food per day. The species was the common *Mus musculus*.

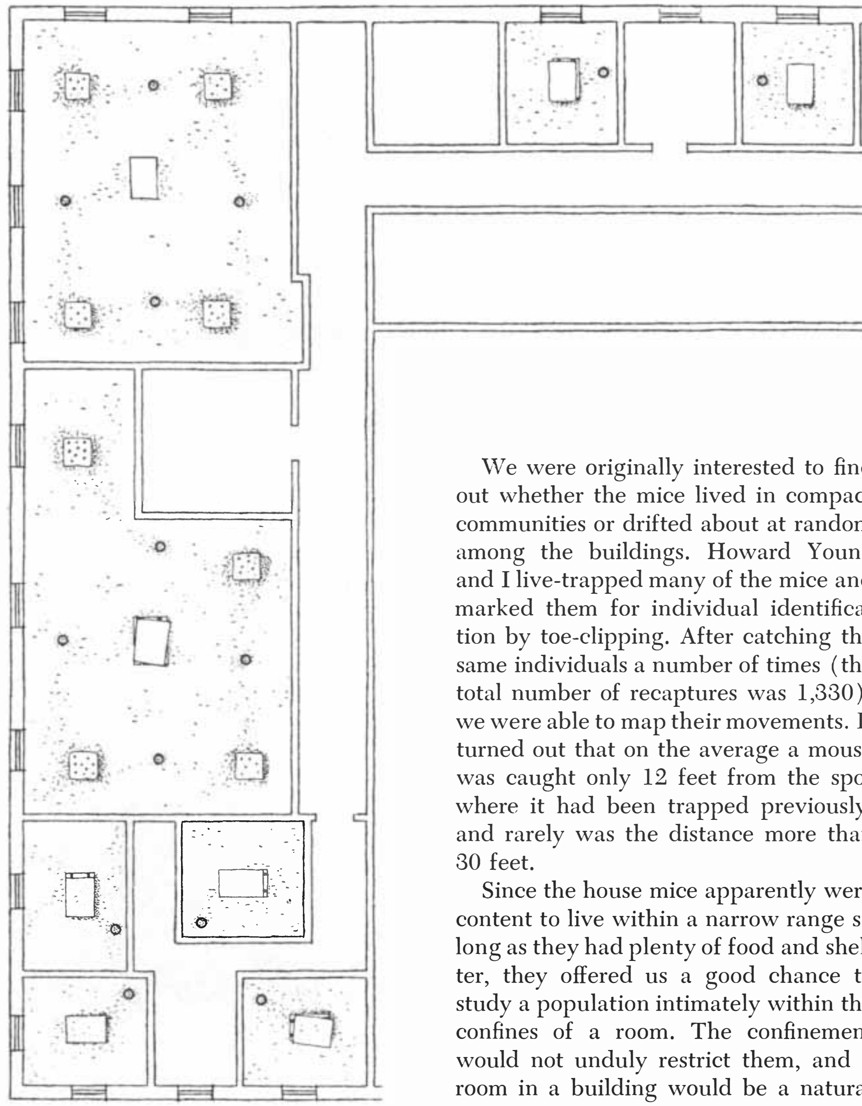
In theory all populations follow a certain basic pattern of development: they tend to multiply according to a growth curve which rises slowly at first and then picks up momentum until it shoots upward almost vertically. If we start with a pair of mice, say, we may expect them to produce a litter of six young, half male and half female, in three weeks. The offspring will mature sexually in five or six weeks and themselves begin contributing to the increase. Within 12 weeks after the beginning the population might total some 32 mice, and soon its numbers would be increasing at a tremendous rate.

A colony of yeast cells, which may divide every 30 minutes, could reach the stage of very rapid growth in numbers in a matter of hours. Elephants, which do not mature sexually until the age of 15, might take a century. But in theory the shape of the curve is essentially the same in each case.

Actually for various reasons populations do not follow this curve of unrestrained growth except on rare occasions such as a sudden plague of insects. Normally the population increase is held in check by the limits of food and water and living room, by predators, accidents and diseases. These factors tend to put a ceiling on the population rise, so that the actual curve of population growth is usually shaped somewhat like an S—first rising slowly, then rapidly, then leveling off. If one of the major limiting factors (*e.g.*, predators) is removed, the population may start rising again, but the



HOUSE MICE WERE CONFINED in pens which had been mouse-proofed with sheet iron to a height of 22 inches. This pen has four locations for food and water and two kinds of shelter. One (*corners*) is filled with paper and cotton; the other, with beaverboard.



EIGHT PENS were constructed in an empty army barracks. The small pens were used chiefly to check on reproduction in winter.

other limitations will soon stop it at a new plateau.

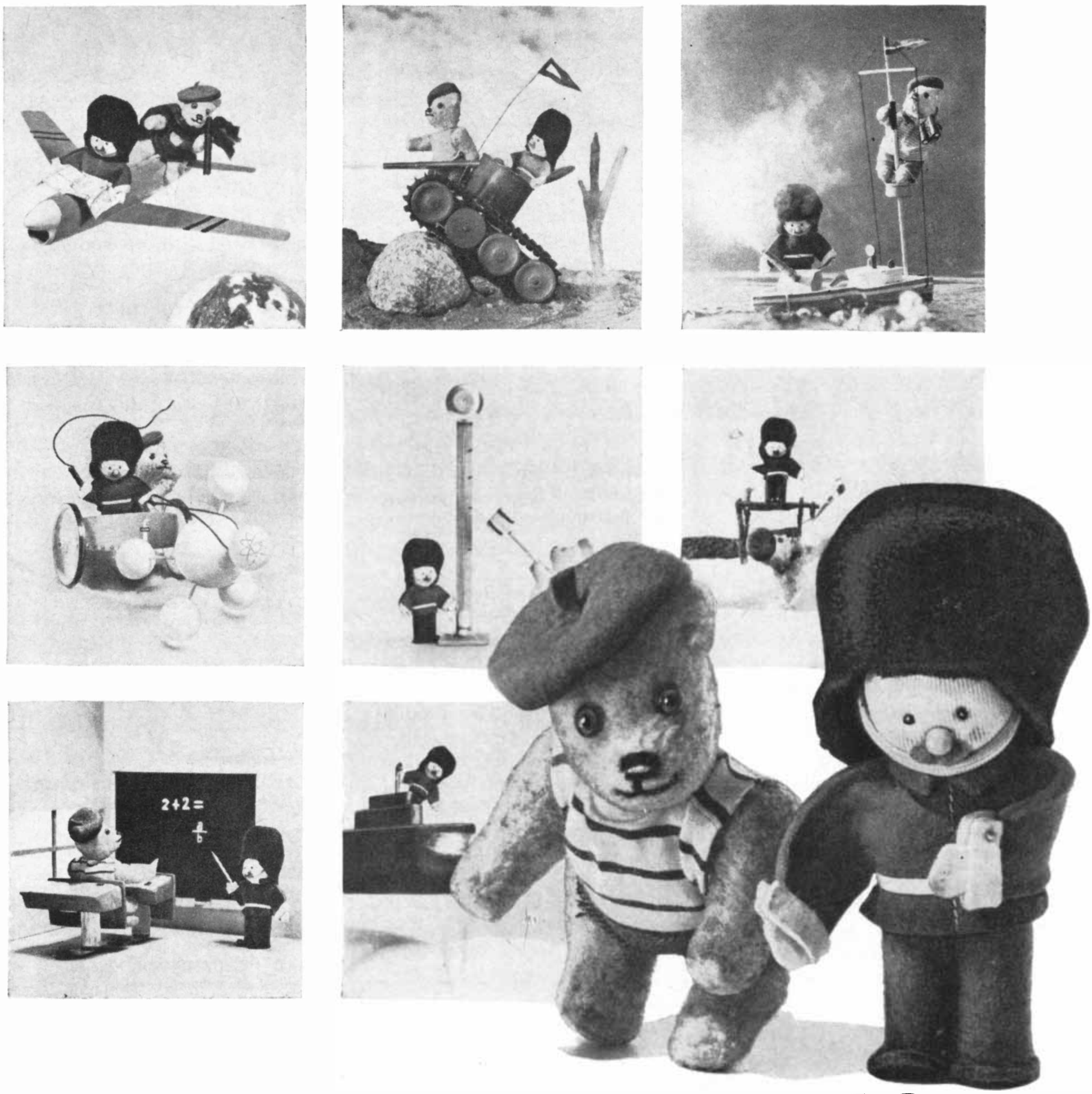
Many attempts have been made to investigate just how the limiting factors control the abundance or scarcity of animals. The studies I shall describe were carried out at the University of Wisconsin under the guidance of John T. Emlen, Jr. The subjects were house mice. Around some of the campus laboratories where various experimental animals were kept in cages, there were several flourishing colonies of the ordinary little wild mice that infest houses. They fed mainly on food they stole from the cages of the laboratory animals. It was curiosity about their movements and community life that led us to discover they would make ideal subjects for detailed population studies.

We were originally interested to find out whether the mice lived in compact communities or drifted about at random among the buildings. Howard Young and I live-trapped many of the mice and marked them for individual identification by toe-clipping. After catching the same individuals a number of times (the total number of recaptures was 1,330), we were able to map their movements. It turned out that on the average a mouse was caught only 12 feet from the spot where it had been trapped previously, and rarely was the distance more than 30 feet.

Since the house mice apparently were content to live within a narrow range so long as they had plenty of food and shelter, they offered us a good chance to study a population intimately within the confines of a room. The confinement would not unduly restrict them, and a room in a building would be a natural habitat for them, as any housewife can testify. Furthermore, house mice are excellent subjects for population study because they reproduce rapidly, frequently and more or less continuously throughout the year.

The home we first chose for the mice was a large room in the basement of one of the campus buildings. It had several large ventilating fans, boxes, jars, lumber, tile and other stored equipment which would supply hiding and nesting places for the mice. The room was closed, but the mice could escape from it if they had to by way of heating pipes and ventilating shafts.

We first undertook to study the effect of limiting the population's food supply. Our plan was to colonize the room with a few mice, to give the colony just 250 grams of food each day and to see what would happen when the number of mice increased to the point where this supply of food could no longer support the growing population. We trapped the mice in the room at frequent intervals to weigh them and mark them individually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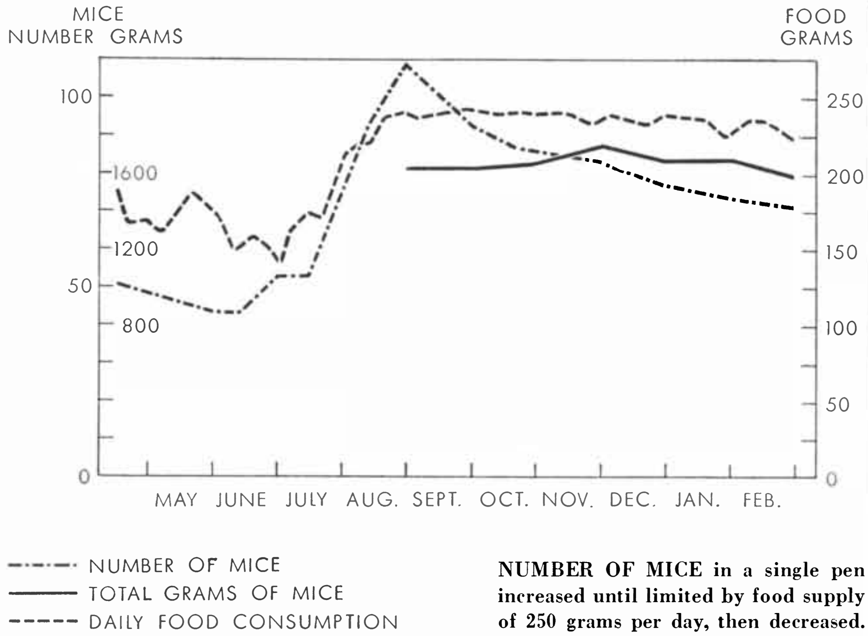
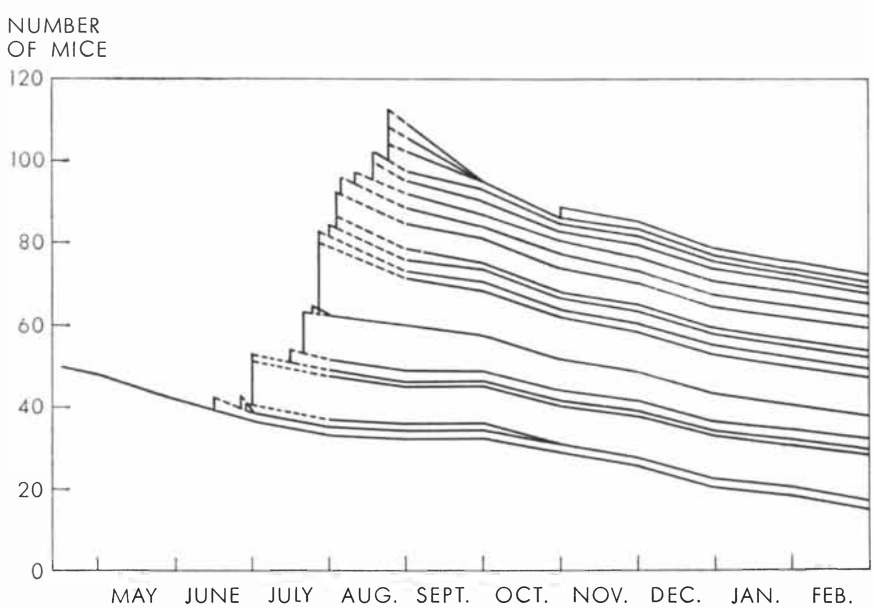


NUMBER OF MICE in a single pen increased until limited by food supply of 250 grams per day, then decreased.

for identification, and we set other traps throughout the building to catch members that strayed from the colony.

During the first eight months only nine marked mice left the room and were caught outside. But by the end of the eighth month, when the population had grown to the point where it was consuming nearly all the daily food supply in the room, the mice began to leave in substantial numbers. In the next three months we caught 82 migrants outside the room. This increased flight from the colony was clearly due to the food limit. Enough mice left so that no actual food shortage developed within the colony.

The tide of mice throughout the classrooms and offices of the building was not enthusiastically received, and we had to put an end to the colony. After trapping the mice, we were interested to see whether the group that had left the colony differed from the population which stayed behind. Did the youngsters tend to move out, while older, established mice remained; or did the vigorous young mice drive out the older ones? Were males more likely to leave than



MAKE-UP OF POPULATION in the same pen developed in this manner. The appearance of each new litter is indicated by a vertical jump from the uppermost line. The solid lines refer to marked mice; the dotted lines extend the record of litters back to the estimated time of birth. The small jump at top right is due to two outside mice which got into the pen.

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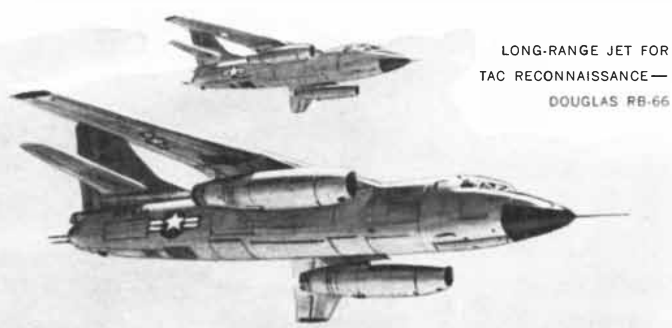

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females? Examination of the groups showed that both were about the same, with no sex or age predominating, except that very young mice still dependent on their mothers of course stayed in the colony. Of the 87 mice trapped in the room at the end of the experiment, a fifth were babies barely out of the nest. Many of the mature females were pregnant, indicating that reproduction had been going on steadily.

To summarize, then, this study showed that as long as there was sufficient food the population stayed pretty much intact, with only an occasional individual deserting; that as a food shortage approached, migration from the colony increased sufficiently to tap off mice as quickly as new ones were born; that reproduction apparently continued normally, and that the population which remained was a cross section, with no unusual features as to sex or age composition. The experiment clearly demonstrated that when some stress, such as an approaching food shortage, is brought to bear on a population, it will spread out and occupy new areas.

We wondered what would happen to the mouse population if members could not escape, if they had to remain in a confined place with only a limited amount of food available. Would the young or the old have the better chance to survive? Would the mice begin fighting and killing one another? Would reproduction slow down or stop?

In an attempt to answer this question we started two colonies of mice in two rooms of an empty building. The rooms were sealed so that mice could not escape. Each room was supplied with shelters, water and 250 grams of food per day. One colony was started with 10 mice, the other with 50 mice, and both were closely watched for 11 months. All mice were individually marked so they could be identified. Every two weeks a thorough search was made to find the newly born mice and record them. Once every four weeks each mouse was caught, weighed and examined for physical condition.

The colony that started with 10 mice did not grow large enough within the 11 months to press on its food supply, so it served only for comparison. The 50-mouse colony grew up to the food limit within four months. When it began to consume all the food each day, reproduction stopped completely. No new baby mice were born, and those already present soon died. However, all the animals past weaning seemed to hold their own. The older members of the colony

what helps a scientist grow?

Here are four factors given by distinguished Avco scientists. They reflect both the thinking and opportunity at Avco Advanced Development Division.

"Top-level associates"

says Dr. Arthur Kantrowitz, noted authority in gas dynamics, member of Avco Advanced Development, and professor, Cornell University.

"A scientist's effectiveness depends on mental stimulation provided by able associates. It's important at all levels and it is essential to a young scientist."

"Technical sophistication"

says Dr. E. R. Piore, former chief Scientist and Deputy Chief of the Office of Naval Research, now Avco V.P. and Chairman of its Committee on Advanced Research.

"The more advanced, more challenging, the more technically sophisticated his work—the better a talented scientist will respond."

"An atmosphere of inquiry"

says Eaton H. Draper, noted nuclear weapons systems expert and Engineering Manager of Avco Advanced Development Division.

"Provide a climate which encourages a healthy questioning of the known, as well as the unknown, and a scientist or engineer will perform at his peak . . . and even beyond."

"Freedom from routine"

says Dr. Mac C. Adams, noted aerodynamicist, author of papers on aerodynamics and gas dynamics, and Director of the Avco Research Laboratory.

"A scientist is most effective when he is free to direct his full energy against major problems. Adequate technical assistance releases him from time-consuming routine."

Helping talented scientists and engineers—at all levels—become more effective is the best way we, at Avco Advanced Development, know of helping our own growth. For that reason, we offer them assignments worthy of their abilities, stimulating associates, and the fullest technical support possible. Add to these factors the unique combination of small-company flexibility and large-company stability—and you have an environment ideally suited to growth. For outstanding men, Avco's long-range expansion—in missiles and in all the physical sciences—offers unprecedented opportunity.

Write Dr. E. R. Piore, Vice-President in Charge of Research, Room 405, Avco Advanced Development Division, Stratford, Conn., or Phone Bridgeport, Conn., DRexel 8-0431.

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combine the scientific skills, and production facilities of 3 great Avco divisions of Avco Manufacturing Corp.: Avco Advanced Development; Crosley; Lycoming which currently produce power plants, electronics, air-frame components, and precision parts.

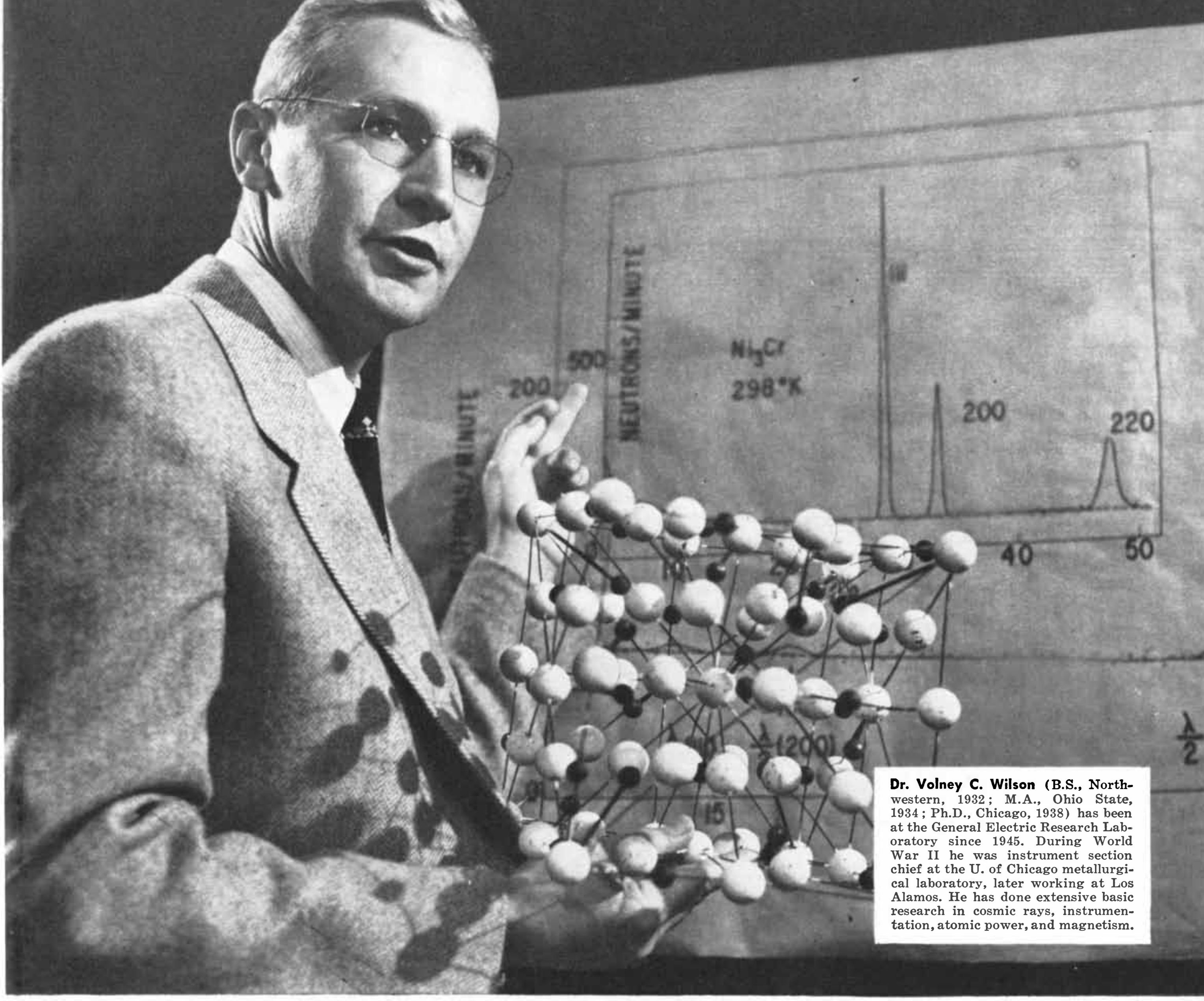
declined in numbers, presumably dying of old age. But the total weight of the colony remained fairly constant, as the weight put on by the growing younger members offset the losses by death. In other words, the food supply maintained a certain weight of live mice for the colony as a whole.

When, at the end of the 11 months, the surviving mice were autopsied, all showed heavy deposits of fat on their bodies, because the experiment was terminated in March, at the end of winter. None of the females was pregnant, as far as could be determined. The building had been unheated during the winter, and the cold would account in part for the suppression of sexual activity. However, it could not have been wholly responsible, for in the companion colony, where the mice had an abundance of food, reproduction did occur during the winter.

The experiments described give us a basis for speculation about the dynamics of population growth and spread, at least among house mice. The population grows rapidly and stays together in a restricted area until the limits of the food supply put pressure upon it. Then some of its members begin to migrate to new areas if they can. If they cannot, the colony may eventually stop reproducing. Probably it does not resume producing young until the pressure is relieved. Unfortunately we lost our building before we could investigate the latter point by observing developments in the spring.

Of course food is not the only factor that influences the development of a population. Other specific studies of house mice have shown, for example, that when mice are strangers to one another, they fight a great deal in establishing social position. The mice already living in an area are very antagonistic to newcomers. Obviously the amount of living space, in terms of the cover available for shelters, will influence the size of the population. Crowding interferes with the construction and maintenance of nests and increases the mortality among baby mice.

While there is no denying that the organization and development of a population, even of house mice, is a complex affair, we need not be discouraged by the complexity. The experiments on house mice indicate that the determining factors can be studied individually, and such investigations should lead us eventually to a fairly clear picture of the related parts played by the various influences on the abundance and scarcity of animals.



Dr. Volney C. Wilson (B.S., Northwestern, 1932; M.A., Ohio State, 1934; Ph.D., Chicago, 1938) has been at the General Electric Research Laboratory since 1945. During World War II he was instrument section chief at the U. of Chicago metallurgical laboratory, later working at Los Alamos. He has done extensive basic research in cosmic rays, instrumentation, atomic power, and magnetism.

Why magnets are magnets

General Electric's Dr. Volney C. Wilson uses neutrons to discover fundamental facts for improving magnetic materials

While Volney C. Wilson was director of instrumentation and control for the first atomic pile, under the University of Chicago stadium, Enrico Fermi demonstrated to him and others working on the project that neutrons could be diffracted in the same manner as x-rays. Several years later, when Wilson's interests turned to an intensive study of magnetism, he recognized the special value neutrons would have in revealing atomic arrangements in magnetic materials. Neutrons are not affected by *electric fields,* but—since they are very much like little magnets themselves—they are scattered by *magnetic fields* within crystals.

Accordingly, Dr. Wilson designed and constructed a unique *neutron diffraction spectrometer* at the General Electric Research Laboratory. It is now in operation at Brookhaven National Laboratory, giving G-E scientists new insight into the problem of why magnets are magnets. Wilson believes that learning new fundamental facts about "atomic-magnetic" structure will result in better magnetic materials—and that even a small improvement in these materials will significantly increase their usefulness in computers, control equipment, and color television.

Progress Is Our Most Important Product

GENERAL ELECTRIC

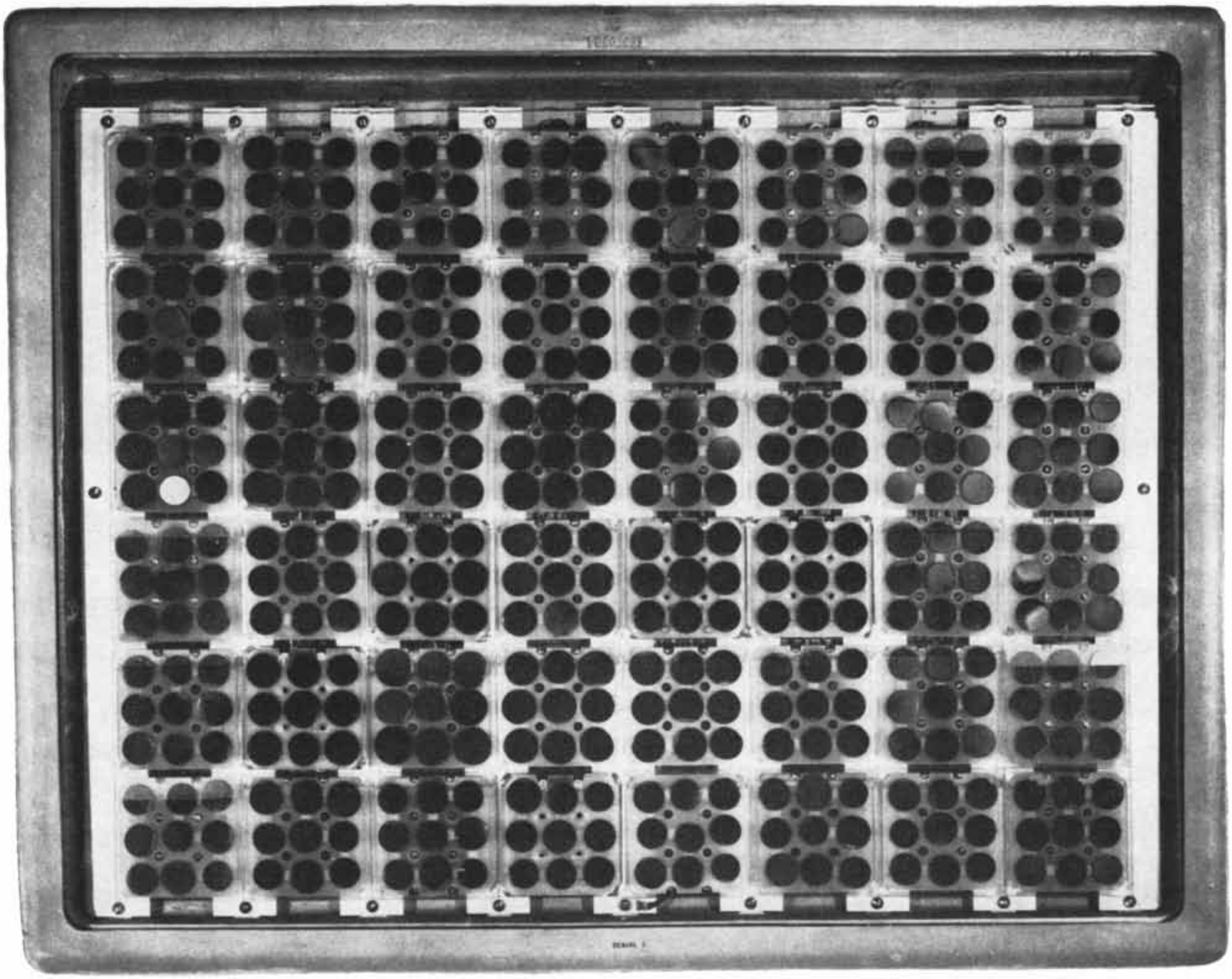
THE SOLAR BATTERY

This close relative of a junction transistor turns sunlight directly into electric current. In its first practical application it is powering eight telephones on a rural line in Georgia

by Gordon Raisbeck

The idea of harnessing the power of the sun has interested both writers of fantasy and serious scientists for a long time. Their interest is easy to understand. In two days the earth receives in sunlight more energy than is stored in all the known reserves of fossil fuels. Time and again men have devised schemes for tapping this energy directly, usually by focusing sunlight to heat something, such as the boiler of a steam engine. None of these attempts to convert sunlight into power has ever achieved commercial success. But in recent years there has been hopeful progress in exploiting the possibilities of the photoelectric cell. This article will describe a solar battery based on a new type of cell.

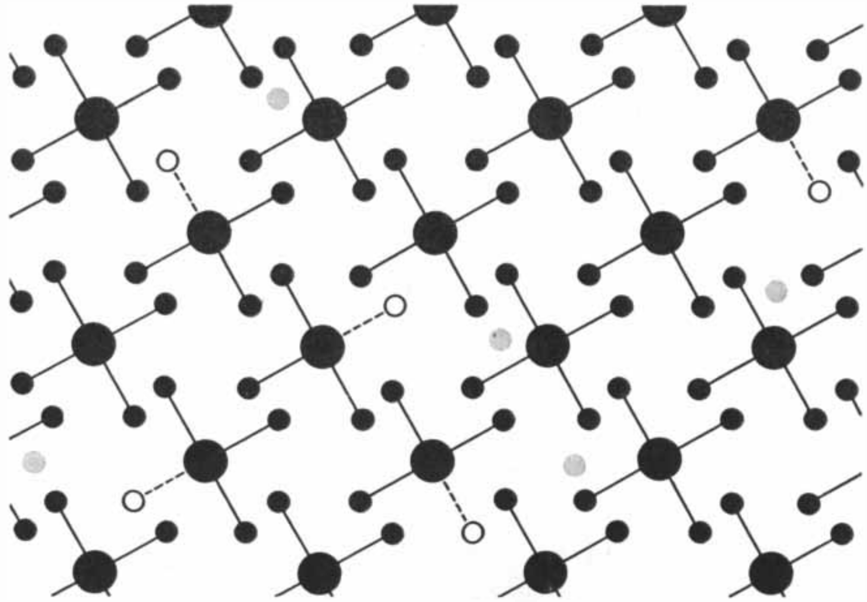
The photoelectric cell has become familiar in the form of the exposure meter



SOLAR BATTERY used in the Georgia field test consists of 432 individual silicon-wafer cells in an aluminum case with a glass lid. On a bright day it generates 10 watts. Excess electricity is reserved in a conventional storage battery for operation at night.

for photography, the "seeing eye" for opening doors, the light-detecting instrument of astronomers, and so on. It can transform light directly into electrical energy. However, the conventional photocell delivers as power only one half of 1 per cent of the light energy it absorbs. Engineers and scientists have felt that this efficiency is too low to make a photocell useful as a source of power. But the Bell Telephone Laboratories are now developing a new photoelectric cell (or solar battery) which is 20 times more efficient than the usual light-detecting types. It is capable of generating electric power from sunlight at the rate of 90 watts per square yard of illuminated surface.

The Bell solar battery is an extension of the physical principles employed in the transistor. To see how it works we must review those principles.

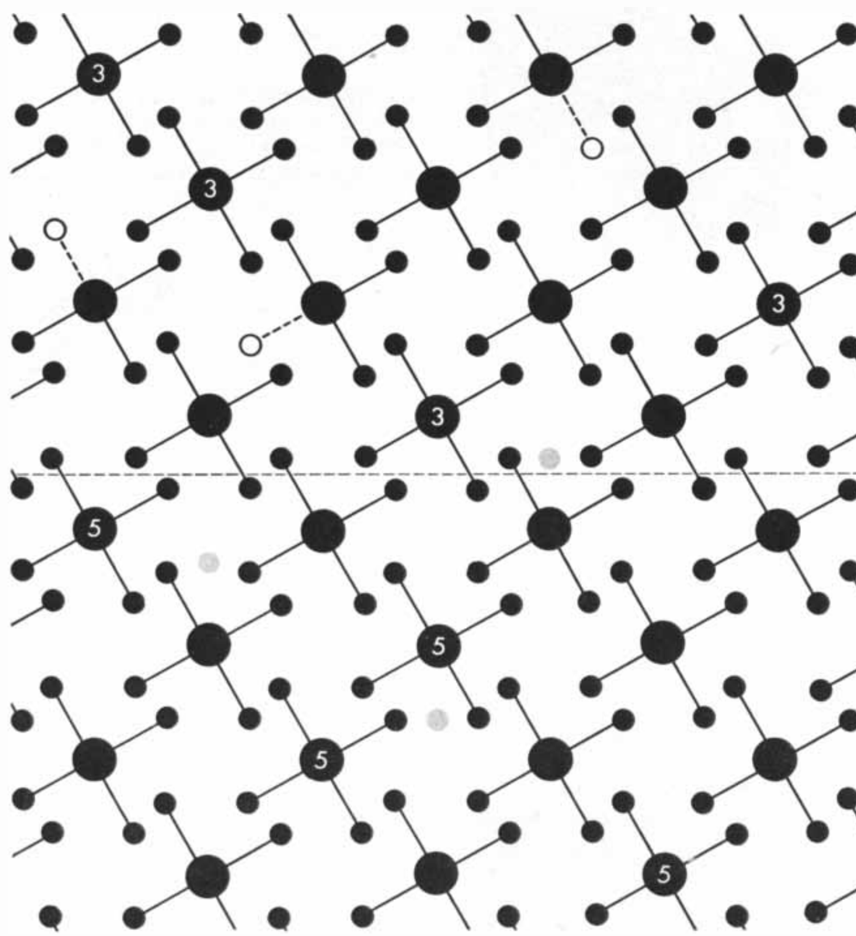


SILICON CRYSTAL is made up of atoms with four valence electrons. Some of the electrons break loose and wander through the crystal as free negative electrical charges (*gray dots*). The stations they vacate, called "holes," can be considered free positive charges.

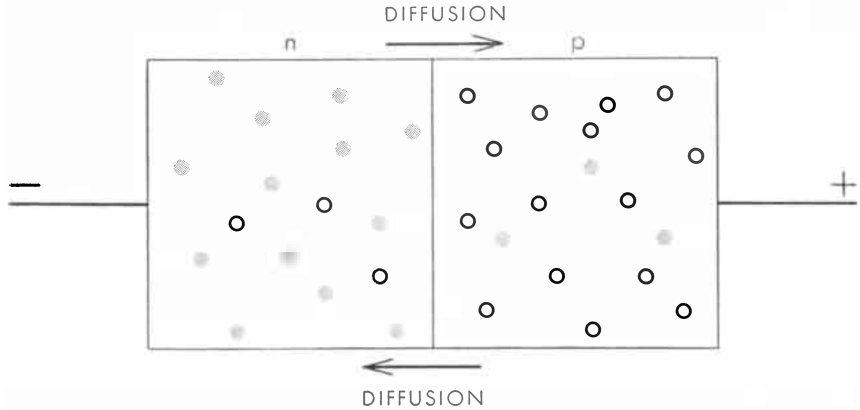
Let us start with a crystal of silicon. Each silicon atom has four valence electrons, by which it is joined to its four nearest neighbors. This is a highly stable arrangement. But energy from outside the crystal, in the form of light, heat or an electric field, may knock an electron from its position. In that case the electron is free to move about among the atoms. The place it has vacated becomes what is called a "hole." Because holes, like free electrons, may move about in the material, they behave like free positive charges.

The situation is much like that at a bridge party with a number of tables. Each table has four players (electrons). If a player gets up from a table and begins to wander, he leaves a vacancy which some other wandering player may fill. The latter, in turn, may have left a "hole" at another table. Thus the "holes," like the players, may move from table to table. However, at most bridge parties with just the right number of players, these events are rare; the teams of four stay put. And so it is in a perfect silicon crystal.

Now suppose we introduce into the crystal some arsenic atoms, each of which has five valence electrons. When an arsenic atom replaces a silicon atom and links itself to four neighboring silicons, its extra (fifth) electron becomes a free wanderer. Conversely, when we replace a silicon atom with a boron atom, which has only three valence electrons, the replacement adds a hole to the crystal. It is as if a number of five-member and three-member groups came to the bridge party. The fifth member of each five-person group is an extra, and he



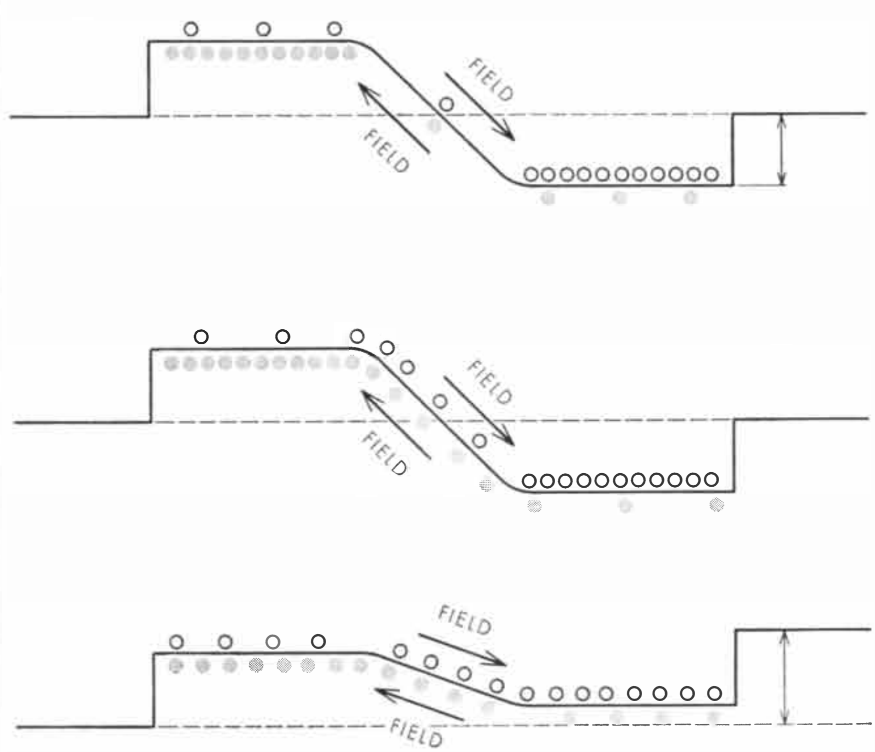
CRITICAL JUNCTION is boundary between one layer rich in electrons and another rich in holes. Five-valenced arsenic (*bottom*) introduces excess electrons; three-valenced boron (*top*) creates holes. Current results from flow of electrons and holes across the junction.



ELECTRON-HOLE DIFFUSION tends to distribute the two kinds of free charges in the two layers. This leaves the n-layer positive with respect to the p-layer, creating a potential.

may move about looking for a vacant chair where he may sit in for a hand (or perhaps he looks for an exit). On the other hand, a three-person group that sits down at a table presents an open invitation for a fourth to join it. In this manner it adds to the party a hole which may move from table to table as players shift.

Draw a line across the middle of the room and imagine that the party starts with all the free players on one side and all the holes on the other. The free players (electrons) and free holes move about at random; in other words, their movement is simply aimless diffusion. But at the boundary between the two halves of the room there has to be, at first, a certain pattern: from the side with the extra electrons, only electrons move across the boundary to the other side; from the side with holes, only holes move across the boundary. Now the first side of the room, previously neutral in charge, acquires a negative charge from the fact that only electrons are coming in. The other side, similarly, becomes positively charged because of the arrival of positive



EQUILIBRIUM of electrons and holes (*top*) is upset when light creates extra charges (*middle*). Arrows at right show increased potential when equilibrium is restored (*bottom*).

CORNING GLASS

BULLETIN FOR PEOPLE WHO MAKE THINGS

CORNING GLASS WORKS, 30-12 Crystal Street, Corning, New York

Please send me the following material:

- ☐ Booklet: "Glass and You."
- ☐ Bulletin B-83: "Properties of Selected Commercial Glassware."
- ☐ Bulletin IZ-1: "Glass . . . its increasing importance in product design."

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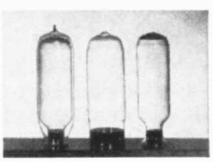
Something for nothing

In 1643 Evangelista Torricelli started studying causes and effects of vacuum. Two hundred years later, Sir James Dewar applied the principle of *insulation by nothing* to the vacuum jacketed vessel for storing liquid gases.

Up-dating on the vacuum vessel brings us to the ubiquitous bottles—useful companion of factory and office workers, picnickers, campers and school children. We play an inside role in this hot-cold game by making the inner-and-outer glass liners which are so important to the function of a vacuum bottle. Why glass? It's easy to clean, doesn't change taste of liquids and may be readily formed into shapes that hold a vacuum.



Component parts by Corning help keep vacuum bottlemakers happy and busy. From right to left —inner blank, outer blank and first assembly of glass liners for vacuum bottles.

Firms like Aladdin Industries, and Landers, Frary, & Clark buy these liners in great quantities. Then, with considerable ingenuity, and with the aid of automatic machinery, they seal the matched glass units, silver the outside of the inner and inside of the outer lining for more effective insulation, evacuate air between the walls, and tip to seal the vacuum permanently.

After 24 hours of testing, liners that make the grade are jacketed in attractive metal and/or plastic castings. Then, thousands of happy customers who want to keep food and drink both tasty, and at the right temperature, buy bottles in a wide variety of sizes, shapes, and styles.

Moral? If you want something for nothing—a vacuum that is—glass can be handy and profitable.

A more detailed story of Corning glass at work in both products and processes is unfolded in "Glass and You." A free copy is yours by request.

Also for your perusal Bulletin B-83, "Properties of Selected Commercial Glassware." It's a handy reference volume that will give you considerable insight into the amazing properties that can be custom-built into glass.

Handling humidity—with a moral for the cost-conscious designer

When it comes to handling and humoring humidity to fit experimental conditions, today's researchers demand precise control.

Toward this end, the Blue M Electric Company, of Blue Island, Illinois, has developed a relative humidity chamber that automatically controls humidity from 20% to near saturation, at any point, depending upon dry bulb temperature.

What interests us (aside from our curiosity about the precise handling of experimental conditions) is the use of a PYREX brand jar as the chamber. No small vessel this, it measures 16 inches in diameter, 12 inches in height.

Blue M's "Vapor-Temp" uses a large PYREX jar as a humidity chamber. Result—production costs and resultant prices go down.

Why a PYREX jar for this somewhat off-beat application?

The obvious answer lies in the full visibility the glass gives the lab technician who wants to observe test specimens from all angles. BUT . . . what *isn't* so obvious (except to Blue M) is the fact that, by using the PYREX jar they eliminate the expense of fabricating costly double wall alloy cabinets.

Blue M gets the jars in the quantities they need when they want them, and at a price that enables them to sell their product, "Vapor-Temp," at a figure in reach of more customers.

In turning to Corning for mass-produced glass components, you get utility *plus* economy—and Corning's capacity to cope with *both* materials and production problems.

Other examples of dollars-and-cents uses of glass components are spelled out in Bulletin IZ-1, "Glass . . . its increasing importance in product design."

How to engineer a continuing status quo

Status quo is the old Roman way of saying "the state existing."

Closely akin, and often of utmost importance to designers and engineers, is dimensional stability — a *continuing* status quo.

Dimensional stability, plus nonabrasive quality makes this glass ring a vital component in Sprague's planetary-valve gas meter.

Which leads us to the problem we ran into when the Sprague Meter people in Bridgeport were putting together their unique planetary-valve gas meter.

The valve ring was the stumper. It had to move continuously in a circular motion, sliding over a soft metal port in order to permit the measured flow of gas through successive orifices.

To be effective, the ring had to keep its shape, have an exceptionally flat finish, and neither wear (nor be worn down by) the metal part it moved against.

It may come as a surprise to discover that glass was selected as the material for the ring.

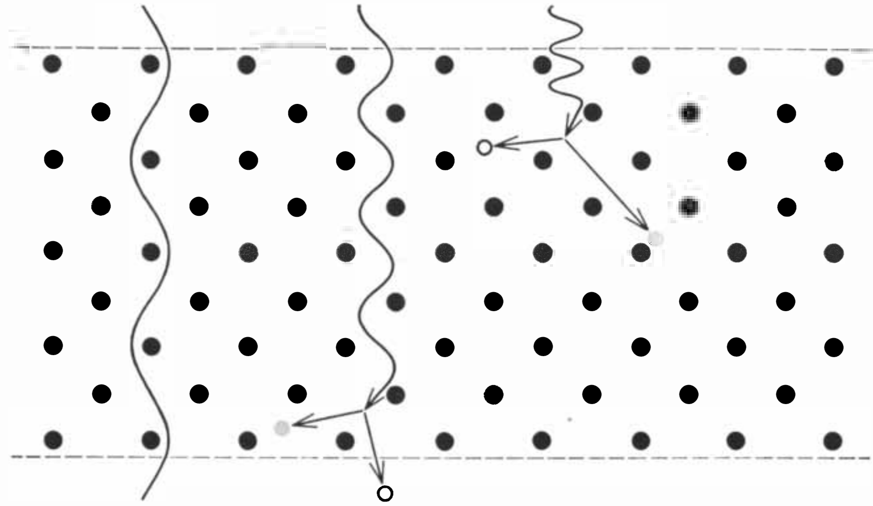
As mass-produced by Corning, this glass valve is precision flat finished by Sprague so smooth that it's nonabrasive to the metal it rubs against; it's hard enough not to be worn down, changing shape not a bit in operation.

Hundreds of material matters (other than Sprague meter valves) have found their successful solution in glass. Perhaps you can get your answer with it. Jot your problem down and send it along. We'll peer into our vault full of 50,000-odd glass formulas to see if we already have a glass to do your job. If not, we may be able to find just the right ingredients. We'd like to hear from you.

CORNING GLASS WORKS

CORNING, N. Y.

Corning means research in Glass



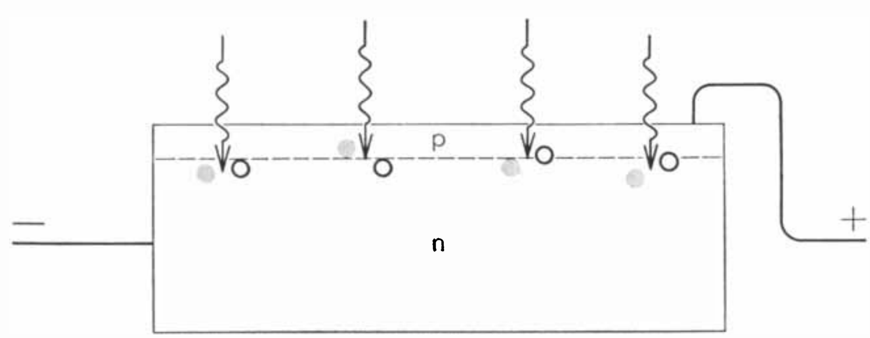
EFFECT OF LIGHT on silicon depends on its energy. Low-energy infrared (*left*) weaves through crystal. The shorter wavelengths are energetic enough to dislodge free electrons.

holes. Thus an electrostatic force develops between the two regions. This force builds up until it is balanced by the pressure of diffusion. At that point the negatively charged region repels any further invasion by electrons and the positively charged region repels holes. The situation is then at an equilibrium with a potential difference between the two regions.

One might suppose that if we attached the two ends of a wire to the two regions, the potential difference would drive a current around the loop. Actually no current will flow, because at the contacts between the wires and the crystal there exists an electric potential which counterbalances the potential difference at the boundary, or "junction," between the two regions. However, we discover that if we upset the equilibrium by producing more holes and more free electrons, we can make current flow. This is the essence of the solar battery idea.

Light shining on a silicon crystal will jolt electrons from their fixed positions, thereby generating free electrons and holes. Each photon of light absorbed creates a hole-electron pair. Not all wavelengths of sunlight have enough energy to dislodge electrons, and some wavelengths have too much energy for efficient use in this way. But about 45 per cent of the energy in the total spectrum of sunlight can be tapped by a photoelectric solar battery.

The basic unit in the battery is a thin wafer of silicon to which have been added very tiny amounts of the impurities mentioned—arsenic and boron. The body of the wafer consists of silicon with a trace of arsenic. This is called n-type (negative) silicon, because it has an excess of free electrons, which can donate negative charge to the crystal. On the surface of the wafer body there is a thin layer of silicon endowed with a trace of boron; this is p-type (positive) silicon,



VERY THIN P-LAYER locates junction only one 10,000th of an inch beneath the surface of the silicon wafer so that it is in the region where light creates fresh electrons and holes.

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with an excess of holes. The boundary between the silicon-arsenic body and the silicon-boron coat is known as a p-n junction.

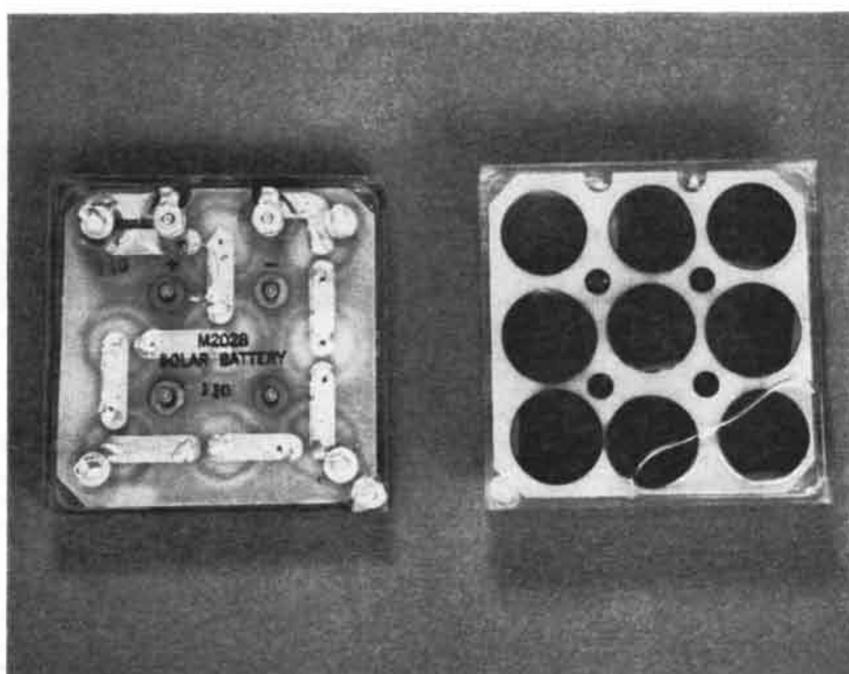
One electrical lead is attached to the n-type material in the body of the wafer and another lead to the p-type material on a surface. The opposite face of the wafer is left bare and exposed to the sunlight. The light striking this face releases electrons. As a result, the equilibrium between the *p* and *n* regions is upset, so that electrons move across the junction into the n-type material and holes across the junction into the p-type material. The charges then pass through the electrical contacts, and a current flows in the wire. What we have is a battery, with the positive terminal at the p-contact and the negative terminal at the n-contact. The battery in practice consists not of a single wafer but a series of them side by side, all enclosed in a transparent plastic case to protect them from damage and corrosion.

The battery is simple, but it is not easy to make. Although silicon is one of the most abundant elements on earth, it is never found pure, because it is extremely active chemically. For a photocell battery it must be purified to less than one part of unwanted impurity in a million—a difficult feat. After the silicon has been refined and crystallized in the form of a single crystal, the crystal is cut into wafers. The desired amount of arsenic has already been introduced into the crystal. Now the wafer is surrounded with a gas containing boron and heated. Boron atoms diffuse a short distance into the wafer and convert the surfaces into a p-type region.

In bright sunlight the solar battery can develop a top voltage of slightly more than one half volt. It can deliver a maximum power of about one hundredth of a watt per square centimeter of exposed surface area.

As we have seen, such a battery cannot respond to more than 45 per cent of the energy available in the sunlight spectrum. Because of various other losses, it could not convert more than 20 per cent of the sun's energy into power, at the most optimistic estimate. But this is enough to make the device interesting to many people.

What could it be used for? We must realize at once that it is impracticable for many ordinary uses. Suppose, for example, that you decided to stop buying electricity from the local power company and to install a solar battery to take care of your household power needs. Since the battery can generate power only while the sun is shining, you would need to add to your plant a storage battery to store power for the periods when it is not shining. The storage battery would have to be big enough to allow for a week or two of cloudy weather. For that you would need one ton of storage batteries, costing about $5,000 to make and $1,000 a year to maintain. In short, the storage batteries



WAFER MODULE is protected from dirt and corrosion by silicone oil and plastic case. The back (*left*) shows the conductors that carry current from the wafers to binding posts.

Lockheed diversification in action...

At right: engineers and scientists work on some of the 46 major projects in progress at Lockheed

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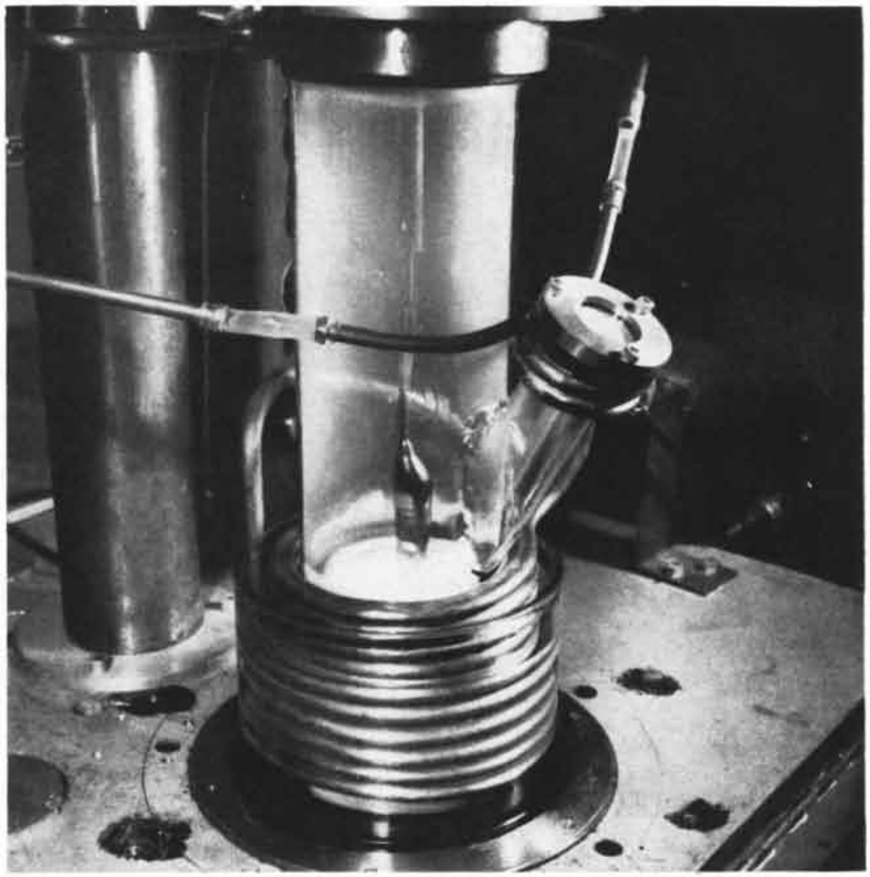


SILICON CRYSTAL is grown in a small induction furnace from a seed of pure silicon augmented by the molten material. Wafers for the battery are sliced from such crystals.

alone would cost you much more than your present annual electricity bill.

It would be a great mistake to jump to the conclusion, on the basis of such discouraging examples, that the solar battery will be of little practical use. Radically new inventions seldom merely replace old devices; they usually create new uses of their own. For instance, the telephone did not replace letter-writing but opened up a new form of communication. Very likely the solar battery will find its greatest usefulness in doing jobs the need for which we have not yet felt.

One field in which we can see immediate applications for it is communications—telephone, telegraph, radio and television. Here is a job ideally suited for the solar battery: the power needed is small, but it is often needed in remote, inaccessible places where no power lines go. The solar battery has one great, overriding advantage over the conventional dry-cell battery in such a situation: it will never run down, because it is fueled and recharged simply by the sun.

Consider a telephone instrument. To transmit your voice it needs some electric power—about one twentieth of a watt. There was a time when the perishable dry cell was the usual source of power. Now one can imagine a permanent battery—a solar battery teamed up with a long-lived storage battery—which would actuate a telephone instrument for years without attention.

A telephone line needs amplifiers, or repeaters, at intervals along the line to maintain transmission of the signal. Where lines span uninhabited areas the repeaters may be far from any source of power. Their power requirement is very small. This need has prompted the first actual test of a Bell solar battery in the field. The battery was installed this fall at a repeater station on a rural telephone line near Americus, Ga. Mounted on top of a telephone pole, the battery generates several watts of electricity during the sunlight hours, and it stores the power that is not being used in a storage battery, which supplies power at night and on cloudy days.

The Bell solar battery is still only a laboratory product. It is manufactured by hand by a rather complicated process. Purified silicon used in making the cells is very expensive. When solar batteries can be made more easily and inexpensively, and when enough is known about them to predict their properties precisely, their uses will certainly grow.

CHILDREN'S BOOKS

Presenting a Christmas survey of books in the various sciences for youngsters

by James R. Newman

In this year's crop of science books for children I can recommend several which your child should not miss. My first choice by a wide margin is Alan Paton's *The Land and People of South Africa;* I cannot remember a more moving and instructive book for youngsters. Also in the field of social studies, E. B. Fincher's *The President of the United States* is a most timely and interesting volume. In the physical sciences, outstanding items are Anne Terry White's *All About Our Changing Rocks* and Irving Adler's book on timekeeping, *Time in Your Life.* In biology, I would call special attention to *Our Wonderful Eyes,* by John Perry; *Introducing Animals-with-Backbones,* by William and Helena Bullough; *The Octopus,* by Olive Earle; *Seals and Walruses,* by Louis Darling; *The Plants We Eat,* by Millicent Selsam, and *Biology and World Health,* by Madeleine Grant. Micheline Morin's *Everest,* a history of 10 expeditions, is absorbing, and so is Walter Buehr's *Harvest of the Sea,* which manages to make commercial fishing sound almost as interesting as mountain climbing. The best of the biographies are those on Humphry Davy and Charles Darwin. And the list includes a topnotch reference book, Volume VIII of the Oxford Junior Encyclopaedia, whose articles on engineering will profit most adults as well as children.

Biography

GREAT DISCOVERERS IN MODERN SCIENCE, by Patrick Pringle. Roy Publishers ($3.00). The lives and achievements of a dozen modern scientists and inventors are sketched in readable fashion. Pringle discusses several men whose work is important but not widely known, for example Sir Edward Appleton, Sir Robert Watson Watt, Sir Frederick Gowland Hopkins, J. L. Baird, Sir Frederick Grant Banting. A good book.

HUMPHRY DAVY, by James Kendall. Roy Publishers ($3.00). Professor Kendall, a noted chemist, has written an agreeable introductory biography of the brilliant chemist who discovered sodium and potassium, was a founder of electrochemistry and invented the miner's safety lamp. Kendall is uncommonly skillful in his scientific explanations.

ISAAC NEWTON, by Harry Sootin. Julian Messner, Inc. ($2.95). A reverential, dramatized biography for adolescents. The author struggles manfully to explain Newton's scientific discoveries and does pretty well on some of them, but it is absurd to pretend that the basic ideas of gravitation, the calculus, the transmission of light and the reflecting telescope can be made clear to readers of any age without the support of a single illustration or diagram.

CHARLES DARWIN AND HIS PROBLEMS, by Evelyn Cheesman. Abelard-Schuman, Inc. ($2.50). Miss Cheesman, a professional entomologist and a very able writer and popularizer, has done a much-needed biography for children of 12 and older. The main part of her book deals with the celebrated voyage of the *Beagle,* which not only afforded Darwin the opportunity for important scientific work in the field but constituted the preparation for his epoch-making theory. Her treatment of natural selection and Darwin's other scientific speculations is a little too terse to meet the requirements of a young reader, but this book is strongly recommended for its other conspicuous merits: good writing, clarity, authoritativeness.

ROALD AMUNDSEN: A SAGA OF THE POLAR SEAS, by J. Alvin Kugelmass. Julian Messner, Inc. ($2.95). Cold, stormy seas and darkness beckoned to Roald Amundsen as sunshine, gold and the fountain of youth beckoned to other explorers. He began to train himself for adventure and privation in his early teens: gnawed on his leather boots to see whether he could subsist on the rations that had kept Sir John Franklin and his men alive, starved himself for days at a time, practiced mountain climbing, mastered the use of skis and snowshoes, learned the waywardness and treachery of polar ice and storms, became an expert sailor and navigator. Amundsen's first effort—a foolhardy attempt to cross Norway in the dead of winter—was a failure. Thereafter he succeeded in every undertaking until the last. He was the first to reach the South Pole; he guided a tiny ship, the *Gjöa,* in an almost incredible zigzag voyage through the Northwest Passage; he flew over the North Pole in a dirigible. In 1928 he lost his life while again flying to the Pole, this time on a rescue mission for the Italian braggart, Colonel Umberto Nobile. This book, for adolescents, gives a stirring account of the remarkable Norseman's career.

CAPTAIN COOK EXPLORES THE SOUTH SEAS, by Armstrong Sperry. Random House ($1.50). James Cook, the celebrated 18th-century English navigator and geographer, was renowned not only for his explorations and discoveries in the Pacific and the southern oceans but also for his humane and enlightened attitude toward the natives of the countries he visited. This is a readable but not always factually accurate biography.

CLARA BARTON—FOUNDER OF THE AMERICAN RED CROSS, by Helen Dore Boylston. Random House ($1.50). Clara Barton was a small woman who intermittently throughout her long life was afflicted by various psychosomatic ailments, ranging from loss of voice to blindness. Despite this fact she managed

EDITOR'S NOTE

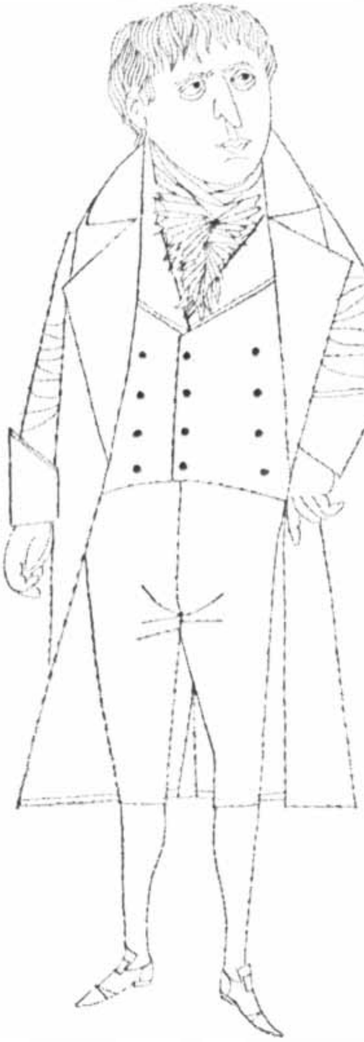
The illustrations that accompany this article are not from the books reviewed here. They were made by Jerome Snyder.

to perform labors which probably would have killed three men as durable as Yogi Berra. She taught school, tended her family, served as a matron in an insane asylum, singlehandedly ran a nursing and relief group during the Civil War, worked in the Patent Office, gave aid to soldiers during the Franco-Prussian, Spanish-American and Boer wars, campaigned and lobbied to persuade the U. S. to sign the Geneva Convention giving official status to the International Red Cross, and founded and became the first president of the American Red Cross. She was obviously a woman as difficult as she was admirable. This story of her life is worshipful but readable.

SIX GREAT INVENTORS, by J. G. Crowther. Hamish Hamilton Ltd. (10 shillings, sixpence). Here are solid biographical portraits of James Watt, George Stephenson, Thomas Alva Edison, Guglielmo Marconi, the Wright brothers and Frank Whittle. For this kind of sketch Crowther, the long-time science correspondent of the *Manchester Guardian,* is undoubtedly the ablest man in the field. He is not an elegant writer but he makes up for stylistic limitations by his straightforwardness, candor, accuracy, understanding of science, appreciation of social forces and refusal to indulge in nice-nellyisms. Crowther makes his characters plain, and, except for the occasions when he is carried away by political bias, makes them come alive. For adolescents and grownups.

CARRY ON, MR. BOWDITCH, by Jean Lee Latham. Houghton Mifflin Company ($2.75). Nathaniel Bowditch, though deprived of the opportunity of an education, became a mathematician and one of the foremost practical navigators of his time (1773-1838). He prepared the famous mariner's bible, *The American Practical Navigator,* and translated with commentaries the first four volumes of Laplace's difficult *Mécanique céleste.* Miss Latham's fictionalized biography recounts Bowditch's boyhood and youth, the long period during which he taught himself computation while apprenticed to a ship's chandler, the sea voyages on which he learned the art and science of navigation. This lively, well-told story about a man too little known will give pleasure to youngsters of 10 and older.

STEINMETZ: MAKER OF LIGHTNING, by Sigmund A. Lavine. Dodd, Mead and Company ($3.00). Charles Proteus Steinmetz, a cruelly deformed, frail gnome, arrived friendless and penniless in the U. S. as an immigrant from Germany in 1889 at the age of 24. Within 10 years he had risen to world fame for his researches on hysteresis, the behavior of alternating currents, the loss of electric power in currents and kindred problems. At the General Electric Research Laboratory, where he worked from 1893 until his death in 1923, he became the "Supreme Court"—the final arbiter on all questions of design, construction and research, the only employee permitted to smoke on the premises, to come and go as he pleased, even to play disagreeable practical jokes (usually involving electric shocks or exploding stoves) on colleagues and directors. This book, addressed to "anyone from 14 up," recounts Steinmetz' career, habits and personality in considerable detail. The scientific explanations are not very clear and the story is too long, but the book is not devoid of merit.



"Humphry Davy"

SAMUEL MORSE: INQUISITIVE BOY, by Dorothea J. Snow. The Bobbs-Merrill Company, Inc. ($1.75). Samuel Finley Breese Morse is remembered as a pretty fair portrait painter of the 19th century and as the inventor of the code and the magnetic telegraphic system which bear his name. Mrs. Snow has written a pleasant, better than usual, not too treacly life of the man. For children of 8 to 11.

Biological Sciences

MONKEYS, by Herbert S. Zim. William Morrow and Company ($2.00). There are 225 species of monkeys. They are sociable animals and dislike cold weather. Old World monkeys, like us, have 32 teeth; New World monkeys have 36. Old World monkeys include the macaques, of which the best known is the laboratory favorite the rhesus—from which we get the term Rh factor. The pig-tailed macaque of Malaya is trained to climb coconut palms, select ripe nuts and throw them down to its employer. The New World monkeys look a little more intellectual and include the capuchins, which for years have teamed up with organ-grinders. When monkeys are caged together, one of the group always takes over and becomes boss. The average life span of a monkey is 10 to 12 years, but a female mandrill has been known to live to 27. Monkeys sleep in a crouched position or leaning against each other or against a branch. An angry monkey draws back its lips in a grimace, and if it sees a human being doing the same it imagines the person is afraid—at least so the book says. Monkeys groom themselves even when they are free of pests. The tidbits they stuff in their mouths during the process are bits of dead skin—not only delectable but nutritious because of their salt content. If you want a monkey for a pet, be prepared for more alarms, diseases and demands on your attention than if you were raising a child. Monkeys are not easily housebroken. *Verbum sap.* A nice performance by Zim for youngsters of 8 to 12.

INTRODUCING ANIMALS-WITH-BACKBONES, by William and Helena Bullough. Thomas Y. Crowell Company ($2.50). This is a sound, delightfully readable little natural history of the vertebrates from the simple *Jamoytius,* which lived in the rivers of Scotland more than 300 million years ago, to blue whales, monkeys and men. The text, by a professor of zoology at the University of London, mixes just the right amount of evolutionary theory with descriptive matter; his

"Introducing Animals-with-Backbones"

wife's illustrations are among the liveliest and best I have seen in a biology primer. Warmly recommended for youngsters 10 and older. A companion by the same authors, *Introducing Animals-without-Backbones,* was reviewed here last December.

OUR WONDERFUL EYES, by John Perry. Whittlesey House ($2.75). Perry's clearly written book discusses how our eyes work, the nature of light, the speed and persistence of vision, color vision, animal vision, the function of the brain in seeing, optical illusions, how to take care of your eyes, what it's like to be blind and how the handicap is overcome. He gives directions for hundreds of simple, informative experiments. Illustrations by Jeanne Bendick. Recommended for children of 12 and older with scientific curiosity about the most blessed of human faculties.

SEALS AND WALRUSES, by Louis Darling. William Morrow and Company ($2.00). Seals and walruses are of the order Carnivora, suborder Pinnipedia. More simply, they eat meat and have fin-like feet. True seals (earless) cannot walk on land and have to slither along; even so they can slither as fast as a man can run. Walruses have long tusks and waddle nicely. Fur seals, of which there are five species, have highly developed breeding habits. Many congregate each year on the Pribilof Islands in the Bering Sea to bear their young and to mate. The bulls, arriving in early June, weigh about 600 pounds, are fat, tough and full of fight. Each one carves out a strip of beach as his domain, collects a harem and fights any other bull encroaching on his property or ogling his wives. (The females are delicate and weigh only 75 pounds.) The business of guarding, bellowing, roaring, fighting, herding and mating goes on for months, during which the bull never gets a chance to eat and can sleep only for seconds at a time. He is "exhausted, wrinkled and thin" by the time he is ready to return to the sea. Sea lions are much bigger than fur seals, have smaller harems (a dozen cows, more or less) and are less aggressive. They spend a good deal of time on land resting and basking in the sun; they don't even seem to mind joining a circus and doing tricks. The milk of true seal mothers has 10 times more fat than a cow's milk, and the pups gain four pounds a day for the first two weeks. Elephant seals weigh up to 5,000 pounds. This interesting book is simply written and helpfully illustrated by the author. Altogether a very nice item for children 8 to 12.

THE OCTOPUS, by Olive L. Earle. William Morrow and Company ($2.00). Despite its horrid appearance the octopus is a timid soul. If you are good to it, it will do you no harm. Octopuses range in size from six-inch species that live in southern Florida waters to 32-foot varieties in the North Pacific. The octopus' eyes are set in knobs that stand out from its head so that it can see in all directions; it has no ears and probably no sense of hearing. As is well known, the animal moves by jet propulsion, squeezing water out of a siphon by contracting its mantle cavity. Some varieties shoot out an ink cloud when pursued by their enemies; others change color in marvelous ways to match their background at the moment. Crabs, crayfish and mussels are the octopus' favorite foods, and it wants them alive. It is much better at opening a mussel than the most experienced human shucker armed with the latest Abercrombie and Fitch gadget. The octopus' method is simply to pull and keep pulling until the sides come apart; this way it never loses or mangles its dinner. A full-grown octopus has few foes to fear; it can either run away or squeeze the predator to death. Miss Earle ably describes this beguiling creature and throws in for good measure material on the argonaut, the pearly nautilus and the giant squid, which has 10 arms, grows to 70 feet, is the largest of all invertebrates and has been known to attack whales and the characters of Jules Verne and Walt Disney.

ANIMAL CLOTHING, by George F. Mason. William Morrow and Company ($2.00). The coverings of animals range from Brooks Brothers shirts and gray flannel suits to the chitin rings on a butterfly's thorax. Elephants have hair so stiff and sharp that "it must be singed off with a blowtorch before circus performers can ride on the animal." Caribou, moose and deer have extremely coarse, hollow hair, with a great deal of air space between the hairs so that body heat is retained. The horn on a rhinoceros' snout is actually a mass of solidified hair. Other animals, from oysters to turtles, have magnificent built-in armor which serves both as a home and clothing. Mason, an experienced naturalist, has written this palatable book for children of 10 to 14.

HOW THE ANIMALS EAT, by Millicent E. Selsam. William R. Scott, Inc. ($2.50). Eat or be eaten is not only a rule of nature but also a bill of fare. In the sea, for example, tiny animals feed on tiny plants; together they make up a kind of thin sea-soup eaten by bigger fish which are in turn gobbled up by still bigger fish. The herring, a typical fish, traps the food particles in the sea-soup with little rakes in its gill slits. The swordfish stabs its prey. The starfish pulls open an oyster's shell and slurps up the oyster with its stomach, thrust out through its mouth. The fish hawk dive-bombs its victims. The beaver cuts down trees with its teeth to get at the tender bark and leaves. Canaries, having no teeth, eat gravel to grind the food in their stomachs. The archer fish of Siam and India fires drops of water from its mouth at passing insects, stunning them so that they are easy to pick up. Mrs. Selsam's book is delightful, though sometimes too babyish.

WHAT'S INSIDE?, by May Garelick. William R. Scott, Inc. ($2.00). A snapshot chronicle of how a baby goose cracks and chews its way out of the egg and becomes a big goose. The text, making every allowance for the very junior audience (4 to 7) whose needs it is intended to meet, is insipid, but some of the photographs by Rena Jakobsen are delightful.

Biology and World Health, by Madeleine P. Grant. Abelard-Schuman, Inc. ($3.50). This interestingly written, well-conceived book for teen-agers (illustrated by Bunji Tagawa) briefly explains some of the fundamentals of biology and then discusses various special topics, such as parasites, microbes, viruses, vitamins, vaccines and serums, antibiotics, natural and artificial defenses against disease. Much space is devoted to the activities of the World Health Organization and to efforts in various countries to assure young and old persons of a better, safer, more comfortable life. Highly recommended, both as a biology primer and as an inspiring report on science in the service of man.

When You Go to the Zoo, by Glenn O. Blough and Marjorie H. Campbell. Whittlesey House ($2.75). One of the best of the many zoo books. It describes the inhabitants of the famous Washington Zoo and purveys diverting sidelights on matters such as how the animals are caught and transported, the kinds of shelters they occupy, how they are fed and cared for, how a zoo is run administratively, how sick inmates are given medical care. It is nice to learn that from Henry Trefflich, an animal dealer in New York City who sells to zoos and circuses, one can buy an "Indian female elephant—two-months delivery—up to five feet" for $3,500; a "dwarf male hippo—good for children, gentle, four years old," for $3,500; "giraffes—spring delivery" for $7,000 the pair; "lion cubs (tame)" for $250 each; and "Royal Bengal tigers—one to two years of age" for $2,000 each. The book, for children aged 9 and older, is illustrated with many photographs.

"The Plants We Eat"

Zoo Pets, by William Bridges. William Morrow and Company ($2.50). This engaging book by the curator of publications at the Bronx Zoo tells, among other things, about a baby wanderoo monkey which broke its tail and had to be hospitalized; a diminutive elephant, Candy, which made friends with a huge female pachyderm named Pinky; a male baby hippo which fell in love with a female baby hippo and now shows its devotion by putting its chin on her back and going to sleep; a hummingbird which takes showers under a running faucet; a small sea lion which was a feeding problem and had to be taught to eat fish. Fine photographs.

Vulcan: The Story of a Bald Eagle, by Robert M. McClung. William Morrow and Company ($2.00). This is a chronicle of the birth, growth, education, love life and adventures of a specimen of the great bald eagle, a fierce and magnificent bird which weighs only three ounces when it is born but within a few months attains a wingspread nearly seven feet across. A nice blend of fiction and natural history.

Insect Friends, by Edwin Way Teale. Dodd, Mead and Company ($3.00). Brief natural histories of some 30 "friendly" insects. They include bees, beetles, praying mantises, dragonflies, fireflies, froghoppers, water striders, crickets, cicadas, katydids, ants and daddy longlegs. The book is illustrated by nearly 100 of the author's photographs, many of which are amazing close-range shots of insect life.

Spiders, by Dorothy Childs Hogner. Thomas Y. Crowell Company ($2.00). A pleasing introduction for children of 8 and up. Mrs. Hogner explains the spider's anatomy and domestic habits, how it hunts and weaves, how it differs from insects, how the black widow serves the military, how a spiderling grows, and kindred matters. Clear, unpretentious, unsentimental. Helpful illustrations by Nils Hogner.

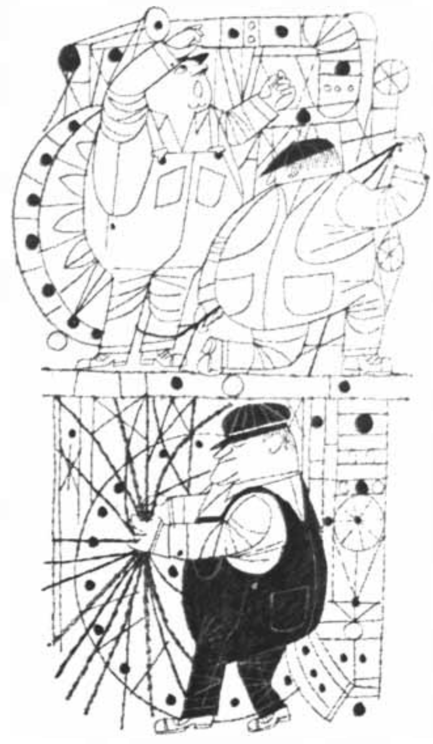
The Plants We Eat, by Millicent E. Selsam. William Morrow and Company ($2.50). Mrs. Selsam continues to hold her place as the best writer of botany primers for children. Here she describes the principal plant foods: roots such as potatoes and beets, stems such as asparagus, leaves such as rhubarb and lettuce, flowers such as broccoli and artichoke, fruits such as tomatoes and oranges, cereal grains such as barley and wheat. The book gives sound botanical details, tells how to grow various plants yourself and has many interesting historical sidelights.

The Story of Mosses, Ferns and Mushrooms, by Dorothy Sterling. Doubleday and Company, Inc. ($2.75). This book is a nice introduction to various remarkable plants which have neither seeds nor flowers, either absorb enormous quantities of water or survive with almost no water at all, require no sunlight, make their own soil by pulverizing rocks. A single meadow mushroom, we are told, may produce 16 billion spores. The liverwort, the first land plant, gets its name from its resemblance to the shape of the human liver. Horsetails are descendants of the 60-foot trees of the Coal Age forests; by adapting to a smaller size they survived, while their more stubborn contemporaries, the dinosaurs, died out. For children of 11 and older.

Men, Microscopes, and Living Things, by Katherine B. Shippen. The Viking Press ($3.00). An ably written biographical history of biology for adolescents. Miss Shippen begins her story with Aristotle's observations of living forms, and in turn sketches the lives and contributions of Pliny, Vesalius, Harvey, Malpighi, Swammerdam, van Leeuwenhoek, Linnaeus, Lamarck, Darwin, Mendel and many less widely known workers. She enlivens the essays with vivid quotations from the writings of the scientists themselves. Illustrations by Anthony Ravielli help make this an attractive book.

Physical Sciences

Time in Your Life, by Irving Adler. The John Day Company ($2.75). The rhythms of nature provide the standards for timekeeping. The author describes a number of these standards: the proces-



"Oxford Junior Encyclopaedia—Vol. VIII"

sion of the stars; the motions of sun, moon and earth in their orbits; atomic radiation; pulsating stars; sunspot cycles; the tides; metabolism; heartbeat. He also discusses the working of various types of man-made clocks, the fiddler crab as a living clock, the fixing of time by geological layers and the carbon-14 dating method. This is an original book which will give much satisfaction to any youngster over 12.

The Wonderful World of Mathematics, by Lancelot Hogben. Garden City Books ($2.95). A vivid catalogue of the growth of mathematics. In 69 pages, more than half of which are devoted to illustrations in full color, Hogben dashes through prehistoric methods of timekeeping and tally, the number systems of ancient Egypt, Babylonia, Rome, Central America and China, the founding and early uses of geometry, the determination of π, the elements of trigonometry, Greek mathematics, methods of navigation, the origin of zero, the application of mathematics to astronomy, the beginnings of algebra, Galileo's discoveries, analytical geometry, gravitation, the infinitesimal calculus, modern computing devices, the theory of relativity and other matters. Under the circumstances it is understandable that not all subjects are fully explained: the calculus, for example, gets half a sentence. But despite the fact that the book sometimes gives the impression of being no more than a glorified assortment of decorative end papers, where Hogben chooses to simplify a subject he often does it with great originality and verve. Many of the illustrations are inspired, and the survey as a whole will afford adolescents and grownups an easier and more enjoyable encounter with mathematics than they would have dreamed possible.

Hurricanes and Twisters, by Robert Irving. Alfred A. Knopf ($2.50). The word hurricane comes from *Hunrakan*, the name of the Guatemala Indian god of stormy weather. Hurricanes form over all tropical oceans except the South Atlantic. A full-grown hurricane can produce 500 million million horsepower, as compared with 150 million horsepower produced annually by all the electric generators in the U. S. Hurricane winds of 200 miles per hour have been recorded. A hurricane which rolled 40-foot waves up the Hooghly River in India on October 7, 1737, killed 300,000 people. During a hurricane in 1759 the *Litbury* cast anchor in what the captain thought was a channel in the Gulf of Mexico; the next morning he found the ship resting in the middle of an island (which had been covered by the storm waters) with its anchor hanging from the branch of a tree. This is a good hurricane book, though it is not as clear on the explanatory as on the descriptive side. For children over 9.

All about Our Changing Rocks, by Anne Terry White. Random House ($1.95). An exceptionally clear, attractively written introduction to geology for youngsters of 10 to 14. Mrs. White explains how mountains and valleys were formed, the modern theories of igneous, sedimentary and metamorphic rocks, fossilization, stratification, the rudiments of paleontology, the nature of minerals and crystals, the constant changes brought about by the sea and the wind. The writing is gracefully simple and always interesting, and the illustrations by René Martin are excellent.

A Child's Book of Mountains and Volcanoes, by James V. Medler. Maxton Publishers, Inc. ($.59). This slim volume contains a surprising amount of interesting information about some of the world's most admired, most loved—and most feared—mountains and volcanoes. The register includes the Matterhorn, first climbed by Edward Whymper in 1865; Paricutín, which pushed itself up in the middle of a Mexican cornfield in 1943; Mount Erebus, the only known volcano in Antarctica; Kilimanjaro, the "Grand Old Monarch of Africa"; Mount Rainier, a huge dead volcano; Mount Mayon in the Philippines, still very much alive and dreaded; Cotopaxi of Ecuador, the tallest active volcano in the world; Sangay, "the flaming terror of the Andes"; Mount Everest; Vesuvius; Etna; Mount Pelée, which in the greatest eruption of modern times (May, 1902) erased within a few seconds the town of Saint-Pierre and killed its 40,000 inhabitants.

THE GOLDEN BOOK OF ASTRONOMY, by Rose Wyler and Gerald Ames. Simon and Schuster, Inc. ($3.95). A survey for young readers over 12. The authors cover the solar system with its planets, the constellations, asteroids, comets, meteors, clusters and nebulae, the Milky Way, island universes, the changes of the seasons, gravity, the tides, eclipses, the measurement of time and space, the tools of astronomy, and of course the usual rigmarole about a rocket-ship voyage to the moon. Their scientific explanations, while dependable, vary considerably in clarity and interest; a few are fresh and help to light up difficult concepts, too many others are stereotyped. The book is colorfully illustrated by John Polgreen.

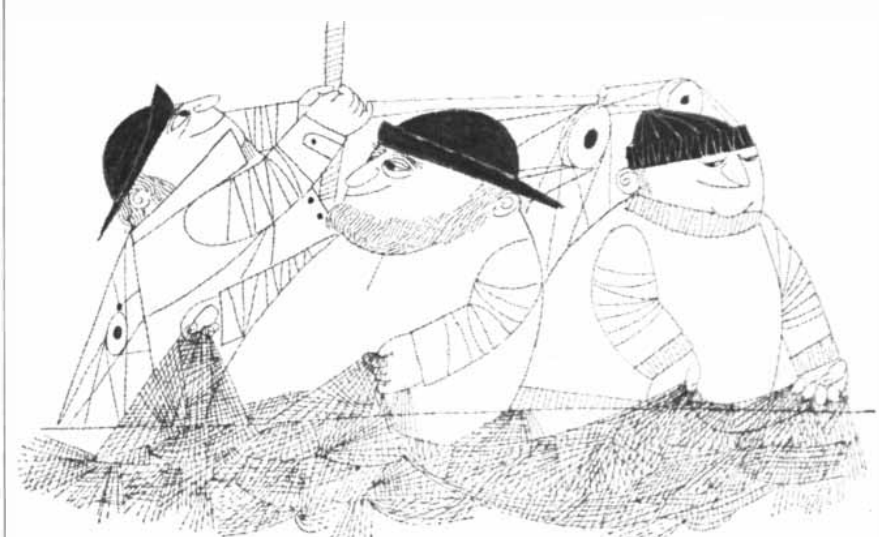
THE PRENTICE-HALL BOOK ABOUT THE STARS, by H. Percy Wilkins. Prentice-Hall, Inc. ($2.75). A primer for children of 12 and older by a British astronomer. Dr. Wilkins discourses knowledgeably about the sun and the planets, the moon (which is his specialty), stars, comets, meteors, constellations and the instruments used by astronomers. He writes straightforwardly but without inspiration.

EXPLORING THE MOON, by Roy A. Gallant. Garden City Books ($2.00). This is a brief, lively text for youngsters over 10 about the origins, birth, appearance and physical influence of the moon. The colored illustrations by Lowell Hess are mixed: some are illuminating, some merely lurid.

MARS, by Franklyn M. Branley. Thomas Y. Crowell Company ($2.50). A dependable, honest, but not always easy account. It covers theories about the origins of the solar system, the geography of Mars, its atmosphere and temperature, the moons of Mars, the canals, life on the red planet. This sound study will appeal to a high-school student who wants more than science fiction or generalities and is prepared to follow the ingenious scientific experiments and reasoning underlying present-day theories about the fascinating planet.

FIRE IN YOUR LIFE, by Irving Adler. The John Day Company ($2.75). This is an admirable explanation of the discovery, chemical and physical nature, uses and dangers of fire and its fuels, but it packs so much into one volume that a reader has to gallop from one subject to the next without a chance to catch his breath.

SCIENTIFIC INSTRUMENTS YOU CAN MAKE, edited by Helen Miles Davis. Science Service ($2.00). Winners in the National Science Talent Search competitions over the past five years describe the instruments they designed and built.



"Harvest of the Sea"

As you might expect of these capable and ambitious youngsters, most of the products are rather advanced, and make good reading only for youngsters with scientific aptitude. Among the instruments are a spectroscope, a telescope, an oscilloscope, cloud chambers, Geiger and scintillation counters, a Van de Graaff generator, electronic computers, a stroboscope, chromatographic apparatus and a three-dimensional Möbius strip.

Your Career in Physics, by Philip Pollack. E. P. Dutton and Company, Inc. ($2.75). A serviceable guide to any youngster who is thinking of becoming a physicist. Chapters are devoted to electronics, atomic energy, aeronautical research, optometry and optical engineering, meteorology, power production, geophysics, astrophysics, biophysics and other branches. Appendices list educational institutions for higher study, tabulate the average salaries that can be expected for different kinds of work and present other pertinent information. This is a levelheaded and practical book.

Exploration

Everest: From the First Attempt to the Final Victory, by Micheline Morin. The John Day Company ($3.50). Last year I reviewed a good short history of the Everest expeditions by Leonard Wibberley. Miss Morin's, translated from the French, is an even better book. It is written with a fine feeling alike for the dramatic happenings, the actors and the magnificent scenery. Lithographs (12 in color) and maps. Recommended for teen-agers and grownups.

Famous Scientific Expeditions, by Raymond Holden. Random House ($2.75). Here are brief accounts of the Beebe-Barton bathysphere descent, the climbing of Mount McKinley (including Dr. Cook's fraudulent jape), the Carter-Carnarvon discovery of Tutankhamen's tomb, the Burden expedition to Komodo Island (where antediluvian dragons were found) and Vilhjalmur Stefansson's Canadian Arctic expedition 40 years ago. Illustrated.

Trails West and Men Who Made Them, by Edith Dorian and W. N. Wilson. Whittlesey House ($2.50). Stories about the great pioneer roads that opened the American continent. Among them are the Golden Trail of the Southwest, from Kansas into Mexico; the Wilderness Road cut by Daniel Boone; the tangled Natchez Trace of swamps, bogs, forests—and cutthroats—that connected Nashville and Natchez; the Santa Fé and Oregon trails, the famous river routes. This is an ideal subject for a book for youngsters, but the authors have crammed their account with so many names and details that half the life has been squeezed out.

Technology

OXFORD JUNIOR ENCYCLOPAEDIA—VOL. VIII: ENGINEERING, edited by Laura E. Salt and Robert Sinclair. Oxford University Press ($7.00). This volume is one of the best in the series. Handsomely designed and well-illustrated, it treats a remarkable wealth of topics, including the calculus, logarithms, trigonometry, electric currents, blast furnaces, calculating machines, timekeepers, machine tools, geometry, wind tunnels, transformers, radio and television, radioactive isotopes, weather instruments, bridges, magnets, heat pumps, shipbuilding, gyroscopes, turbines, fuels, friction, mining, electron microscopes, dams, harbors, automatic controls. For an adolescent boy and for many an adult this is an ideal gift—and also a bargain.

FAMOUS INVENTORS AND THEIR INVENTIONS, by Fletcher Pratt. Random House ($2.75). Vignettes of 50-odd inventions, from explosives to quick freezing, all in 137 pages. Even for a veteran explainer and skillful condenser this is too much material for the allotted space. Readable, of course.

MORE MODERN WONDERS AND HOW THEY WORK, by Captain Burr W. Leyson. E. P. Dutton and Co., Inc. ($3.50). Captain Leyson explains in considerable detail the workings of a curious collection of artifacts: guns, locks, atomic submarines, ultrahigh frequency, hydraulic transmissions, weather instruments, phonograph records. He is a painstaking expositor and his book is well illustrated; it will appeal to mechanically minded males over 12.

EXPERIMENTAL PLANES, by R. Frank, Jr. Thomas Y. Crowell Company ($2.50). A report on subsonic and supersonic aircraft. Among the airplanes covered are the Skystreak, the X-1 (first to break the sound barrier), the Skyrocket, the X-1A, vertical takeoff planes and the delta-wing XF-92A. The most interesting sections of this book deal with the complex and ingenious strain and pressure gauges, yaw meters, cameras, electrical dials, controls, pumps, ejection machinery and other devices built into these research craft to keep them flying, keep the pilot alive and gather essential information. The Skyrocket, for example, has tucked away in its tiny cabin a refrigerating unit which weighs only 100 pounds but could cool the inside of a theater seating more than 3,000 persons.

"The Land and People of South Africa"

THE PRENTICE-HALL BOOK ABOUT INVENTIONS, by Egon Larsen. Prentice-Hall, Inc. ($2.75). The author, an experienced journalist and biographer, writes a reasonably accurate account of the invention of the steam engine, the mechanical loom, the electric light, the automobile, the airplane, photography and so on. It is hard to identify the audience for this brief survey; youngsters under 12 will find the book too difficult, while adolescents will regret the absence of clear or detailed explanations.

HELICOPTERS: HOW THEY WORK, by John Lewellen. Thomas Y. Crowell Company ($2.00). Youngsters of 11 to 14 will find in this little book an admirably clear report on the helicopter: its history, the different types and their uses. In the first chapter the author describes vividly a 31-mile flight in a helicopter on a rainy winter night from the roof of Chicago's Merchandise Mart to a gas station near his home in the country, during which the pilot had to keep nosing the craft down to find his way by reading illuminated street signs and following car tracks.

ATOMS TODAY AND TOMORROW, by Margaret O. Hyde. Whittlesey House ($2.50). A primer of atomic energy, from ore to atomic locomotive, for youngsters over 12. An everyday sort of book.

ELECTRONICS FOR YOUNG PEOPLE, by Jeanne Bendick. Whittlesey House ($2.75). This revised edition has an enlarged section on atomic energy and discusses some of the more recent applications of electronics. Better than average.

FUN WITH YOUR CAMERA, by Mae and Ira Freeman. Random House ($1.50). Commandments, prohibitions and general hints for young beginners in photography. How to focus, how to load, how to compose scenes and groups, how to catch action, how to do candid shots, how to make flash and trick pictures. Photographs illustrate the principles. A book of modest merit.

THE TRUE BOOK OF CLOTH, by Esther Nighbert. Children's Press ($2.00). For young readers 6 to 10. It gives small capsules of information about the processing of wool, the weaving of cloth, the manufacture of cotton and linen, the spinning of silk, the making of nylon and rayon.

THE FIRST BOOK OF ROADS, by Jean Bothwell. Franklin Watts, Inc. ($1.95). Miss Bothwell's little volume on roads maintains the satisfactory standard of "The First Book" series by this publisher. She presents the historical background of road building and describes some of the famous ancient highways. Among them are the Via Salaria, which ran from Rome to the salt beds of Ostia and gets its name from the fact that along it was carried the salt allowance given to each Roman soldier, the source of our word "salary"; the Amber Route from the Baltic to the Mediterranean, dating to 2000 B.C.; the 1,755-mile Royal Road from the Persian Gulf at Susa to Ephesus and Smyrna on the Aegean Sea; the road traversed by Paul of Tarsus in what is now Turkey; the great Appian Way; Watling Street, the old Roman road through the middle of England. South America also had roads representing remarkable engineering feats by the Incas. The story is brought up to date with discussions of the growth of the southern, western and transcontinental trails in the U. S. and the planning and building of modern automobile highways. An informative and readable book for children 10 and older.

Harvest of the Sea, by Walter Buehr. William Morrow and Company ($2.50). A clear, attractively illustrated account of commercial fishing in the U. S. Some of the data on fish catches are astonishing: the people of the U. S. eat 150 million pounds of shrimp a year, 600 million pounds of Pacific salmon, 15 million pounds of lobster. From the Atlantic Coast purse seiners take 400 million pounds of menhaden or pogy—a fish which is not good to eat but is used in manufacture and as a fertilizer. A very good book for children 10 to 14.

Social Sciences

The Land and People of South Africa, by Alan Paton. J. B. Lippincott Company ($2.75). The distinguished South African novelist and poet, author of *Cry, the Beloved Country,* here takes the reader on an escorted tour of Capetown, of the diamond city Kimberley, of the gold-mining town Johannesburg, of the Kruger National Park (where you may not leave your car because there are lions running free), of the capital Pretoria, and all the way to Victoria Falls in Rhodesia. Paton is a man who loves his country and knows it well, who appreciates and can describe its beauty, its wildness, its contrasts of squalor and splendor, who takes pride in what is worthy of pride and does not hesitate to express his shame over what is shameful. Along the journey he recalls the past of the Union of South Africa: the struggles and bloodshed, the blunders of politicians, the bitterness and prejudice and injustice which, still continuing, are the fruits of earlier follies. One of Paton's most illuminating little stories concerns the Afrikaner (Dutch) teacher who taught English at an Afrikaner school and began his lesson with the words, *"Kinders, laat ons nou met die vyand se taal worstel"* ("Children, let us now wrestle with the enemy's language"). I cannot speak too highly of this richly informative, delightfully readable, wise and moving book. It is a model for children's books in any field.

The President of the United States, by E. B. Fincher. Abelard-Schuman, Inc. ($3.50). Who may be President? How are the candidates chosen? What are the principal features of presidential elections? What are the President's powers? These and many other questions are fully answered in

Professor Fincher's plainly written book, which also gives a wealth of historical material, including tables and charts, about the men who have striven for and held this office, the problems they have faced, the decisions they have taken, the philosophy of executive duties they have brought to it. An excellent job for youngsters of high-school age.

THE YOUNG TRAVELER IN GERMANY, by Egon Larsen; THE YOUNG TRAVELER IN ITALY, by David Raymond; THE YOUNG TRAVELER IN NORWAY, by Beth and Garry Hogg. E. P. Dutton and Company, Inc. ($3.00 each). These are the latest volumes in a sound series on various countries. The young traveler has an enviably enjoyable and carefree time living with other youngsters his age in the country he is visiting, attending school, partaking in games and festivities, exploring famous towns and other places of interest, learning from knowledgeable guides about local history, folklore, customs and the like.

TRAVEL AND TRANSPORT THROUGH THE AGES, by Norman E. Lee. Cambridge University Press ($2.50). This book, first published in Australia by the Melbourne University Press in 1951 and now substantially revised, presents an entertaining and informative account of the way men have moved themselves and their belongings from place to place since the Stone Age. The author takes us on a rambling journey through various periods of history and many topics: Przhevalski horses, locomotives, the invasions of Rome and Britain, famous ships, the building of roads, bicycles and airplanes, the evolution of the stirrup and the horse collar, the railway age, water transport, stagecoaches.

THE STORY OF OUR ANCESTORS, by May Edel. Little, Brown and Company ($3.00). Mrs. Edel's story, pointed to the 12-and-up age group, deals with the critical period in the evolution of man when certain of his predecessors decided to come down from the trees, walk erect and try life on the ground. She describes various nearly human and early human types, and depicts the scientific reconstruction, from odd bones, tools and similar remains, of the appearance and habits of Australopithecus, Neanderthal man, Peking man, Pithecanthropus, Sinanthropus, Gigantopithecus and other kinsmen. Despite the fact that the author is a clumsy writer, she knows her interesting subject so well and is so conscientious in presenting it that this is a worth-while book.

THE AMATEUR SCIENTIST

About the preparation of microscope slides, the testing of telescopes and other matters

John De Haas, whose system of phase contrast microscopy was described in this department in the July issue, makes a hobby of learning how to study protozoa the easy way. He combines the use of the phase contrast microscope with simplified methods of preparing slides which, he says, reduce the labor of preparation so much that they double the time one can spend on observing.

"My first rule," he writes, "is to shun the temptation to make permanent slides. They are handy for reference, of course, but I suspect that most permanent collections accumulated by amateurs (including mine) owe their existence largely to our simian love of bright trinkets. You can learn more about protozoa by studying live material than by collecting desiccated specimens.

"Here is one way of preparing a live slide that is the essence of simplicity. Put a drop of culture on a clean slide, ring it with a little dike of vaseline applied by the tip of a toothpick and drop a cover glass on top. The vaseline retards evaporation around the edge of the cover glass and also prevents it from crushing the animals. Don't worry about smothering them. Long after fatigue has dimmed your eye, the protozoa will be darting about, feeding and reproducing. When you finish observing, return the organisms to a storage jar and wipe the slide clean.

"It is possible to make a lot more work out of this simple operation. You can, for example, purchase slides with circular concavities for the organisms, and you can make elaborate watertight seals to cover them. Some workers spend hours building little ponds on flat slides with rings of plastic or waterproofed cardboard. Others make cells of special cements involving rubber, gutta-percha, shellac and so on. Although many of these slides are pretty and display astonishing craftsmanship, the effort expended does not show up in noticeably better results when you look through the eyepiece.

"It is also easy to make hard work out of the preparation of a permanent slide. Back in the days when slides took the form of machined blocks of ivory fitted with mica windows held in place by slip rings, a proficient worker was lucky if he finished one per week. Some amateur microscopists still get fun out of making replicas of these historic slides as well as the time-consuming glass types.

"Anyone who wishes to save time in making a permanent slide will appreciate the method devised about 25 years ago by a German biologist named Bresslau. It is especially suited for mounting ciliated protozoa, because they have relatively tough hides.

"A culture of paramecia makes good practice material to work with while you are mastering the technique. This minute creature looks somewhat like a transparent football covered with a fuzz of short hair. You can cultivate paramecia from timothy hay. Pack a quart stewpan about half full of hay and add enough water to cover it. Boil the preparation for 10 minutes. This kills many of the fungi, spores and other unwanted organisms in the hay. Then discard the water, let the hay drain for a few minutes and transfer it to a clean pint jar filled with either pond water or distilled water. After the infusion has incubated for a week at room temperature, the paramecia cysts will have developed and you will find the jar swarming with organisms. Some workers increase the yield by adding a nutrient, *e.g.*, a generous pinch of powdered skim milk.

"Place a drop of the culture on a clean slide. To stain it, make a concentrated solution of opal blue in water, boil a half teaspoon of it in a small test tube and place one drop of this boiling hot stain on a slide near a drop of the culture. Mix the two drops quickly and smear out lightly with a toothpick. Avoid pressure, for it may crush the larger paramecia. The staining process is completed in about five minutes. On a very dry day it may be necessary to put the slide into a moist chamber to prevent the stain from evaporating before it has had time to act. When the staining is complete, let the slide dry completely. Then add a drop of Canada balsam and gently press the cover glass into place.

"The procedure is not half as complicated as it sounds, and the whole job should not take more than 10 minutes. If it is done correctly, most of the paramecia will show no shrinkage or distortion. Speed, and care in applying pressure, are the only critical elements in the process. I have eight-year-old slides of paramecia [*see photographs on opposite page*] which show no deterioration."

The Foucault test for determining the shape of a concave mirror, capable of accuracy to a millionth of an inch, is the essence of simplicity. You make a pinhole in a tin can, put a candle inside and shine the rays from the pinhole (a synthetic "star") on the mirror. If the mirror has the figure of a true sphere, the reflected rays converge to form an image of the pinhole. When the mirror is viewed from a point just behind this image, it appears evenly illuminated and flat, like the disk of the full moon. And if you pass a knife-edge through the center of the image, the mirror should darken uniformly.

That is the way the test is *supposed* to work. In practice it is much more interesting—or exasperating, depending upon your temperament. The slightest departure of the mirror from a true sphere—or an equivalent change in its position or an abrupt variation in the density of the surrounding air—destroys the apparent flatness of the disk. With appropriate modifications of the light source, you can take advantage of this sensitive property and use the apparatus for photographing rifle bullets in flight complete with the shock waves. Similarly, you can photograph sound waves, convection currents, streamlines around airfoils and so on. The setup can even be adapted as an ultrasensitive seismometer, which will pick up the vibrations of traffic miles away.

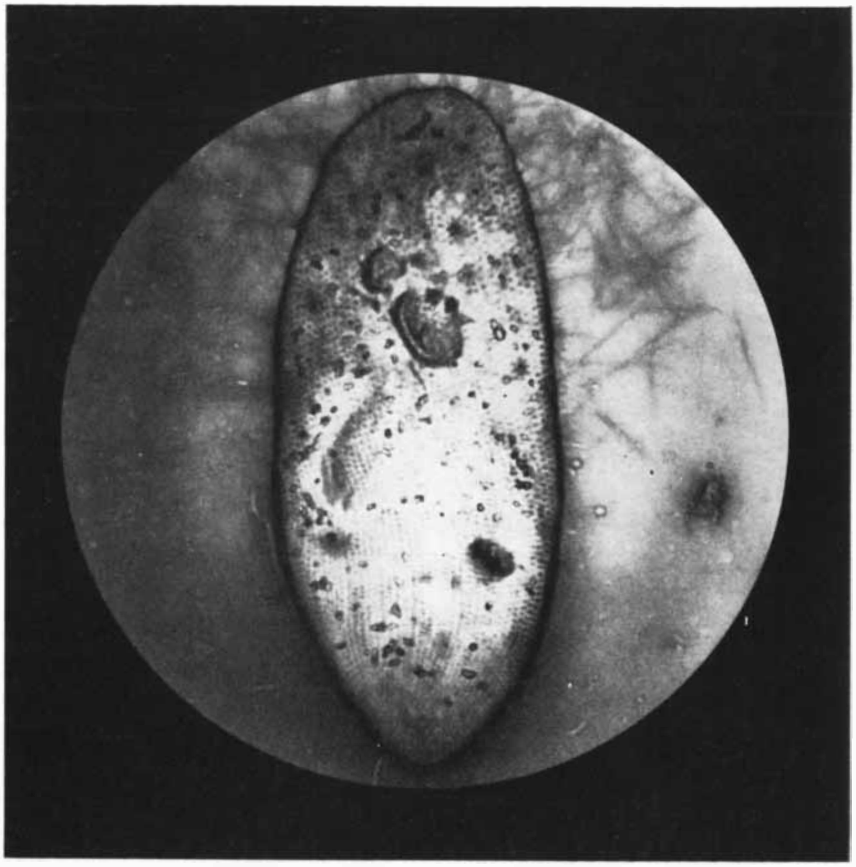
Amateur telescope makers have a lot of fun doing experiments like these. But primarily they use the test as the French physicist Jean Foucault intended it: for determining when the mirror has been polished to the figure of a parabola, the shape required for a good reflecting telescope. When the parabola is examined at the knife-edge, it presents a pattern shaped somewhat like a doughnut instead of a flat disk. As the ratio of the focal length to the diameter of the mirror is increased, the distinction between the two patterns tends to disappear. The doughnut becomes flatter with increasing focal length. At about $f/15$ the curve of the parabola coincides with that of the sphere for all practical considerations, and the Foucault pattern for both appears flat. Below $f/5$ the "doughnut" develops such pronounced shadows that interpretation becomes difficult and the test loses its usefulness.

Many amateurs have dreamed up schemes for making the Foucault apparatus less finicky. The trouble stems from the fact that, as conceived by Foucault, the pinhole must be situated somewhat off the optical axis of the mirror, so that the reflected image will form on the opposite side, where there is space for the amateur's eyeball. The strongly shadowed doughnut of short-focus mirrors results from this angular illumination.

Carl Bergmark, an amateur telescope maker of San Francisco, submits a solution he has devised for the problem:

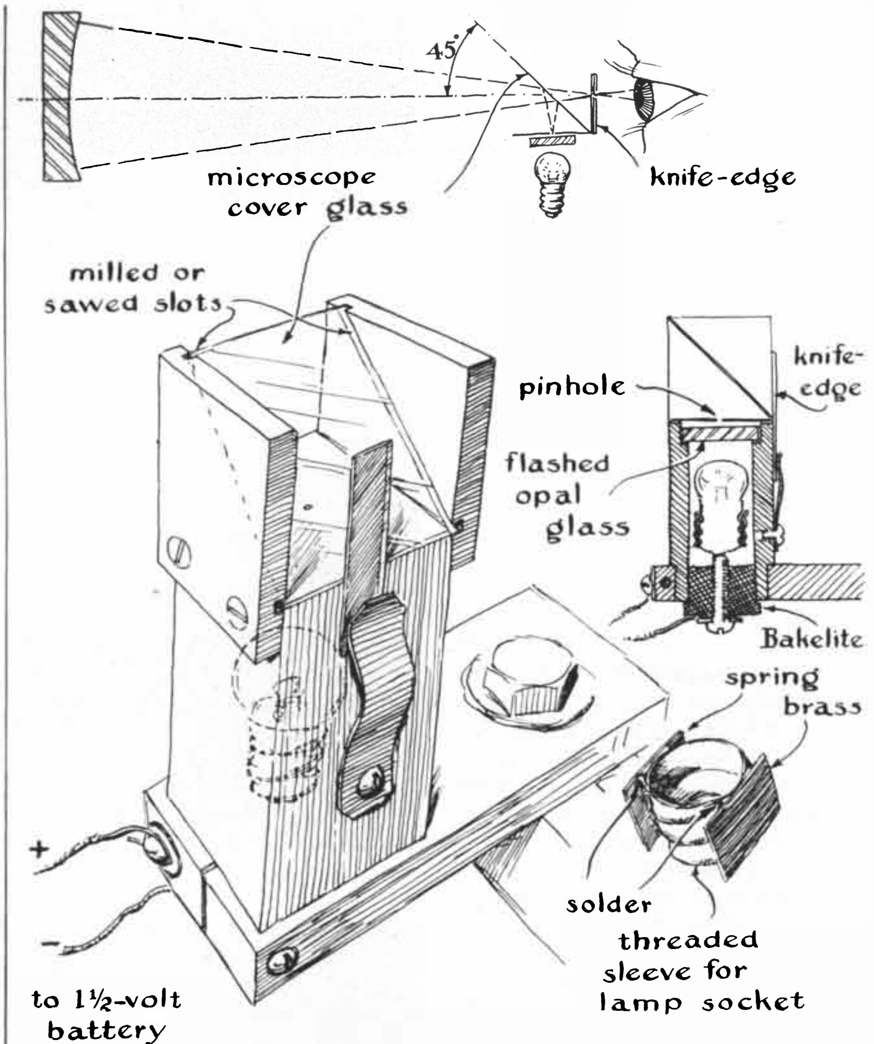
"One of the defects of the Foucault test when working with short-focus mirrors is the error introduced by the lateral distance between the pinhole and the knife-edge. I believe that my test rig eliminates this shortcoming [*see drawings on next page*]. The light from the pinhole is reflected into the axis by a microscope cover glass instead of being directed straight toward the mirror. This arrangement causes some loss of illumination, but the comparatively great light-gathering power of the short-focus mirror compensates for it. Rays reflected from the mirror, as shown by the upper drawing, are transmitted to the eye through the cover glass, the knife-edge being inserted at the point of convergence between them. Although the surfaces of the cover glass reflect a double image of the pinhole, the glass is so thin that the two images may be regarded as a point. I am lucky in having access to a nine-inch metal lathe, the compound rest of which serves as a handy carriage for the gadget. While under test the mirror is supported on a wall bracket behind the lathe."

After making the drawings to illustrate Bergmark's rig, Roger Hayward,



A paramecium photographed with an amateur's version of the phase microscope

Three paramecia are photomicrographed. Both slides are eight years old



A Foucault-test rig for short-focus mirrors

who is an old hand at devising optical tricks, observed: "I have a feeling that Bergmark's scheme of using a microscope cover glass for an image divider is not altogether new, but I cannot remember having seen it applied in just this way. The secret of its success lies in the fact that, bad as cover glasses are optically, a very small area of one is always good enough. Incidentally, the formula for computing the difference between the position of the knife-edge at which the center of the mirror appears to darken uniformly and that at which any radial zone of a parabola similarly darkens is computed by the equation: $D=r^2/2R$, where r is the radius of the zone, R the radius of the mirror's curvature and D the difference in position through which the test rig must be moved to achieve the desired darkening."

For some time amateur telescope makers have been wondering how to make use of the war-surplus lenses of wide aperture and short focal length which have been much advertised at prices of less than $20. Many are cemented achromats of superb quality—corrected for two colors and manufactured to rigid tolerances. A number are coated for maximum light transmission and come ready-mounted in precision cells. The catch in using these lenses as telescope objectives, of course, is that their focal length is only about 10 to 20 inches and their magnification is correspondingly low. A one-inch eyepiece gives a magnification equal to the focal length of the objective lens in inches. A half-inch eyepiece doubles this power; a quarter-inch quadruples it and so on. To utilize the maximum light which the surplus lenses are capable of gathering, one would need an eyepiece only an eighth of an inch or less in diameter, and so small an objective is impracticable.

Wilfrid T. Patterson, an optician of Guelph, Ontario, suggests an ingenious if unconventional solution for the prob-

Boeing engineers create America's first jet transport

Here is another important "first" for Boeing engineers. It is the Boeing Jet Stratoliner 707, shown here as it will look when it takes to the air. Many Boeing engineers are now at work perfecting this epochal airliner. Other engineers are developing years-ahead airplanes and missiles that will continue to enhance Boeing leadership—and their own professional prestige.

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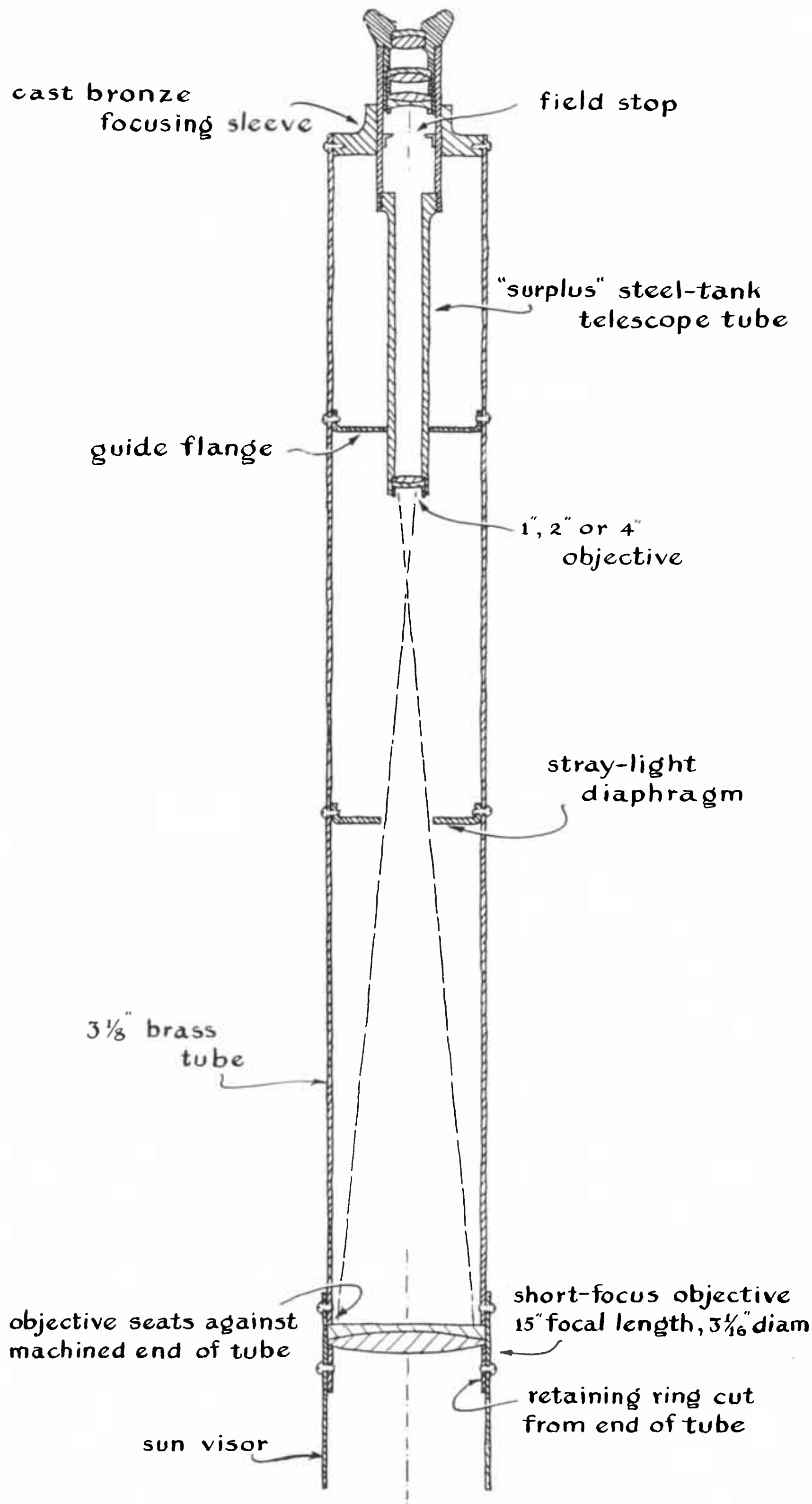
lem. "I rather doubt that my idea is new," he writes, "but I can assure you that it works. Some time ago I obtained an $f/5$ photographic lens of four inches diameter. It was assembled as the objective of a refracting telescope fitted with an Erfle eyepiece taken from what appeared to have been part of a bomb sight. The combination proved excellent for scenic viewing and bird study. The image was inverted, of course, but years of playing with astronomical telescopes had accustomed me to looking upside down. While working with this instru-



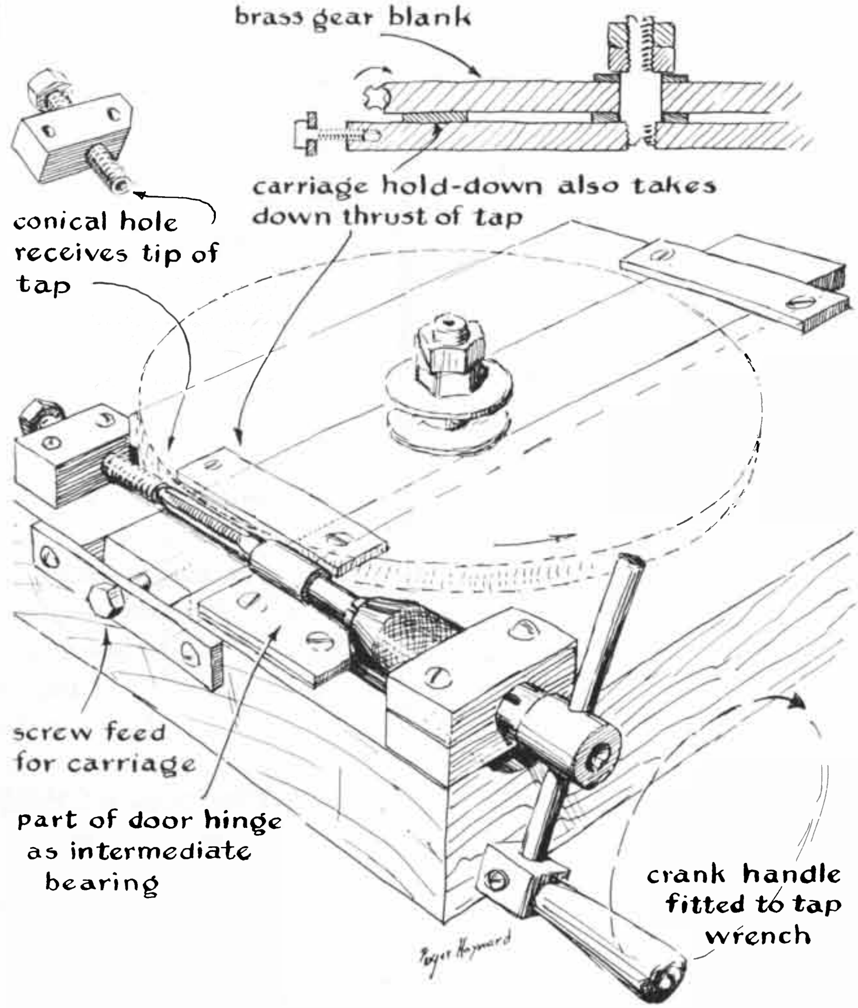
A short-focus refracting telescope with a microscope eyepiece ment, I got an urge to try out some of the surplus objectives. They turned out to be of substantially higher quality than the camera lens. The images were much more brilliant and showed astonishing resolution. It was obvious that they could withstand high magnification without becoming fuzzy. Why not examine them under a compound microscope?

"The idea was given a try by means of a hybrid arrangement using a 40-power microscope of the type designed for machine shops. This gave the completed instrument an over-all power of 400 diameters [*see drawing on opposite page*]. The field of view was exceptionally wide and sharp to the very edge. Almost the whole face of the moon appeared in exquisite detail. The objective did not gather quite enough light at this magnification for a satisfactory view of Saturn.

"I next assembled from surplus parts a microscope which could be varied through a wide range of powers. The objective lenses were selected from an assortment of achromats picked up at a few cents apiece. They work nicely as low-power elements and, incidentally, can also be used for building excellent eyepieces. Various tubes designed for spotting scopes and tank sights also are available on the surplus market. One end of these tubes is usually machined to take eyepieces, and the other can easily be modified as a cell for the objectives. With a selection of three or four objectives and eyepieces you have a microscope, ranging in power from 10 to 100 diameters, which will find endless use around your shop as well as in the telescope.

"Alignment of the optical train is critical. The holes in the focusing sleeve and guide flange must be carefully centered. The body of my scope is made of seamless aluminum tubing. It is stocked by dealers in surplus optical parts and is easily worked with hand tools. Hayward, when he made the drawing of the instrument, observed that by using an arrangement in which a thick tube must slide in a solid brass sleeve I am asking for trouble. The combination may stick and even freeze. A springy sleeve would be preferable. The problem was solved in old microscopes by lining the sleeve with velvet—and a fine solution it is."

Patterson equips his astronomical telescopes with slow-motion drives using homemade worm gears. "These drives," he says, "have many applications. They are handy for adjusting the position of remote optical parts, shifting the fre-



An amateur's device for cutting worm gears

quency of electronic oscillators, driving the charts of pen recorders and so on. With the fixture shown here [*drawings above*] you can turn out a $20 gear for $1.50. The teeth of the gear are cut by means of a tap, and those of its companion worm, by a matching die.

"I cut the blank gear from brass plate, usually a quarter of an inch thick. The approximate radius of the disk is found by dividing the gear ratio desired by 6.28 (2π) times the number of threads per inch which the tap cuts. If the desired gear ratio is 365 to 1, for example, and you use a tap which cuts 16 threads per inch, the blank should have a radius of approximately 3.66 inches. In practice you make it just a trifle larger to allow for the depth of the threads.

"A hole is drilled in the center of the blank disk so it will turn freely on the stud of the fixture. The blank is advanced by means of the feed screw of the fixture and the tap is rotated lightly through one revolution of the blank to mark the points at which the teeth will be cut. The work is then examined to assure that the tooth spacing will come out even. If the blank has been made oversize, the spacing between the first and last tooth will be too wide. The blank is then dressed down and another experimental cut is taken.

"There is nothing hard and fast about the design or dimensions of the tooth-cutting fixture. It would be simple, for example, to drive the tap with an electric drill instead of the arrangement shown. But that would hurry the job. After you have spent two evenings or more making the fixture, you will feel cheated unless you have the fun of turning the crank for half an hour or so."

Despite the storms and floods in New England this fall, more than 200 amateur astronomers and a generous sprinkling of professionals turned out for the annual Stellafane meeting at Springfield, Vt.

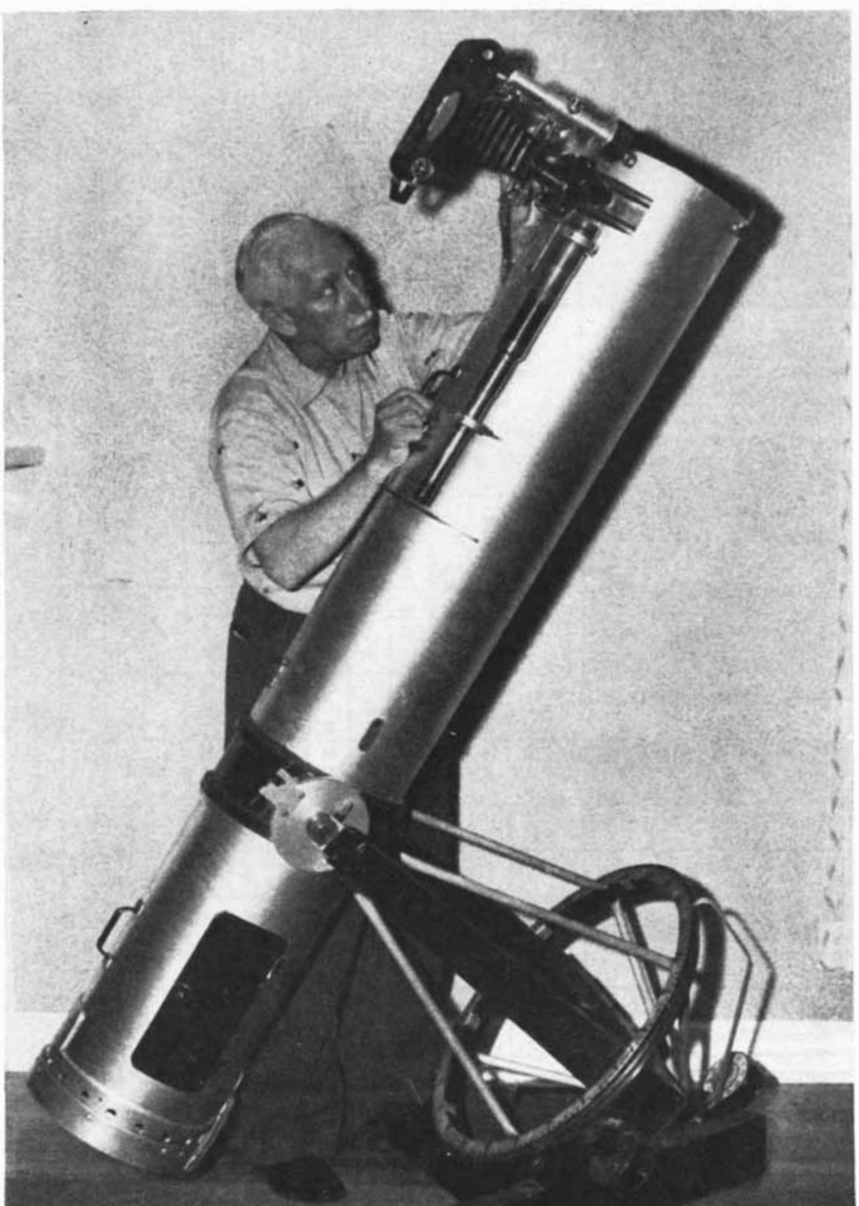
James W. Gagan, secretary of the Amateur Telescope Makers of Boston and one of the meeting's moving spirits, reports that the weather cleared to 96 per

cent seeing and held good for two nights. "Many of the gang," he writes, "camped on Breezy Hill and enjoyed naked-eye observation of clusters and nebulae. Arcturus and the Alcor-Mizar system, along with a comet about nine degrees below Polaris, provided excellent objects for judging the resolution of telescopes placed in competition.

"Winfred Lurcott of Cranford, N. J., who spent two days behind the wheel of his car detouring New England's flooded areas, arrived just in time to set up his big portable reflector and take both first prizes. His 10-inch Newtonian has a rigid yoke mounting, a clock drive, a rotating multiple-eyepiece turret and accurate setting circles [*see photograph below*]. It can be stowed in the trunk of a car, and can be unlimbered and set up ready for observation in five minutes flat.

"Other awards were taken by John E. Welch of Springfield, Mass.; Guy Gordon of Natick, Mass.; John Sanford of Newburgh, N. Y.; George Random of West Acton, Mass., and Bruce Woodward of Rye, N. Y. Incidentally, the committee is still trying to locate unidentified winners. The judges tried out a system of tagging entries by number to eliminate any possibility of bias. It worked so well that two contestants left for home without their awards.

"August 11, 1956, has been set as the date of the next Stellafane meeting, that being the first Saturday after the new moon in August."



Winfred Lurcott and his 10-inch Newtonian reflector

INDEX OF ADVERTISERS

DECEMBER, 1955

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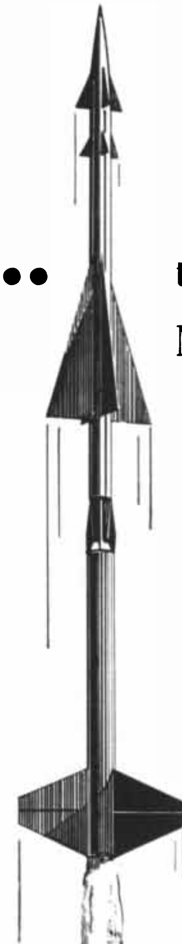
LIFE AT HIGH ALTITUDES

OBSERVATIONS UPON THE EFFECT OF HIGH ALTITUDE ON THE PHYSIOLOGICAL PROCESSES OF THE HUMAN BODY, CARRIED OUT IN THE PERUVIAN ANDES. J. Barcroft and others in *Transactions*

Douglas announces...

the formation of a separate Missiles Engineering Department



Growing importance of missiles in the nation's defense has led to the separation of missiles engineering from aircraft engineering functions at Douglas Aircraft Company.

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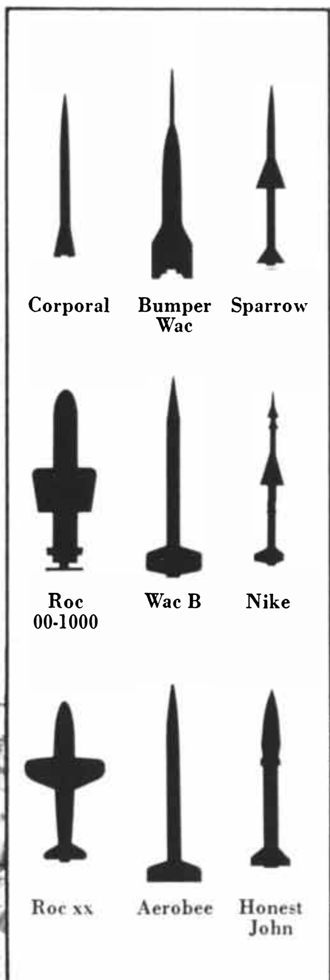
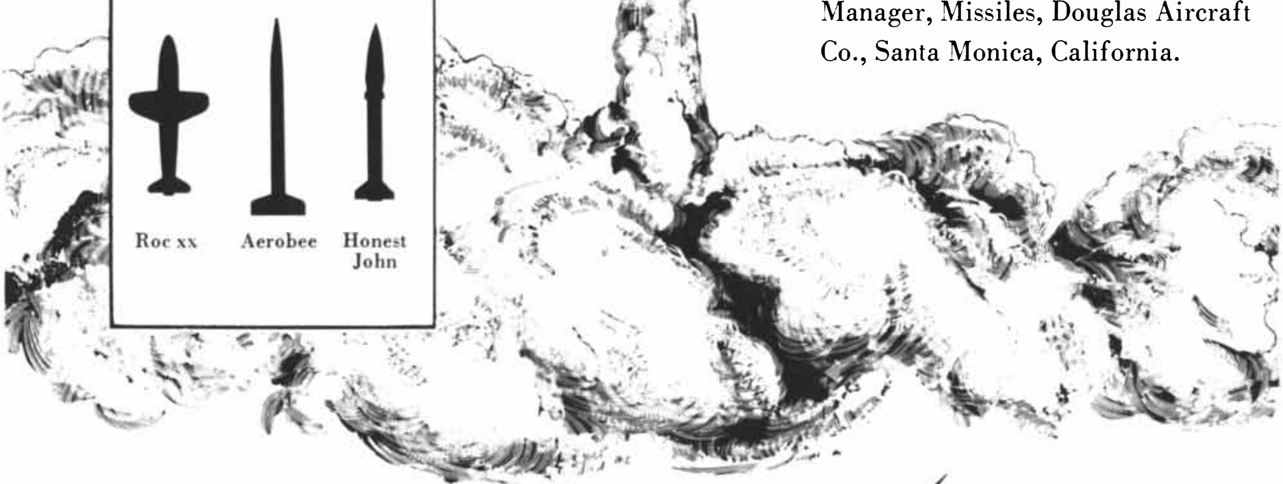
Formation of the new department at Douglas opens new opportunities for engineers and scientists interested in the missiles field. Write to: E. C. Kaliher, Engineering Personnel Manager, Missiles, Douglas Aircraft Co., Santa Monica, California.





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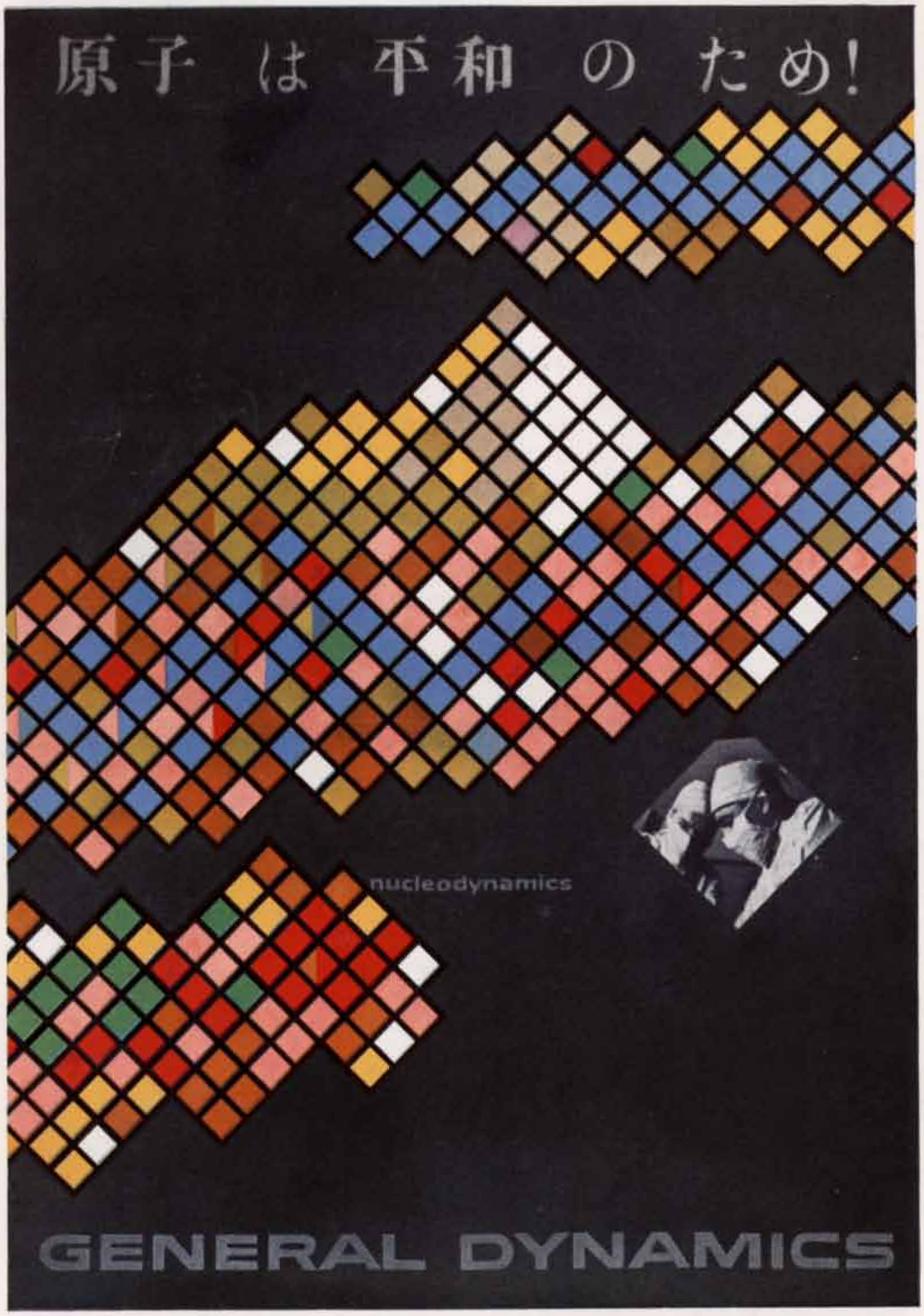

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