SCIENTIFIC AMERICAN

PALEOLITHIC ART

FIFTY CENTS

August 1953

Another new development using

B. F. Goodrich Chemical *raw materials*

B. F. Goodrich Chemical Company does not make this yarn. We supply the Geon resin for the coating only.

Lighted cigarette won't burn through.

Outstanding durability— won't stretch or corrode

Tough Screen made of Armored Glass Threads

Start with fibrous glass yarn, add a manufacturer who knows what Geon vinyl materials can do, and you come up with a new super-tough yarn that's headed for sales stardom—in a new type window screen, for instance!

Glass threads are treated with a formulation of Geon resin. The result: yarn with high tensile strength and abrasion resistance. It is fire and chemical resistant. It can be heat-sealed to vinyl film for extra reinforcement. Name your color—and you can get it.

Window screens woven of this yarn are but one outstanding example, with other uses in the offing.

Geon has a way of sparking good sales ideas. For Geon materials come in a variety of forms to fit so many needs—resin, plastic granules, liquid latex. They can be used for extrusions, molding, casting, coating or dipping. They can make products resistant to heat and cold, wear, oils, greases and many chemicals. Perhaps a Geon material can help you develop or improve products—we'll help with technical advice. Just write Dept. D-5, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

GEON RESINS • GOOD-RITE PLASTICIZERS . . . the ideal team to make products easier, better and more saleable

GEON polyvinyl materials • HYCAR American rubber • GOOD-RITE chemicals and plasticizers • HARMON colors

WINGS for faster fledglings

JET pilots still have to learn to fly in propeller-driven aircraft, so the Air Force has adopted the high-speed T-28 as its advanced trainer — a plane specifically designed for preparing future jet pilots.

For this newest and most modern trainer, Goodyear Aircraft Corporation builds the complete wing assembly — as well as components for the ship's empennage—at Goodyear's Litchfield Park plant in Arizona; and optically clear Rotoform canopies, plus wheels and brakes for the T-28, at its Akron plant.

This production ability is typical of Goodyear Aircraft, which has complete facilities for building the largest type aircraft in use today—as well as the engineering skill it takes to produce such highly technical devices as electronic computers, radar assemblies, radomes and many other types of aviation equipment used on all military and commercial aircraft today.

This flexibility—in engineering, design, testing and fabrication—makes Goodyear stand out as America's most versatile aircraft manufacturer.

If you would like more details on the unique "air support" provided the aviation industry by Goodyear Aircraft, write: Goodyear Aircraft Corporation, Department 65, Akron 15, Ohio.

Complete wing assemblies—built by Goodyear Aircraft—for North American Aviation's T-28 airplane. The T-28, newest and most modern of the Air Force training planes, actually carries more equipment than the famed Mustang fighter of the Second World War.

OPPORTUNITIES UNLIMITED—for engineers!

Goodyear Aircraft has many opportunities in research, design, development and production of AIRPLANES • AIRSHIPS • HELICOPTERS • GUIDED MISSILES • ELECTRONIC COMPUTERS • AIRCRAFT COMPONENTS • RADOMES • BONDED SANDWICH STRUCTURES • RADAR STRUCTURES • WHEELS and BRAKES and many others.

Submit a brief resumé of your qualifications and experience, or write today for an application blank and further information. Address: Dr. K. Arnstein, Vice President of Engineering, Goodyear Aircraft Corporation, Akron 15, Ohio.

GOODYEAR AIRCRAFT

★ PROUD OF ITS PART IN AVIATION'S 50 YEARS OF PROGRESS ★

We think you'll like THE GOODYEAR TELEVISION PLAYHOUSE — every other Sunday—NBC TV Network

LETTERS

Sirs:

Your excellent article on chelation by Harold F. Walton [*Scientific American*, June] gives the impression that the Swiss chemist Gerold Schwarzenbach originated this interesting "new" branch of chemistry about eight years ago. Actually the term "chelation" was applied at least 23 years ago.

Reference is made to a communication from the Laboratory of Organic Chemistry of the University of Wisconsin in *The Journal of the American Chemical Society* (Vol. 154, page 3686; September, 1932), of which the undersigned is a co-author. This may be the first time chelation was "discovered" in the U.S. On the same page, however, a footnote refers to an article by Sidgwick and Brewer, published in *The Journal of the Chemical Society* (Vol. 127, page 2379; 1925) and a book by Sidgwick, *The Electronic Theory of Valency*, published by the Oxford Press in 1929.

It was while doing research in 1930 with Dr. Homer Adkins and taking a course in advanced physical chemistry under Dr. Farrington Daniels (currently president of the American Chemical Society) that the undersigned ran into a puzzling phenomenon in the laboratory which only chelation could explain.

ROBERT N. ISBELL

Colonel, USAF
Director of Nuclear Applications
Office of Deputy for Development
Headquarters, Air Research and Development Command
Baltimore, Md.

Sirs:

The finding that the universe is twice as large and twice as old as previously believed ["A Larger and Older Universe," by George W. Gray, *Scientific American*, June] provides a striking testimonial to the remarkable insight of Albert Einstein. When Einstein first formulated the relativistic equations for the form of the universe in 1916-17, he was forced, by his assumption of a static universe with a uniform distribution of matter, to introduce an arbitrary correction factor *lambda* in order to make his equations apply to a universe of finite dimensions. Later, the "cosmological constant" (as *lambda* came to be called) turned up again, when Georges Lemaître put forward the theory of an expanding universe. In particular, *lambda* was included in the expanding universe equations of A. S. Eddington, in which it served to reconcile the calculated age of the universe, to some extent at least, with observation. Without *lambda*, at any rate, the calculated age of the universe would have come out less than the known age of the earth's crust.

Now, although he had originally introduced it, Einstein always disliked *lambda* and soon abandoned it. When others pointed out that *lambda* was required by known astrophysical data, Einstein replied that *lambda* destroyed the economy and elegance of the cosmological equations and that the data demanding its inclusion was really very sketchy and might well prove wrong. He was, it may be added, substantially alone in this position; virtually all other cosmologists accepted *lambda*.

The developments so ably described by Gray proved Einstein right. The age of the universe is related inversely to Edwin P. Hubble's constant of recession, h, the constant describing the outward flight of the galaxies. The finding that the universe is twice as large as hitherto supposed cuts the calculated value of h in half. Halving h yields a plausible age for the universe from the cosmological equations (about 3.5 billion years) without the use of *lambda*.

LEONARD ENGEL

Larchmont, N. Y.

Sirs:

In his very interesting article "The Mortality of Trout" [*Scientific American*, May], Paul R. Needham states that the sampling of Sagehen Creek indicated the presence of 176 trout over six inches long per mile. He also states that the stream contained more than 24,900 trout, a total of 647 pounds.

If my calculations are correct, this means an average weight of ½ ounce per trout! Small wonder the anglers

Scientific American. August, 1953, Vol. 189, No. 2. Published monthly by Scientific American, Inc., 2 West 45th Street, New York 36, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

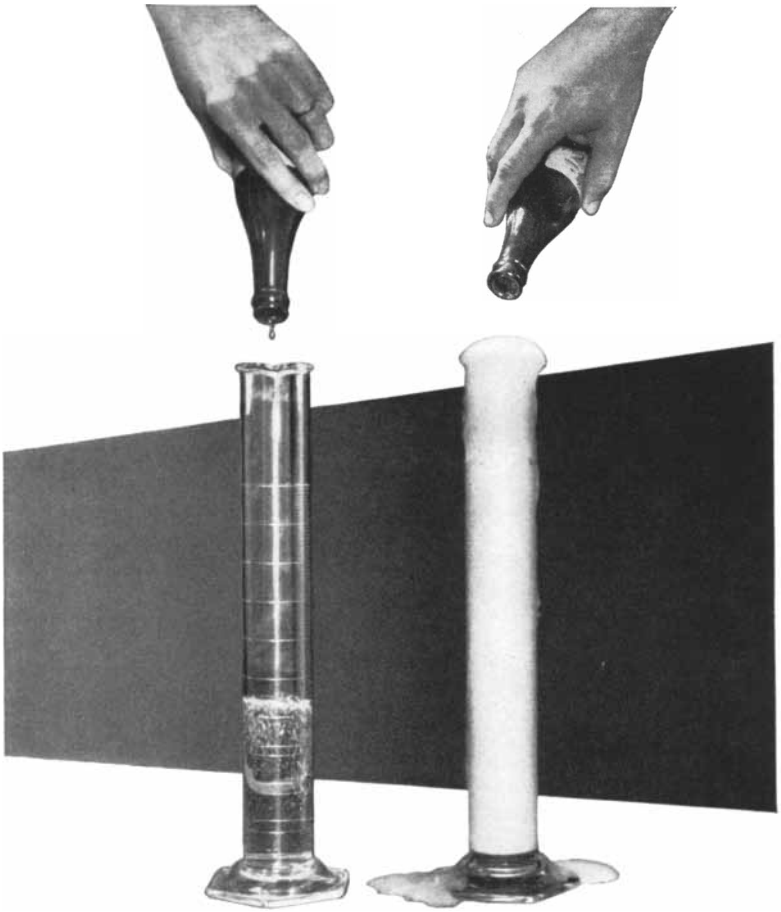
Editorial correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Martin M. Davidson, Advertising Manager, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y.

Subscription correspondence should be addressed to Circulation Manager, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.

Subscription rates for U.S.A. and possessions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $10; 3 years, $14. All other countries: 1 year, $8; 2 years, $12; 3 years, $16.



Beaker at left: Club soda poured into empty container produces only a slight effervescence.

Beaker at right: Club soda poured into beaker containing a trace of pure glycyrrhizin (a licorice derivative) produces an abundant white foam.

***LICORICE**-stabilized foams are rich, white and durable*

If a rich, stable foam is necessary or desirable in any of your products or processes, *don't overlook licorice.*

All licorice extracts, including Flotite, a secondary extract, are prolific foam producers. Many licorice-stabilized foams are tough and durable – their tiny bubble structure remains stable in some systems for hours on end. Adequate knowledge of these facts might lead to substantial improvement in some product or process of your own.

The foam-producing characteristic of licorice—combined with its efficiency as a wetting, dispersing and conditioning agent—has aroused widespread interest in new uses and improved applications of both the primary and secondary extracts. Recent developments have launched a new wave of licorice research and prompted industrial concerns in a score of industries to start experimental work.

Other new and potentially valuable uses for licorice (without special emphasis on its foam-producing quality) are listed in the right-hand column. If anything in this list has even a remote association with your products or problems, or if the foaming quality of licorice interests you, it may pay us both to get together. Feel free to send for the informative material offered. A sample of one or more licorice products will also be sent if requested on your business letterhead, and without obligation.

Some New or Potential Uses for Licorice And Licorice Derivatives

Flotation agent in ore separation • Stabilizing acid latex • Component in feeds for horses, cattle and chickens • Soothing ingredient in cough syrups • Therapeutic agent in treatment of Addison's Disease • Soft drink flavor • Aging and mellowing smoking pipes • Prolonging foam in porter and ale • Improving meat and fish sauces Antioxidant to keep chewing gum fresh • Flavor for ice cream

Write today for your free copy of "The Story of Licorice." *We will mail it promptly. You're sure to find it interesting, and you might find it profitable as well.*

MACANDREWS & FORBES COMPANY

Licorice and Licorice Products • Since 1870

200 Fifth Avenue, New York 10, N.Y. ***Plant:*** **Camden, New Jersey**

complained—the author was counting the angleworm bait rather than the fish.

HOWARD W. MATTSON

New York, N. Y.

Sirs:

Mr. Mattson's arithmetic is perfectly correct. Counting half-ounce trout is indeed possible and, as a matter of fact, a half-ounce trout is fairly large. In Sagehen Creek 22 trout measuring from 5.9 to 6.3 inches were taken during the 1952 sampling program; their average weight was only 1.28 ounces. During the same period we found that the average weight of a sample of 56 trout fingerlings ranging from 1.7 inches to 2.4 inches in length was only .05 ounce.

The greater part of the estimated 24,900 trout in Sagehen Creek were smaller than the six-inch size. Some readers may recall that only 176 trout were found to exceed the six-inch size in each mile of stream. Therefore, according to our calculations, for the total 10 miles there were approximately 1,760 trout over six inches long in the stream at the time of sampling.

PAUL R. NEEDHAM

Department of Zoology
University of California
Berkeley, Calif.

Sirs:

A shocking error on page 8 of your June issue is hereby called to your attention. It is hoped that you will not attempt to evade responsibility by use of the time-worn excuse that publishers should not be held responsible for errors in advertisements.

The gent with rolled-up shirt sleeves and poignant expression executing the Beethoven Fifth plays E natural with the right fifth finger, at the same time playing F natural and E flat with the left thumb and index finger!

This cannot be in Beethoven. Not only are you, inadvertently of course, contributing to the delinquency of young musicians, but worse, this casts the shadow of doubt upon every word and picture in your publication. For example, how can one be certain when you mention one billion light years that the correct distance isn't one billion and one, or perhaps even two, light years?

Let us hope that this will result in mending your ways. It should prove that advertisements in *Scientific American* are read, and that your subscription list does not lack cranks.

EDGAR ROSENTHAL

New York, N. Y.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

AUGUST, 1903: "Mme. Curie, the discoverer of polonium, maintains that it is not yet decided whether polonium is an element or not. The supposition that any radioactive substance is a separate element was verified in the case of radium, but is rendered uncertain by the phenomena of induced radioactivity. The case of polonium is rendered doubtful by the fact that the spectrum shows only the rays of bismuth. On the other hand, it is possible to concentrate the radioactive substance contained in radioactive bismuth, and this would not be possible if bismuth alone were present."

"H. Haga and C. H. Wind maintain, against the criticism of B. Walter, not only that they have photographed a true diffraction effect of Röntgen rays, but they have obtained even more unmistakable evidence of it than they had before. The values for the wave-length of X-rays deduced from their observations differ widely, but are in any case extremely small, and more of the order of the size of a molecule than of the order of length of light waves."

"According to M. Allegretti the Edison phenomenon, consisting of the passage of electricity from the extreme negative end of the filament of an incandescent lamp to a metallic plate introduced into the bulb, has not yet been fully explained, although much work has been done upon it by Preece, Fleming and others. The main question is as to whether we have here a phenomenon of ionization or a true projection of negative particles. The author believes that the phenomenon is primarily due to ionization, but that at the higher vacua it is enhanced by the production of cathode rays which may be deflected by a magnet in the same way as the ordinary cathode rays."

"The designs for our latest battleships of the *Louisiana* and *Connecticut* class are marked by an omission of one of the most effective offensive elements of the modern warship, an omission which may be considered so serious that it is questionable whether these ships, large, swift, and powerful as they are, can be reckoned as strictly first class. We refer to the fact that no provision whatever has been made for the installation of

torpedo tubes, and this at a time when the latest ships of the foreign powers are using them in large numbers. The reason for omitting the torpedo from our new warships is to be found in the disastrous behavior of this weapon in the two last naval wars—that between China and Japan and our own Spanish war of a few years later. In each war there were instances of vessels being destroyed by the explosion of their own torpedoes. But it is a fact that the risk has been entirely eliminated, and the weapon is perhaps the most deadly element in the armament of a modern warship."

"It will be remembered that last year Prof. Rutherford produced striking evidence for the view that, in the very slow break-up of radium that is concomitant with its radioactivity, the inert gas helium is one of the products formed. Recently Sir W. Ramsay and Mr. F. Soddy have succeeded by means of the spectroscope in detecting helium in the gases extracted from a radium salt. If, as the present observations indicate, the radium salt shines spontaneously in the dark largely by light belonging to the different element helium, another important step is gained in elucidating the nature of the instability of such chemical elements of high atomic weight and the radioactivity associated with it."

"On July 4 the dream of the late John W. Mackay of girdling the earth with his cable and telegraph system was realized, for on that day the laying of the Manila section of the Pacific cable was completed. About 10 o'clock in the evening the last connection in the new cable was made at Honolulu, and a test message was flashed around the world in nine and a half minutes."

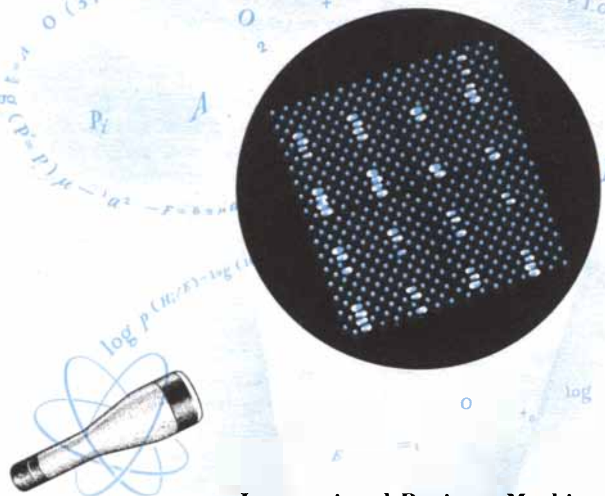
"Mr. Edison states that such is the destruction wrought by X-rays that one of his laboratory assistants, Charles Daily, was so seriously injured that it was necessary to amputate his left arm and the fingers of his right hand. The physiological effect noted is the direct result of the killing or paralyzing of the white corpuscles of the blood. Mr. Edison himself has suffered not a little from stomach trouble as the result of experiments with X-rays."

SCIENTIFIC AMERICAN

AUGUST, 1853: "The experiments with coke as a fuel for the passenger engines of the Baltimore and Ohio Railroad continue highly successful. A few nights since the train for Baltimore was run through from Cumberland with no other fuel, and notwithstanding the de-

NO. TWELVE IN A SERIES

pioneers in precision



International Business Machines Corporation
recently installed the first production model of the IBM high-speed electronic calculator, the "701." Most recent successor to the pioneer large-scale digital calculator first developed by IBM in 1944, the "701" solves in minutes a problem which would take one man, using a desk computer, seven years to complete.

Miniature Precision Bearings, Incorporated,
are the originators and pioneer developers of precision ball bearings in miniature sizes (1/10″ to 5/16″ o.d.). Exclusive MPB methods assure thousands of discriminating customers ultra quality bearings for vital equipment.

MPB ball bearings supply the unerring accuracy and proven dependability necessary in providing many devices with anti-friction qualities. MPB ball bearings function effectively with deft delicate responsiveness under extreme operating conditions. They are fully ground, lapped, honed, and/or burnished to ABEC 5 tolerances or better.

The possibilities offered by MPB ball bearings are being profitably explored by leading instrument makers of the future. We would welcome the opportunity to discuss the matter with you. Branch offices in New York and Boston and Engineering Representatives in Principal Cities are eager to serve you. Ask for detailed data sheets SA 8.

Immediate delivery on most sizes and plant capacity to promptly meet your additional requirements.

have you ever wondered how precision ball bearings are made?

The new 15 minute 16 mm sound-color movie "Mighty Miniatures" tells of the manufacture and use of these precision components. It is available to qualified groups. Write Engineering Dept. MPB Inc. Keene, N.H. for dates.

Miniature *precision* Bearings

Incorporated — MPB — Keene, New Hampshire

"pioneer precisionists to the World's foremost instrument manufacturers"

save space weight friction

tentions by burthen trains, amounting in the aggregate to near an hour, the time required by the schedule was easily made. There was not only an abundance of steam, but almost more than the engineer could manage."

"Endeavors are now being made in London to form a telegraph company for laying down a line in the Atlantic between Ireland and some point on the coast of North America (Newfoundland no doubt). The length of the submarine cable will be about 1,700 miles. The estimates made of expenses are from $1 million to $3 million. We hope this great scheme will be carried out. Then we shall be able to communicate from New York to London in a few minutes, and the racing of steamships and locomotives, to bring early news, will become obsolete."

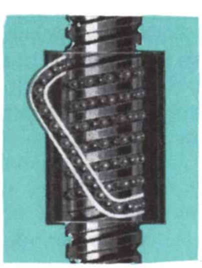
"Mr. Wise, the celebrated navigator of nearly 200 aerial voyages, writes concerning the opinion of SCIENTIFIC AMERICAN that, for one vertical flash of lightning that reaches the earth, fifty are horizontal. 'I think you are correct in your conclusion,' he says; 'the dissipation takes place in the lower cloud surface. I have witnessed the same thing when sailing above the lower layer of clouds during thunder storms. In rain storms there are always two layers of clouds, and the heaviest discharges of electricity take place when the rain or hail falls the fastest from the upper through the lower cloud.' "

"That eminent chemist Justus Liebig says in his *Letters on Chemistry*, 'The quantity of soap consumed by a nation would be no inaccurate measure whereby to estimate its wealth and civilization.' By this measure we could justly claim for the United States the title of the wealthiest and most civilized nation in the world. Pillars of soap, busts of soap, windows of soap, soap of all colors, in all shapes, in all sizes and of all smells mark the vast extent of our soap manufacture. We are no doubt the best washed people in all creation."

"Prof. Pierce spoke on the subject of Saturn's ring at the recent meeting of the American Association for the Advancement of Science. 'I am now convinced,' he said, 'there is no conceivable form of irregularity and no combination of irregularities, consistent with an actual ring, which would permit the ring to be permanently maintained by the primary if it were solid. Hence, it follows, independently of observation, that Saturn's ring is not solid.' "

"The city of New Orleans is severely afflicted with yellow fever this summer; no less than 200 have died in one day. The cholera was not half so deadly."

The way we change angles on
'Copter Blades
puts a brand new slant on controlling power



One of these days, when you hop from home to the office in your personal helicopter, you'll marvel at the way you "shift gears"... from "straight up" to "full speed ahead"... from "side-winder" to "hover". It will be done fast, smoothly, accurately.

Today, helicopter builders are using Cleveland Pneumatic's friction-less combination of a screw and some balls to adjust the angle of the whirling blades on the 'copter. This device is called a "ball-screw actuator".

Ball-screw actuators are useful in many applications in either of two ways... to multiply the power of a drive... or to increase its speed. You also get the hair's-breadth accuracy of a metal-to-metal drive that eliminates merely-approximate positioning of other systems.

Somewhere in your product or your idea for a product, you may be able to use Cleveland Pneumatic ball-screw actuators. They've been engineered by us in all sizes... from tiny ones for 'copter blades to the giants that we make to raise and lower bomber landing gears.

If you wish to know more about Cleveland Pneumatic, write for our 16-page booklet.

Cleveland Pneumatic
Tool Company CLEVELAND 5, OHIO

Department D-8

BALL-SCREW ACTUATORS • AUTOMOTIVE SHOP EQUIPMENT
AIR-OIL IMPACT ABSORBERS

World's Largest Manufacturer of Aircraft Landing Gears

To CUSHION SHOCK

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

THE AUTHORS

DONALD J. HUGHES ("The Nuclear Reactor as a Research Instrument") has been working with atomic piles since the first one went into operation in a University of Chicago squash court. He was born in Chicago in 1915 and educated at the University of Chicago, receiving his Ph.D. in physics in 1940. Until early in 1943 Hughes worked at the Naval Ordnance Laboratory on mine and torpedo detectors. Then he transferred to the Manhattan District in Chicago and has been working in the field of nuclear physics ever since. He did research on pile neutrons first in Chicago with the original pile and later at the Hanford Engineer Works when the big plutonium-producing reactors were built. After the war he joined the Argonne National Laboratory as director of its nuclear physics division. In 1949 Hughes went to the Brookhaven National Laboratory, where he is now.

HALLAM L. MOVIUS, JR. ("Archaeology and the Earliest Art") is associate professor of anthropology at Harvard University and curator of paleolithic anthropology in the University's Peabody Museum. Since his graduation from Harvard College in 1930 Movius has been digging and studying in such varied locales as Czechoslovakia, Palestine, Ireland, Java and France. He first worked in France in 1948 on a Wenner-Gren Foundation grant, where his party turned up "a very remarkable art object" which led him to the study of the whole field of Upper Paleolithic art. This work won him the Wenner-Gren Foundation's Viking Fund Medal in archaeology in 1950. This year he is making preliminary excavations in the Dordogne of southern France. If evidence of prehistoric occupation turns up, the George Grant MacCurdy Fund and the Ancient Monuments Commission of France, which are supporting the work, expect to enlarge it over a five- or six-year period.

C. L. W. SWANSON ("Soil Conditioners") has been head of the Connecticut Agricultural Experiment Station's Soil Department since 1946. There he directs a detailed survey of Connecticut soils, the first undertaken in the state, and continues the research on soil conditioners which he reports in his article. The possibility of chemical soil conditioners had occurred to Swanson before they were first announced. In a 1950 paper he suggested "maybe we could use some kind of chemical to hold the soil from eroding, which would also act like organic matter. Fantastic? So was hybrid corn." Born in Iowa in 1910 and raised on a farm, Swanson has been in agricul-

First home television camera, RCA's "TV Eye," connects to any TV set—lets you watch children in the nursery or at play.

RCA "TV Eye" gives schools a private TV network, takes talks and demonstrations to classrooms.

In a railroad yard, RCA vidicon camera lets employees check car numbers at long range.

RCA vidicon camera in a bank, lets tellers verify the signatures on checks by television.

Tireless "TV Eye"

New RCA TV camera an alert watchman for home, school, industry

Based on the vidicon tube, developed by RCA, a new instrument is on the way for homes, business, and schools—the RCA "TV Eye."

Light, compact, easy to use, "TV Eye" is a camera unit which can be connected to standard home receivers —makes any of the 23 million TV sets now in use a potential closed-circuit television system.

RCA's industrial version of the vidicon camera has already proved its place as an observer and guardian in science, industry, transportation, business—with new uses still being explored. Wherever distance or danger preclude a human observer's presence, the vidicon camera can take his place and stand watch.

"TV Eye" plugs easily into standard TV sets. You just switch to the selected channel, and see everything that the camera sees.

RADIO CORPORATION OF AMERICA

World leader in radio—first in television ture all his life. After taking his doctorate at Iowa State College in 1941, he taught for two years at the University of New Hampshire before entering the Army for a four-year hitch. In 1946 he came to the Connecticut station.

DANIEL MAZIA ("Cell Division") went to California, where he is now associate professor of zoology at the University of California, because of the "big, ripe, juicy sea urchins" that are to be found there the year around. He was born in Scranton, Pa., and educated at the University of Pennsylvania, where he took a doctorate in physiology under L. V. Heilbrunn. After a year at Princeton University as a National Research Fellow, he went to the University of Missouri to teach, remaining there until 1951 with three years out for military service as an aviation physiologist. Hearing the call of the sea urchin, he then entrained for Berkeley. His work has centered on "those aspects of the structure and activity of the cell that relate to heredity," and for these studies the sea-urchin egg is invaluable. Mazia exhibits a strong loyalty to his adopted state, saying that he had expected to find Berkeley the Boston of the West, but now realizes that Boston is but the Berkeley of the East. He is the father of two daughters and spends his spare time "reading and loafing and avoiding such activities as building ships in bottles and being a connoisseur of this or that."

DUANE AND DUANE H. D. ROLLER ("Francis Hauksbee") are respectively father and son. Duane is assistant director of the Hughes Aircraft Company's Research and Development Laboratories; Duane H. D. is a teaching fellow at Harvard University. The elder Roller holds a Ph.D. in experimental physics from the California Institute of Technology and has spent most of his professional career teaching at the University of Oklahoma, Hunter College and Wabash College. He has also been a visiting professor at Harvard University.

A. J. HAAGEN-SMIT ("Essential Oils") came to the California Institute of Technology, where he is professor of bio-organic chemistry, by way of Harvard University and the University of Utrecht in the Netherlands. He was born in Utrecht in 1900 and educated at the University there. After receiving his Ph.D. in 1928 he remained as a faculty member in the chemistry department until 1936, when he came to Harvard University as a lecturer in biochemistry. The following year he went to Caltech. Haagen-Smit has worked mostly with natural products, having done important research on plant hormones, alkaloids and food flavors in addition to his work on essential oils. For the latter studies he won the Fritzsche Award of the Ameri-

can Chemical Society in 1950. His interest in tastes and odors made him a logical man to investigate the highly aromatic Los Angeles smog, and he has been one of the leading workers in air-pollution studies. This is Haagen-Smit's second article for SCIENTIFIC AMERICAN, his first, "Smell and Taste," having appeared in March, 1952.

H. BENTLEY GLASS ("The Genetics of the Dunkers") is professor of biology at The Johns Hopkins University, associate editor of *The Quarterly Review of Biology*, and, at the moment, acting chairman of the editorial board of the American Association for the Advancement of Science, responsible for the publication of *Science* and *The Scientific Monthly*. What with a weekly, a monthly and a quarterly magazine to worry about, he remarks, "life is full of deadlines." Glass was born in China in 1906 and had his pre-college education in mission schools there. He took his undergraduate work at Baylor University and his Ph.D. at the University of Texas.

HELMUT E. LANDSBERG ("The Origin of the Atmosphere") is Director of Geophysics Research at the Air Force Cambridge Research Center. Born in Frankfurt, Germany, in 1906, Landsberg was educated at the University of Frankfurt. There in 1930 he took his Ph.D. under Beno Gutenberg, famous earthquake expert who is now at the California Institute of Technology. Landsberg came to the U. S. in 1934 to take a position at the Pennsylvania State College, where he inaugurated a Geophysical and Meteorological Laboratory. In 1941 he transferred to the University of Chicago to teach meteorology and climatology. When the war broke out, he started to do consulting work for the Air Force and by 1943 was working full time as an operations analyst, making strategic weather and climate studies for the 20th Air Force. After the war he worked for a time on a study of rainfall in Hawaii for the Pineapple Growers Association, spent a brief period with the U. S. Weather Bureau and served with the Research and Development Board before joining the Cambridge Center.

JULIAN S. HUXLEY, who in this issue reviews George Gaylord Simpson's "Life of the Past," is equally famous as a biologist and an author. He was born in 1887, the son of Leonard Huxley, a writer, and the grandson of T. H. Huxley, the great 19th-century biologist. Educated at Oxford, Julian Huxley taught for many years there and at other institutions, including the Rice Institute in Texas (for four years before the First World War). From 1935 to 1942 he was Secretary of the Zoological Society of London, and from 1946 to 1948 served as Director-General of UNESCO.

What JACK & HEINTZ *is doing about...*

OBSOLESCENCE

Ordinarily, product improvements result in costly obsolescence—but not in the case of a new Jack & Heintz starter for commercial airlines. This new design features 10 major improvements that can be incorporated in thousands of earlier models now in service . . . to lengthen life, improve performance and reduce maintenance.

Our business is to design and build highly specialized electrical, electromechanical and hydraulic devices. To improve our equipment for generating, applying or controlling power without creating obsolescence is a fundamental J&H engineering objective—in 40 different starter models, approximately 90 per cent of all parts are interchangeable.

The name ***Jack & Heintz*** on aviation or commercial products stands for advanced engineering . . . precise manufacturing . . . pretested performance. Jack & Heintz, Inc., Cleveland 1, Ohio.

JACK & HEINTZ *Rotomotive* EQUIPMENT

©1953, Jack & Heintz, Inc.

means electrical, hydraulic or mechanical devices designed to solve unusual problems of developing power, controlling it or using it.

Aircraft Generating Equipment—a-c and d-c—including Control Systems and Components • Electric Starters • Actuators and Special Aircraft Motors • Custom-built Commercial Motors • J&H Eisemann Magnetos

THE COVER

The photograph on the cover shows a group of Old Stone Age drawings (*see page 30*) in the cave of Niaux in southern France. In the center is a bison. At upper right is another bison pierced by two black and two red arrows. At upper left are the legs of a third bison; at lower left, the head and back of a horse. The photograph was made by Romain Robert, a French attorney who has made many fine pictures of cave art.

THE ILLUSTRATIONS

Cover photograph by Romain Robert

Page	Source
23	Brookhaven National Laboratory
24	James Egleson (*top*), Brookhaven National Laboratory (*bottom*)
25	James Egleson (*top and middle*), Brookhaven National Laboratory (*bottom*)
26-27	James Egleson
29	James Egleson (*top*), Brookhaven National Laboratory (*middle and bottom*)
30-31	Eric Mose
32-33	Romain Robert
34-35	Eric Mose
36	C. L. W. Swanson
37-38	B. W. McFarland
54	John D. Roslansky
55	Irving Geis
56-59	John D. Roslansky
60	Irving Geis
61-62	Shinya Inoué
65-67	Courtesy Duane and Duane H. D. Roller
71	U. S. Forest Service
72	Sara Love (*top*), courtesy Fritzche Brothers, Inc. (*bottom*)
74	Courtesy Fritzche Brothers, Inc.
77-80	Bernarda Bryson
83	Bunji Tagawa
84	Sara Love
89	American Museum of Natural History
94-96	Roger Hayward

ELECTRONIC TEST INSTRUMENTS

-hp- 522B Electronic Counter

IS YOUR MEASURING PROBLEM HERE?

FREQUENCY	TIME INTERVAL
Production quantities	Elapsed time between impulses
Nuclear radiations	Pulse lengths
R.P.S. and R.P.M.	Camera shutter speed
Power line frequencies	Projectile velocity
Very low frequencies	Relay operating times
Frequency stability	Precise event timing
Oscillator calibration	Interval stability
Pulse repetition rates	Frequency rates
Weight, pressure, temperature, acceleration	Phase delay

Investigate this new, low-cost all purpose -*hp*- counter

This new electronic counter can save you time and money by speeding and simplifying research and manufacturing measurements. It is a compact, low-cost, extremely versatile instrument offering you accurate frequency, period *or* time measurements. It performs all functions without extra-cost modification. Results are displayed instantly and automatically in direct-reading form. Unskilled personnel can use the instrument immediately without training.

Model 522B measures rate of occurrences from .00001 to 100,000 per second. It measures time from 10 microseconds to 27.8 hours. Counting is available over periods of 1/1,000, 1/100, 1/10, 1 and 10 seconds or multiples. Stability of time base is 5 parts per million. Time of display can be varied to any duration, counts are automatically reset, action is repetitive. Results are presented direct in cps, kc, seconds or milliseconds. Decimal point is automatically indicated.

The instrument consists of five decade counters, a wide range time base plus gating and auxiliary circuits. The unknown is applied to the counters through the gate circuit. For frequency measurement this circuit remains open for a precise interval controlled by an oven-housed quartz crystal.

-hp- 522A Electronic Counter

For applications where wide-range frequency and period measurements are desired. Frequency counting facilities are identical with 522B, except gate time for frequency measurement is 1 second or multiples, and standard frequency counted for period measurement is 100 kc. Decimal point and time interval measuring circuits are omitted. $775.00

Data subject to change without notice. Prices f. o. b. factory

SPECIFICATIONS—MODEL 522B

FREQUENCY MEASUREMENTS:

Range: 10 cps to 100 kc.
Accuracy: ± 1 count ± stability (5/1,000,000 per week).
Registration: 5 places. Output pulse available to actuate trigger circuit for mechanical register to increase count capacity.
Gate Time: .001, .01, .1, 1, 10 seconds. Extendable to multiples of 1 or 10 seconds by manual control.
Display Time: Variable .1 to 10 seconds in steps of gate time selected. Display can be held indefinitely.

PERIOD MEASUREMENTS:

Range: .00001 cps to 10 kc.
Accuracy: ± .03% ± stability (for measurements over a 10 cycle period).
Gate Time: 1 or 10 cycle of unknown. Extendable to any number of cycles by manual control. (For frequencies under 50 to 60 cps.)
Standard Freq. Counted: 1, 10, 100 cps; 1, 10, 100 kc; or external.

TIME INTERVAL MEASUREMENTS:

Range: 10 µsec to 100,000 seconds (27.8 hrs.)
Accuracy: ± 1/std. freq. counted ± stability.
Trigger Slope: Pos. or neg. on start and/or stop channels.
Trigger Amplitude: Continuously adjustable on both channels from —100 to +100 volts.
Standard Freq. Counted: 1, 10, 100 cps; 1, 10, 100 kc; or external.
Price: $900.00 f.o.b. factory.

Write for complete details

HEWLETT-PACKARD COMPANY
2707S PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
SALES REPRESENTATIVES IN ALL PRINCIPAL AREAS
Export: FRAZAR & HANSEN, LTD., New York • San Francisco • Los Angeles

Instruments for *Complete* Coverage

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR AUGUST, 1953 VOL. 189, NO. 2

ARTICLES

THE REACTOR AS A RESEARCH INSTRUMENT by D. J. Hughes

The enormous quantities of neutrons released by atomic chain reactions provide physicists with a potent means of studying matter. A survey of some of the ingenious techniques and results of pile neutron research. **23**

ARCHAEOLOGY AND THE EARLIEST ART by H. L. Movius, Jr.

Working by lamplight in dark corners of western European caves, our Old Stone Age ancestors produced the first known works of art—representations of animals which were part of the religion of hunting peoples. **30**

SOIL CONDITIONERS by C. L. W. Swanson

The new and much-publicized agricultural chemicals are still in the process of being scientifically evaluated. Used properly, they are proving that they can stabilize some types of soil and can improve crop yields. **36**

CELL DIVISION by Daniel Mazia

To understand mitosis, the elaborate process by which living cells duplicate themselves, is one of the biologist's central problems. Recent advances in chemistry and microscopy are yielding much information. **53**

FRANCIS HAUKSBEE by Duane and Duane H. D. Roller

The story of an 18th-century English artisan whose mechanical skill and keen insight made him one of the most brilliant experimenters of his day. He initiated a great advance in the understanding of electricity. **64**

ESSENTIAL OILS by A. J. Haagen-Smit

An array of products ranging from costly perfumes to ordinary housepaint contains natural oils. Chemistry tells us what they are made of and how to produce them artificially, but we are not sure how plants use them. **70**

THE GENETICS OF THE DUNKERS by H. Bentley Glass

The members of a small religious sect who have isolated themselves from their neighbors for more than 200 years show striking evidence of "genetic drift"—the process that may produce racial varieties in man. **76**

THE ORIGIN OF THE ATMOSPHERE by Helmut E. Landsberg

Since the earth was formed its mantle of air has undergone three major changes. The present life-giving mixture has lasted for about a billion years so far and seems good for a few billion more if men do not destroy it. **82**

DEPARTMENTS

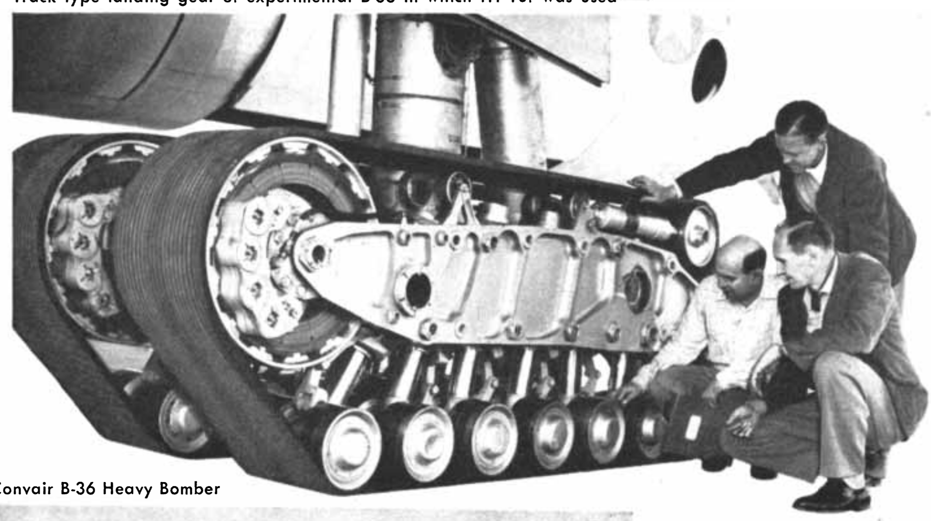
LETTERS **2**
50 AND 100 YEARS AGO **6**
THE AUTHORS **12**
SCIENCE AND THE CITIZEN **40**
BOOKS **88**
THE AMATEUR SCIENTIST **94**
BIBLIOGRAPHY **100**

What's Happening at CRUCIBLE

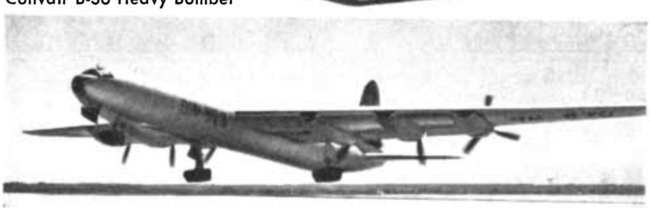
about HY-TUF alloy steel

Crucible metallurgists, working closely with aircraft engineers, developed new steels specially designed to withstand the exceptional stresses and severe impact to which landing gear assemblies of high speed and heavy bombing aircraft are subjected. One of the most successful grades used is Crucible HY-Tuf alloy steel.

Track type landing gear of experimental B-36 in which HY-Tuf was used



Convair B-36 Heavy Bomber



what HY-TUF is

HY-Tuf is a nickel-silicon-manganese-molybdenum alloy grade, designed for applications where maximum strength and toughness are required. Its typical composition is 0.25 carbon, 1.40 manganese, 1.50 silicon, 1.80 nickel and 0.40% molybdenum. It provides exceptionally high toughness and fatigue strength at the extremely high tensile strength levels of 200,000 — 240,000 psi., and has an Izod impact strength of more than 20 foot pounds.

aircraft applications

HY-Tuf was selected by Convair for the inner cylinder axle assembly of the bogie shock struts of the experimental track-type landing gear designed for their B-36 heavy bomber.

Although heavier than the standard wheel assembly, the track-type gear distributed weight over a larger area. Important weight savings were accomplished by a combination of good design and the use of HY-Tuf high strength alloy steel, which made possible reduction in size of structural parts.

Douglas uses HY-Tuf in the landing gear and arresting fittings of its A2D *Skyshark* attack plane. Landings, especially when made on the flight deck of an aircraft carrier in rough seas, constitute a rugged testing ground for even the best of steels.

Douglas *Skyshark*

Crucible Engineering Service Available

As with alloy steels, the Crucible Steel Company of America is the leading producer of special purpose steels. If you have a difficult application problem don't hesitate to call in one of our engineers. And when you need any one of an extremely wide variety of special steels, you will find them readily available from your nearest Crucible warehouse.

CRUCIBLE first name in special purpose steels

53 *years of Fine steelmaking*

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

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

SCIENTIFIC AMERICAN
AUGUST, 1953 VOL. 189, NO. 2

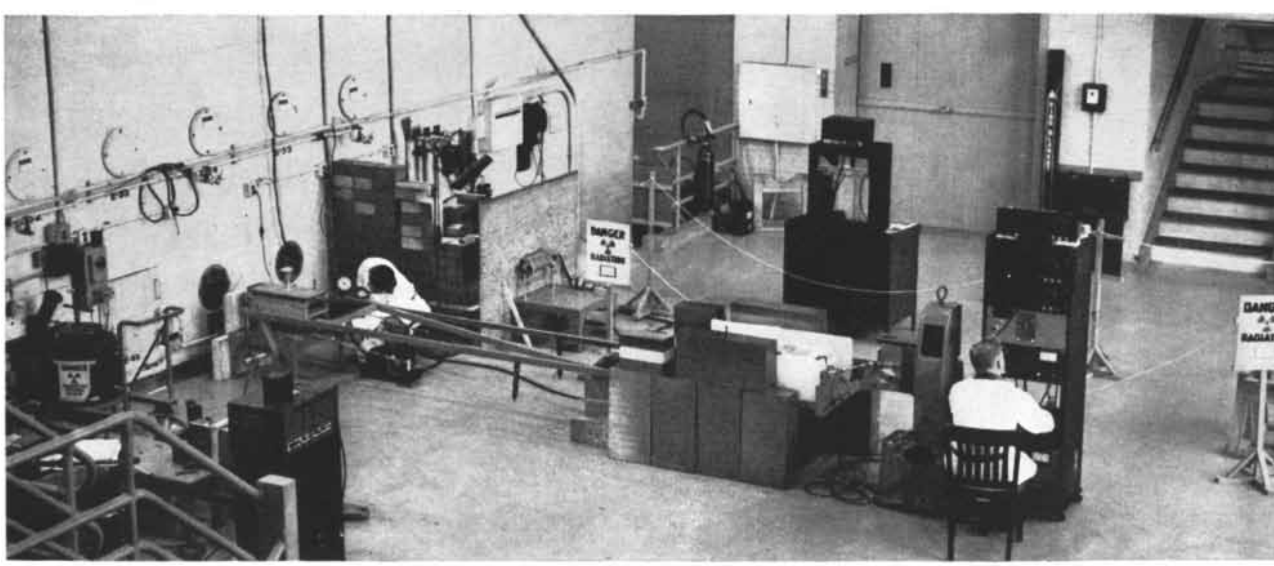
The Nuclear Reactor as a Research Instrument

The blizzard of neutrons in an atomic pile may be channeled to probe the nature of matter. Their application in ingenious experiments makes important contributions to basic physics

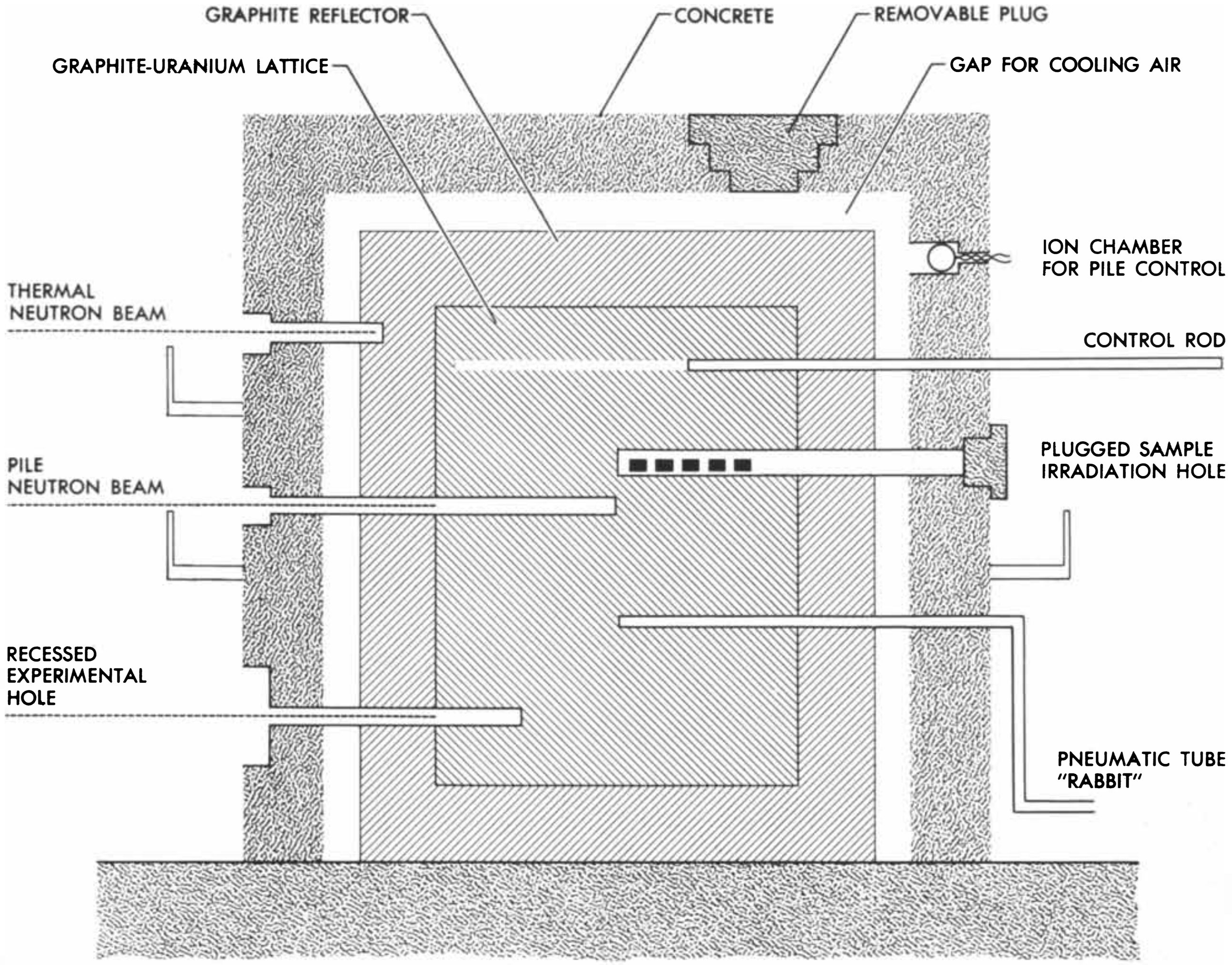
by Donald J. Hughes

Nuclear reactors manufacture, among other things, plutonium, heat and neutrons. Public attention has centered on the first product, as an ingredient of atom bombs, and the second, as a potential power source. Scientists are almost exclusively concerned with the third. As fundamental constituents of matter, neutrons are interesting in themselves, and they are one of the most powerful tools in the kit of the experimental physicist [see "The Neutron," by Philip and Emily Morrison; Scientific American, October, 1951]. In pre-reactor days we had to make neutrons by hand, so to speak, and in small quantities. With reactors we are mass-producing them in numbers beyond our wildest dreams of a few years ago. The torrent of neutrons now available provides us with an ideal means of investigating one of the central problems of physics—the nature of matter.

Why are neutrons so effective as probes of matter? First, they have no electric charge. Unaffected by the clouds of negative charge with which electrons surround atomic nuclei, neutrons pass easily through swarms of atoms. When they finally chance to strike a nucleus, neutrons penetrate it easily, being equally unaffected by its positive charge. Especially important is the fact that even very slow neutrons are highly penetrating. All other experimental projectiles, such as protons or alpha particles, must move so fast to get into the nucleus of the atom that they cannot be used to investigate the intricate details of its



REACTOR at Brookhaven National Laboratory is used solely for experimental purposes. The shield of the reactor is at the left; it is pierced with holes that emit neutrons. Here most of the holes are plugged, but one is open for a neutron-reflection experiment. The neutron "mirror" is at the left end of the long apparatus.



CROSS SECTION of the Brookhaven reactor shows its experimental features in simplified form. The uranium fuel of the reactor is embedded in a graphite moderator, which is surrounded by a graphite reflector, which is surrounded by a concrete shield. The moderator and reflector are pierced with holes that emit the neutrons.

HOLE extending into the center of the Brookhaven reactor is a foot square and 20 feet deep. At the far end of the hole may be seen an arrangement of bismuth blocks. The neutrons that emerge from this hole are utilized in experiments involving the "fast chopper" *(see illustrations at the bottom of the opposite page)*.

structure. Such details can only be observed with slow neutrons of accurately controlled velocity.

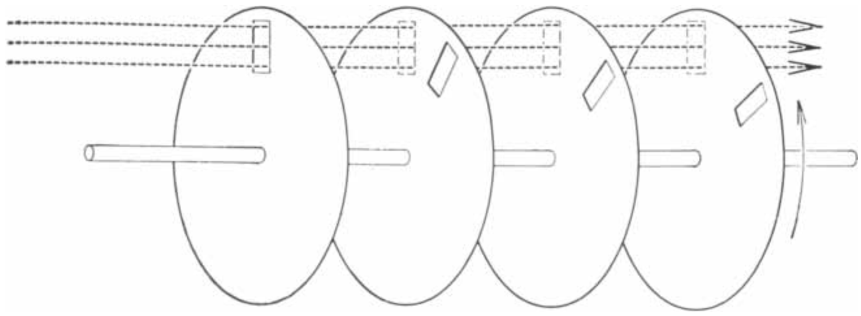
Second, the neutron is magnetized. Thus it reacts with the magnetic fields of atoms, yielding valuable information about magnetic properties. Finally, the neutron is a wave; or rather, like all bits of matter, it is both particle and wave. Some of the most informative experiments we can perform are based on the wavelike interaction of neutrons with matter. Only the intense beams that reactors provide make it possible to take practical advantage of the wave nature of neutrons.

THE very quality that makes neutrons so valuable as an experimental probe makes them hard to utilize. Charged particles are docile beasts. We can speed them up or slow them down with electric fields, steer and aim them with magnets. The uncharged neutrons, however, are unaffected by these forces and are difficult to maneuver. Even to know where they are is something of a problem since they do not announce themselves directly by leaving ion trails in cloud chambers or photographic emulsions as charged particles do. Before neutrons could be put to use a great deal of experimental ingenuity went into learning how to manipulate them.

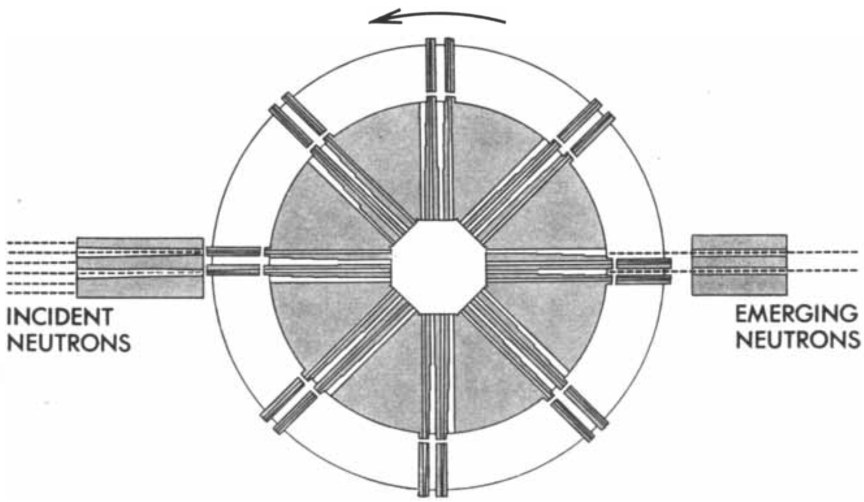
Experimenting with neutrons means, in essence, exposing a piece of material to them and observing how they are affected. Some may be absorbed, others deflected from their original path. The "cross section" of various atomic nuclei for absorbing or scattering neutrons (*i.e.*, the probability that the atom will absorb or scatter a neutron that hits it) tells us a good deal about the atoms and about the neutrons themselves.

A direct and comparatively simple way to use reactor neutrons for cross-section measurements is to put the material being studied inside the reactor. Despite their great size, reactors are extremely sensitive to changes in the number of neutrons available to maintain their chain reaction. An accurate measure of the availability of neutrons in the reactor can be obtained by noting how far the reactor's control rod must be pulled out in order to get the chain reaction started. When even a tiny sample of foreign, neutron-absorbing material is inserted in the reactor, the control rod will have to be pulled out measurably farther than normally. The extra distance measures the neutron absorption of the sample and hence its cross section. Another way to get this result is with the "pile oscillator." Here the sample is moved in and out of the reactor at a steady rate so that its power level rises and falls.

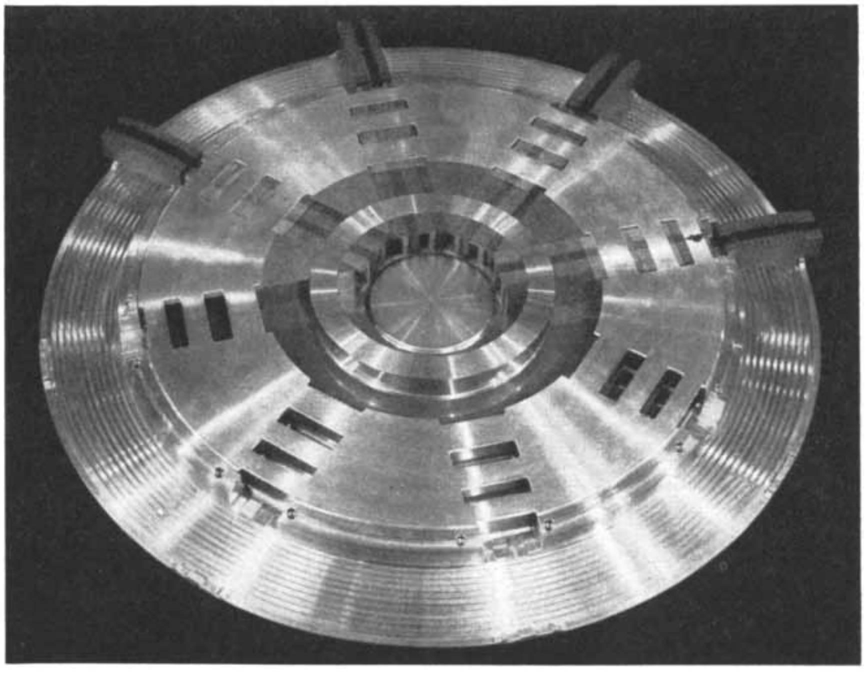
IN THESE experiments the reactor is itself a measuring instrument. For most work, however, it serves merely as



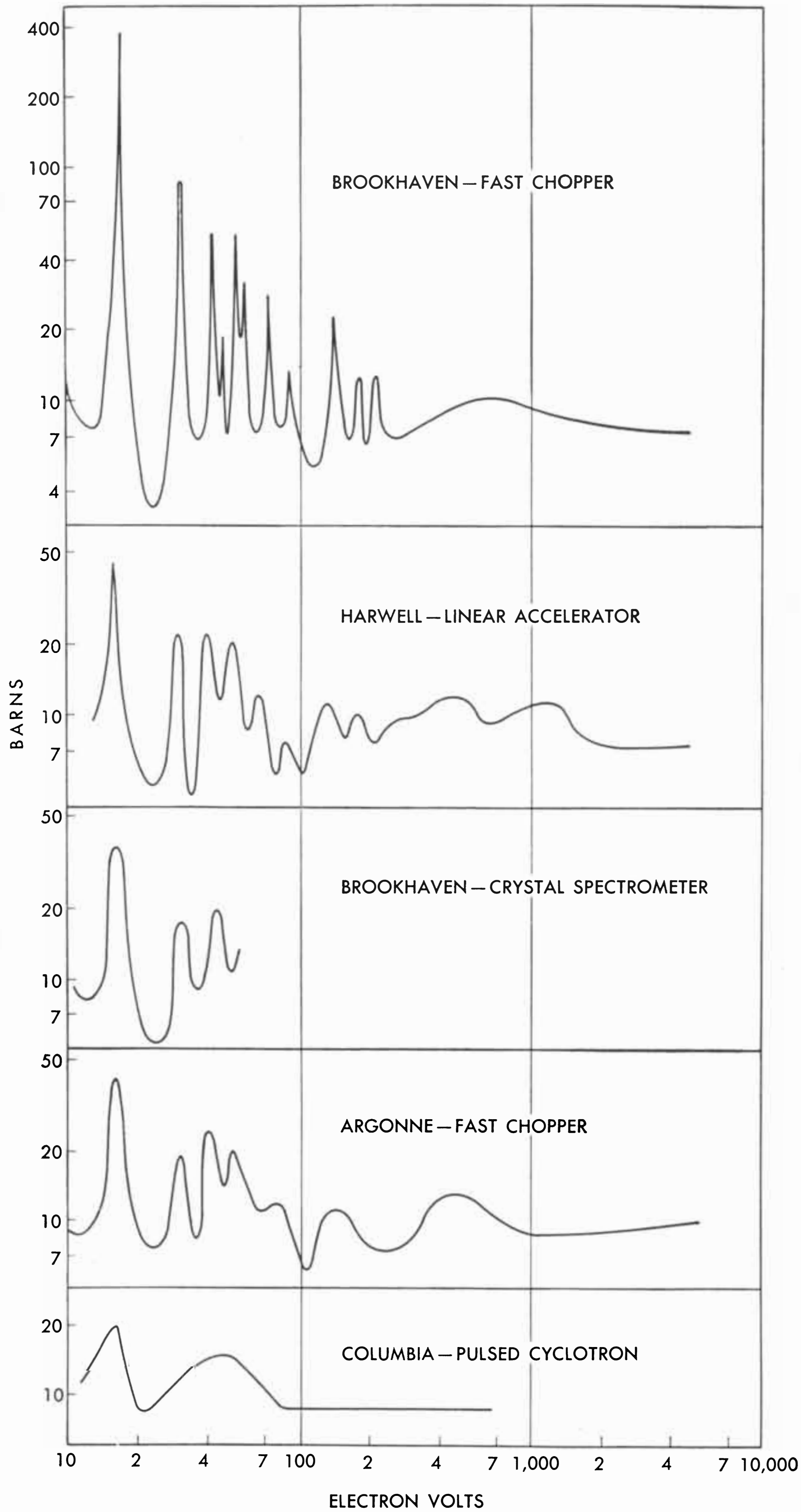
SPIRAL MONOCHROMATOR produces a beam of slow neutrons with uniform speed. Its slotted cadmium disks are turned on the same shaft. Only neutrons of a narrow range of speed will pass through all four of the slots.



FAST CHOPPER is shown in cross-sectional top view. It is a disk traversed by 16 pairs of channels through which neutrons can pass. When the disk is whirled in a vacuum at high speed, the neutrons emerge at right in bursts.



ROTOR of the chopper is made of forged aluminum with plastic inserts which form the channels through which the neutrons pass. When the rotor is spun at full speed, it is able to chop 1,000 bursts of neutrons per second.



HIGH RESOLUTION of the Brookhaven fast chopper in the measurement of nuclear "cross sections" is illustrated by these curves. The cross section of the nucleus, measured in "barns," is the probability that it will absorb a bombarding particle. Each curve represents the cross section of the silver nucleus when bombarded with neutrons of various energies, measured in electron volts. Because the Brookhaven chopper produces neutrons of precisely known energy, it is able to reveal cross sections in unusually fine detail.

a neutron source. Neutrons are brought out of the pile through holes running from the interior out through the shield. The beam that pours out of the experimental holes contains enormous numbers of particles in a wide range of energies. The fastest, coming directly from fissioning uranium atoms, have energies as high as 10 million electron volts. The slowest, those that have lost almost all of their energy in passing through the graphite (or, in the case of some reactors, heavy water) moderator, have an energy of only .0001 electron volt. Thus the fastest neutrons are some 100 billion times more energetic than the slowest. Each particle, it must be remembered, is also a wave. The formula for particle wavelength tells us that it varies inversely with speed. The fastest neutrons in the beam have wavelengths of a few hundred-thousandths of an angstrom unit, even shorter than the diameter of an atomic nucleus (an angstrom unit is a hundred-millionth of a centimeter). The slowest neutrons, on the other hand, have a wavelength of 30 angstrom units, far longer than the distances between atoms in crystals.

In different sections of this broad energy spectrum the neutrons have wholly different properties, both as to the way they must be manipulated and as to their effects on matter. High-energy neutrons behave like solid pellets; slow neutrons lose their particle character almost entirely and act like almost pure waves. The principal task of the reactor experimenter is to sort neutrons of various speeds and to observe how particles of each speed interact with matter.

THE NEUTRON beam divides into three main speed ranges. The so-called fast neutrons are those with energies extending from 10 million down to about 10,000 electron volts. Below these in the hierarchy of energies are "resonance" neutrons, from 10,000 electron volts to .01 electron volt. Finally there are the thermal neutrons, with energies from .01 to .0001 electron volt.

In many experiments we do not try physically to separate the various particles from one another. Instead we use detecting devices that respond only to the type of neutron we are studying. Thus fast neutrons make themselves known by knocking protons out of a detecting substance such as paraffin. In cloud chambers the protons produce ion trails from which we can deduce the energy of the particles, and hence the energy of the neutrons that produced them. Counting the proton tracks of a particular energy tells us how many neutrons of corresponding energy are in the beam. Suppose we want to measure the cross section of gold for million-volt neutrons. First we expose the detector to the reactor beam and count only the million-volt neutrons. Then we put a thin gold foil into the beam and note the decrease in these particles, which represents the number of million-volt neutrons removed by the gold. Most basic research in the fast range deals with nuclear cross sections, either for absorption or scattering.

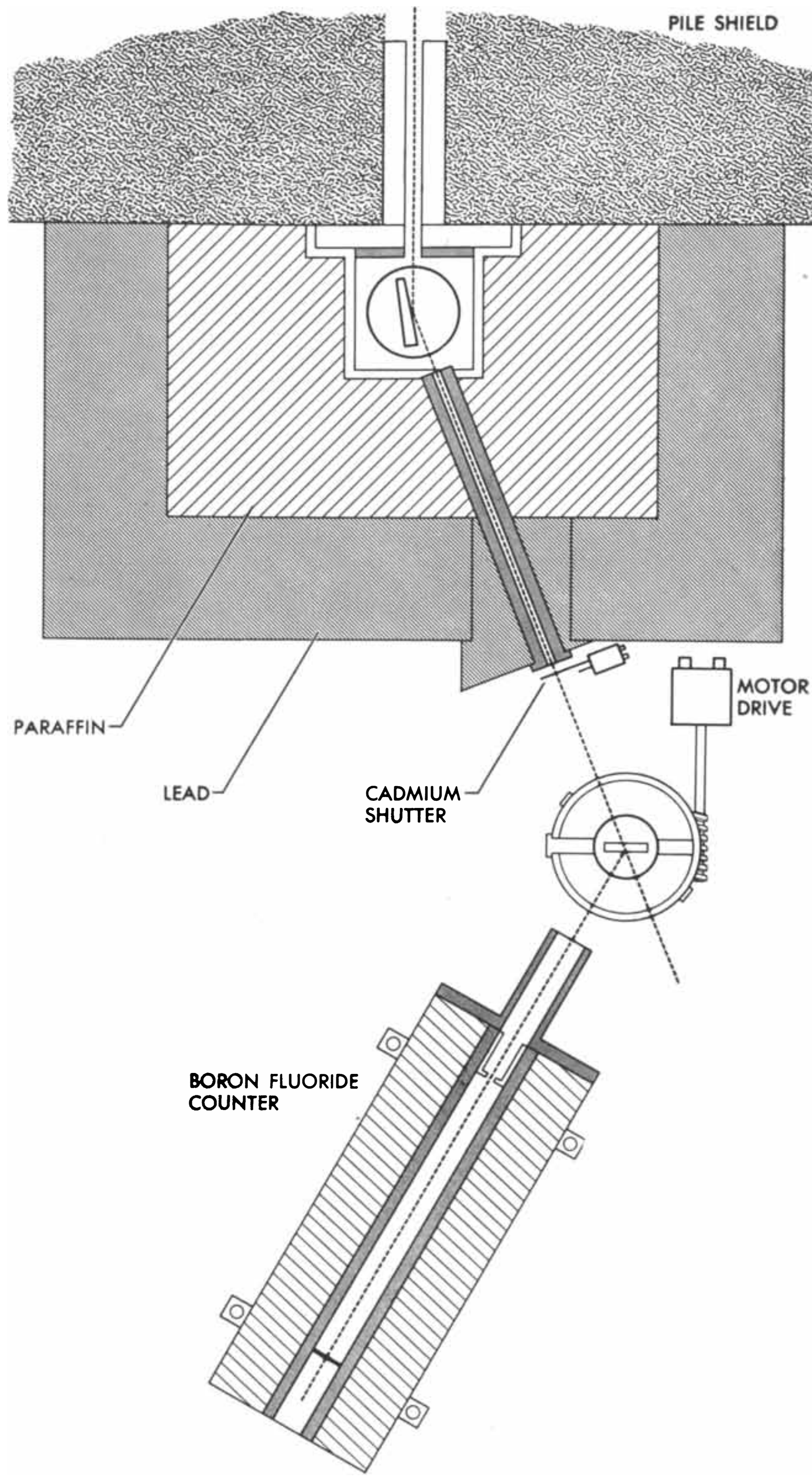
RESONANCE neutrons are a kind of mixed breed. The faster ones must be handled like particles, but their effects depend on their wave nature. Having wavelengths of about the same size as nuclear diameters, they interact with nuclei in a wavelike manner. At certain wavelengths they resonate with a nucleus, which means they are strongly absorbed; at slightly different wavelengths they are "out of tune" and their absorption greatly decreases. The neutron absorption curve of a particular nucleus thus shows sharply separated peaks at isolated wavelengths.

Nuclear physicists are very interested in these curves because they promise to throw light on one of the murkiest problems now facing us—the internal structure of the nucleus [see "The Structure of the Nucleus," by Maria G. Mayer; SCIENTIFIC AMERICAN, March, 1951]. Is it formless, like a liquid drop, or does it have a "shell" structure? The shell theory states that neutrons and protons occupy fixed orbits or shells in the nucleus, much as the electrons do outside it. A nucleus whose outermost shell is completely filled should be very stable. The numbers of neutrons and protons required to fill successive shells are known as the "magic numbers."

Neutron absorption experiments give some strong evidence for the shell model. One of the magic numbers is 50, and tin contains 50 protons. When we compare the absorption spectrum of tin with that of silver, we can see that tin is indeed unreactive. Whereas the silver nucleus finds many neutron energies that excite it, tin is apparently satisfied with its make-up and rejects all neutrons indifferently.

BUT we are still far from having a satisfactory theory of the nucleus. We need much more information on the activity and energy levels of various nuclei, and neutron absorption experiments are one of the best ways to get it. It is essential to find out just which energies are absorbed by each nucleus, and which rejected. This means that we must be able to distinguish sharply between neutrons of different speeds. The sharper our separation, the greater the resolving power of our nuclear spectroscope, and the less the chance that what appears to be a single absorption peak is really two or more separate ones.

The device with which we are now getting the sharpest separations is the "fast chopper," recently developed by F. G. Seidl at the Brookhaven National



NEUTRON DIFFRACTION experiments at Oak Ridge National Laboratory employ the arrangement depicted in this top view. The neutrons emerge from the reactor at the top. They are reflected from a crystal set at a shallow angle as a means of selecting those of a certain energy range. The neutrons are then allowed to pass through a second crystal mounted on a turntable. This crystal diffracts the neutrons in certain preferential directions; when it is turned, the counter at the bottom will detect the number of neutrons diffracted in each direction. In this way the experimenter can measure the interaction between the neutrons and the atoms in the crystal.

Laboratory. It is a solid disk traversed by a few narrow slits through which neutrons can pass. When the disk is whirled very rapidly it acts as a shutter for the beam, allowing short bursts of neutrons to pass each time a slit swings into the proper position. At full speed the chopper yields 1,000 pulses per second, each lasting a millionth of a second. The slits are an inch high by .01 inch wide. The extremely narrow beam that they produce makes it possible to work with small samples of material, as little as a hundredth of a gram. This means that we can experiment with separated isotopes, which are available only in fractions of a gram.

To detect the neutrons we use a crystal that scintillates when they strike it. The crystal is set up about 100 feet from the chopper. As each burst of neutrons traverses the long path, it becomes elongated in the direction of motion, the fast particles heading the parade and the slow ones bringing up the rear. Attached to the scintillating crystal are 100 separate counters, each turned on for successive intervals lasting a hundredth of the total flight time. A beam of light, which passes through the slits with each burst of neutrons, triggers the counting sequence, starting the first counter just in time to pick up the first neutrons. Thus each counter records particles in a very narrow range of speed. To record an absorption spectrum the counters are read first with an unobstructed neutron beam. Then a sample of material is placed between the chopper and detector and the counters read again. The silver spectra reproduced on page 26 show how much sharper resolution we get with the Brookhaven chopper than with earlier methods of selecting neutron velocities.

THE fast chopper works well with neutrons of about 10,000 to 10 electron volts. At the lower end of the resonance range, from 10 to .01 electron volt, the neutron waves are long enough for us to take advantage of their optical properties. These waves are about as long as the distance between atoms in crystal lattices and are diffracted by crystals just as X-rays are. The angle at which they are scattered in a given crystal depends on their wavelength, so that these neutrons can actually be separated according to speed in a crystal "monochromator."

Having obtained a beam of single-energy neutrons, we generally use it to study other crystals. X-rays, of course, have been used in the same way for half a century, but neutrons can do things that X-rays cannot. Neutron diffraction has opened an entirely new field in crystal analysis—the investigation of magnetic structure.

Every neutron is a tiny magnet. When it is scattered by magnetized atoms its deflection depends not only on the "grating spacing" of the crystal lattice but also on the magnetic forces. Neutron diffraction patterns are, therefore, different from X-ray patterns for magnetic substances, and from the difference we can read the magnetic configuration of the crystal.

At several laboratories neutron diffraction has been applied to the study of anti-ferromagnetic materials. In a ferromagnetic substance such as iron each atom is a magnet and all the atoms are lined up with their north poles facing in the same direction. Anti-ferromagnets also have magnetized atoms, but show no over-all magnetism. This has been explained by assuming that the individual atoms are aligned, but with their north poles pointing alternately in opposite directions. There was no way of checking this assumption, however, until C. G. Shull and J. S. Smart of the Oak Ridge National Laboratory tried neutron diffraction. They exposed a manganese oxide crystal to a monochromatic beam of neutrons. If the atoms are actually arranged according to the theory, a neutron will be attracted by one, repelled by the next, attracted by the third and so on. Because of this alternate attraction and repulsion the "unit cell"—the fundamental structural unit of the crystal—is twice as large when viewed by neutrons as by X-rays. The diffraction pattern should then contain neutrons at positions where there would be no energy in an X-ray pattern. Neutrons were found in the diffraction pattern in just these expected positions, but only when the crystal was kept at very low temperature. At room temperature the pattern disappeared, showing that the rigid anti-parallel alignment of the atoms no longer held good. Other anti-ferromagnetic substances are believed to have much more complicated magnetic structure than the simple scheme of manganese oxide. Knowing how their atomic magnets are arranged is important both for our basic understanding of the solid state and for a number of potentially useful applications. With neutron diffraction we can now find out.

BELOW the resonance range are the slowest neutrons, the thermals. They have this name because, by repeated collisions with carbon nuclei in the reactor, they have been slowed to speeds equal to, and even less than, the average vibrational speeds of the graphite molecules. These neutrons have energies from .01 to .0001 electron volt. At their slowest they travel only about 600 feet per second, corresponding to a temperature of only two degrees centigrade above absolute zero.

We have various ways to sort out thermal neutrons of different speeds. One of these is a slow chopper, which operates in the same way as the fast chopper. Another is the "spiral monochromator," an elaboration of the chopper idea that actually filters particles of a single speed out of the beam. It is made of a series of slotted disks on a single shaft, the position of the slots being adjustable (*see diagram on page 25*). The disks are set so that each successive slot stands at a fixed angle to the one before it, or, in other words, so that the open path through the array of disks is a spiral. When the apparatus is rotated, a particle entering the first slot at the right speed will find each following slot moving into position just in time to let it through. Particles at other speeds will bump into the solid disks. By adjusting the angle between the slots or the speed of rotation of the shaft we can pick out neutrons of any desired speed.

Very slow neutrons are particularly useful for studying the motions of atoms in crystals. Moving in the same speed range as the particles they bump into, the neutrons can gain or lose a large proportion of their energy in collisions. From the energies of the scattered neutrons we can infer the motions of the atoms in the crystal lattice.

THE WAVELENGTHS of thermal neutrons are so long that it becomes just possible to reflect them with mirrors. Mirror reflection requires a smooth surface, and smoothness is a relative matter which depends upon the wavelength involved. The longest neutron waves are still 1,000 times shorter than waves of visible light, so that an "optically smooth" surface still looks very rough to a neutron. But just as a highway can reflect light that strikes it at a grazing angle, so a mirror that is rough to neutrons can reflect them when they strike at an exceedingly small angle, about a tenth of a degree.

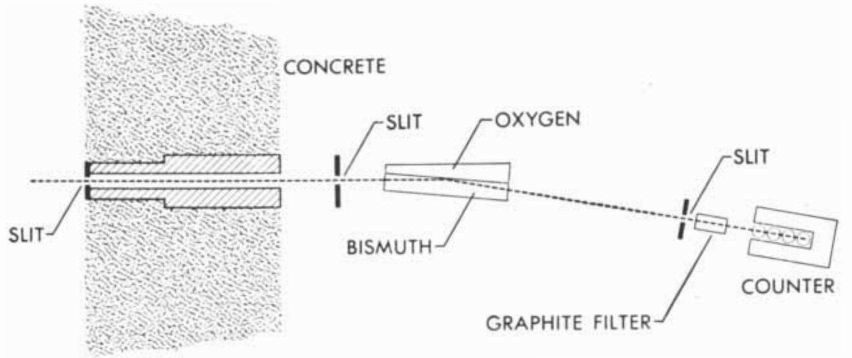
Neutron mirrors are an effective means of measuring nuclear forces. This is because the force between the neutron and the atomic nuclei of mirror materials determines the maximum glancing angle at which reflection is possible. We can measure this "critical angle" quite precisely, and so calculate the nuclear force accurately. The method can be applied to a variety of atoms, since many materials make suitable mirrors. We have used highly polished solids, such as iron, nickel and beryllium; liquids, such as mercury, water and benzene, whose surfaces are sufficiently flat when quiet; gases, such as helium and nitrogen, contained in vessels with polished walls.

RECENTLY neutron mirrors have given us an accurate measurement of one of the smallest of all interactions between fundamental particles, the one between the neutron and the electron. It might seem at first that the force between these two fundamental particles should be zero, for the neutron has no charge. According to modern meson theory, however, the neutron spends part of its life in a dissociated form, split into a proton surrounded by a cloud of mesons. It is still electrically neutral when seen from outside the meson cloud, because the negative charge of the mesons just balances the positive charge of the proton. But inside the cloud, which extends about 10^{-13} centimeter from the proton, there is an electric field. An electron inside the meson cloud should be attracted to the proton with a minute but measurable force.

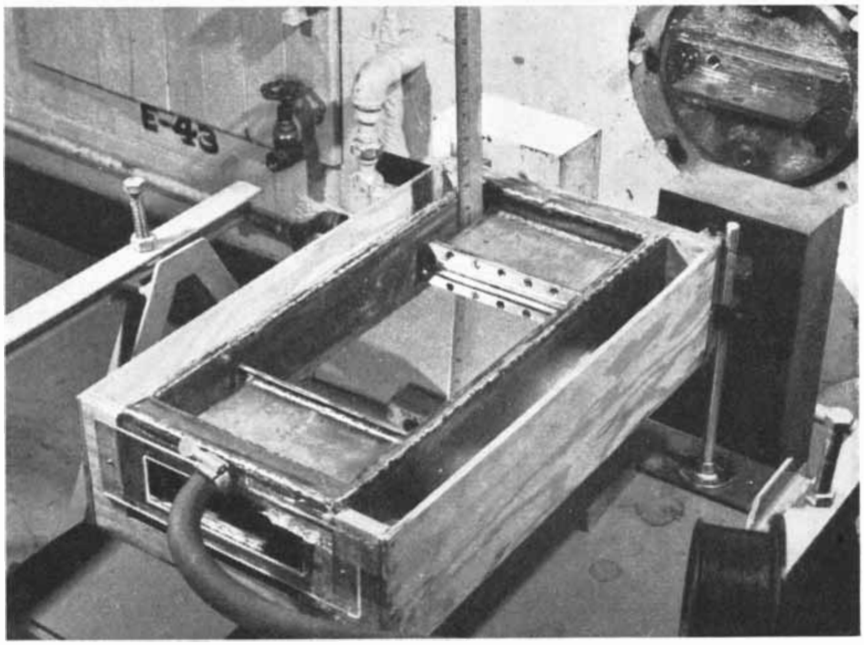
When we try to measure this force, however, we run into a major difficulty. The neutron-electron interaction is about 10,000 times weaker than that between the neutron and the atomic nucleus. It is impossible to study the interaction of neutrons with isolated electrons, and so the force we are after is always masked by one very much greater. To sidestep the large nuclear force the writer and his colleagues at Brookhaven, J. A. Harvey, M. D. Goldberg and Marilyn J. Stafne, devised a special neutron mirror. A block of bismuth was polished on one side and fitted into a tank so that a layer of liquid oxygen could be placed in contact with the polished surface. The neutrons were reflected from the boundary between the two materials. It happens that oxygen and bismuth have almost exactly the same nuclear interaction with neutrons, so the nuclear scattering balances for the two. The electron scattering, however, is quite different on opposite sides of the dividing boundary because each bismuth atom has 83 electrons and each oxygen atom only eight. So far as the neutrons are concerned the experiment is essentially the same as if they were reflected from a mirror made of electrons alone. The critical angle for the mirror thus gives the strength of the neutron-electron interaction directly.

The measured force turns out to be much smaller than predicted by the meson theory; in fact, it can be completely accounted for by a small magnetic interaction between the neutron and electron that does not involve the meson cloud at all. This means that there is some error in the present simple idea that neutrons exist transiently as protons and mesons. It may be that the proton itself, instead of being a point particle, is spread out to such an extent that its more distant parts act weakly on the electron; it may be that the splitting produces both positive and negative mesons, which cancel the electrical effect. To answer these questions fully we will have to design still subtler experiments as well as perhaps construct better theories of fundamental particles.

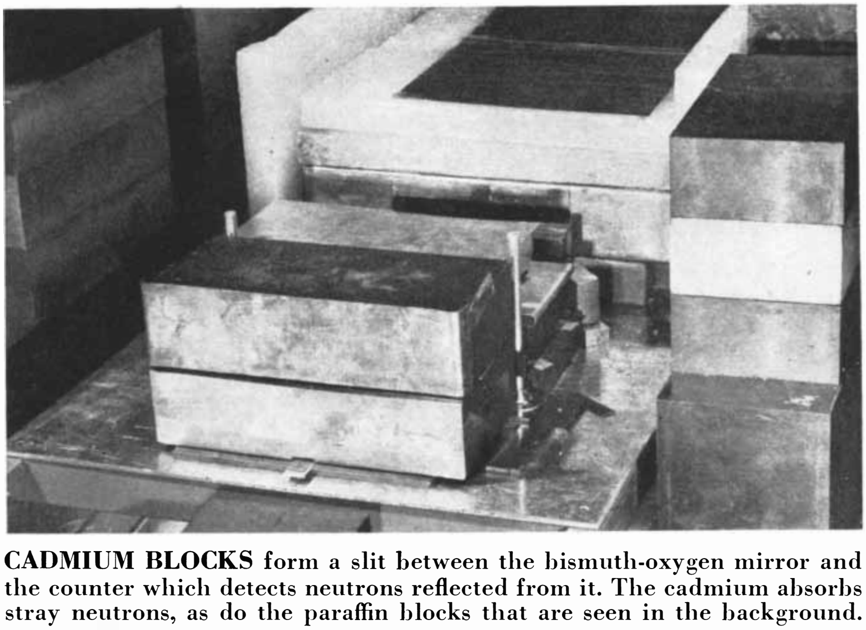
One thing seems certain. As more research reactors are built, and with higher neutron fluxes, their neutrons will play an increasingly important role in the search for the secrets of matter.



NEUTRON MIRROR experiments at Brookhaven utilized the arrangement shown in this side view. The neutrons emerged from the pile at the left and were reflected from the boundary between bismuth and liquid oxygen.



BISMUTH MIRROR is used in the arrangement depicted in the diagram above. During an experiment liquid oxygen is poured into the container around it. The neutrons emerge from the pile hole through the slit at right.



CADMIUM BLOCKS form a slit between the bismuth-oxygen mirror and the counter which detects neutrons reflected from it. The cadmium absorbs stray neutrons, as do the paraffin blocks that are seen in the background.

ARCHAEOLOGY AND THE EARLIEST ART

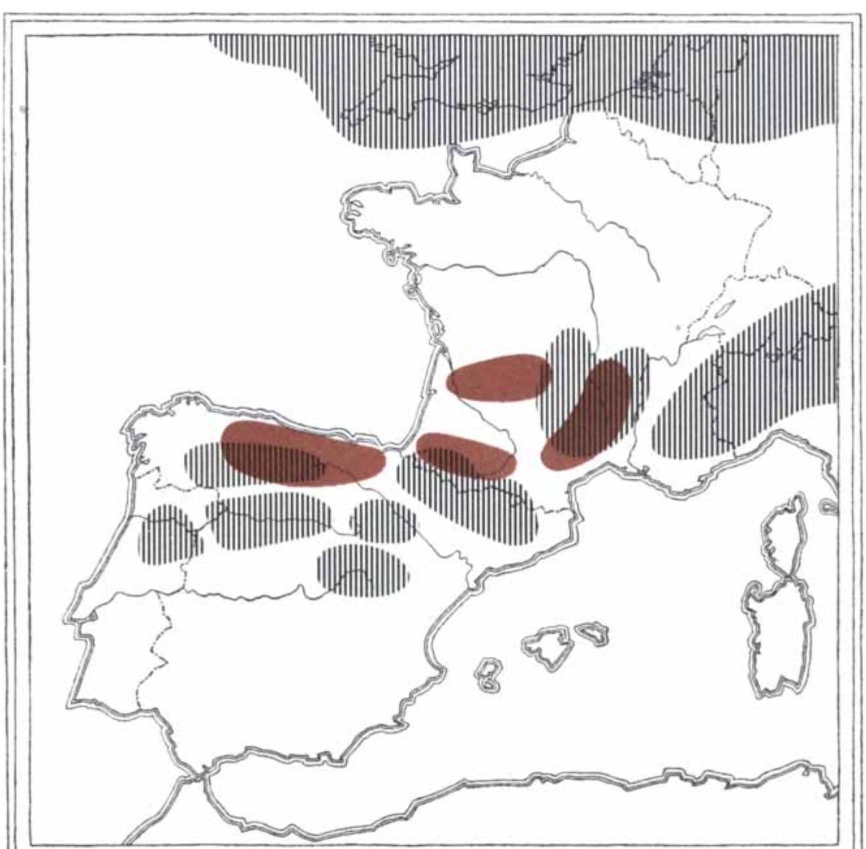
The mightily creative men of Upper Paleolithic France and Spain adorned caves with everything from finger tracings to paintings. Where do these works fit into history, and why were they made?

by Hallam L. Movius, Jr.

OF ALL the works of early man, none so stirs the imagination of his modern descendants as the art that is found in the caves of southern France and northern Spain. These remarkable representations of animals, some of them now extinct, were made by various hunting peoples who lived in the Upper Paleolithic period—some 10,000 to 20,000 years ago. The art takes five main forms: finger tracing, engraving, bas-relief, sculpture and painting. All these were done on the cave walls; in addition many fine works appear on fragments of bone, ivory and stone. This is called *art mobilier*, or portable art. To it belongs a group of small round statuettes, mostly of women, that is found from western Europe to east-central Siberia. Because the motivation of this art form appears to differ from that of the others, it will not be discussed here.

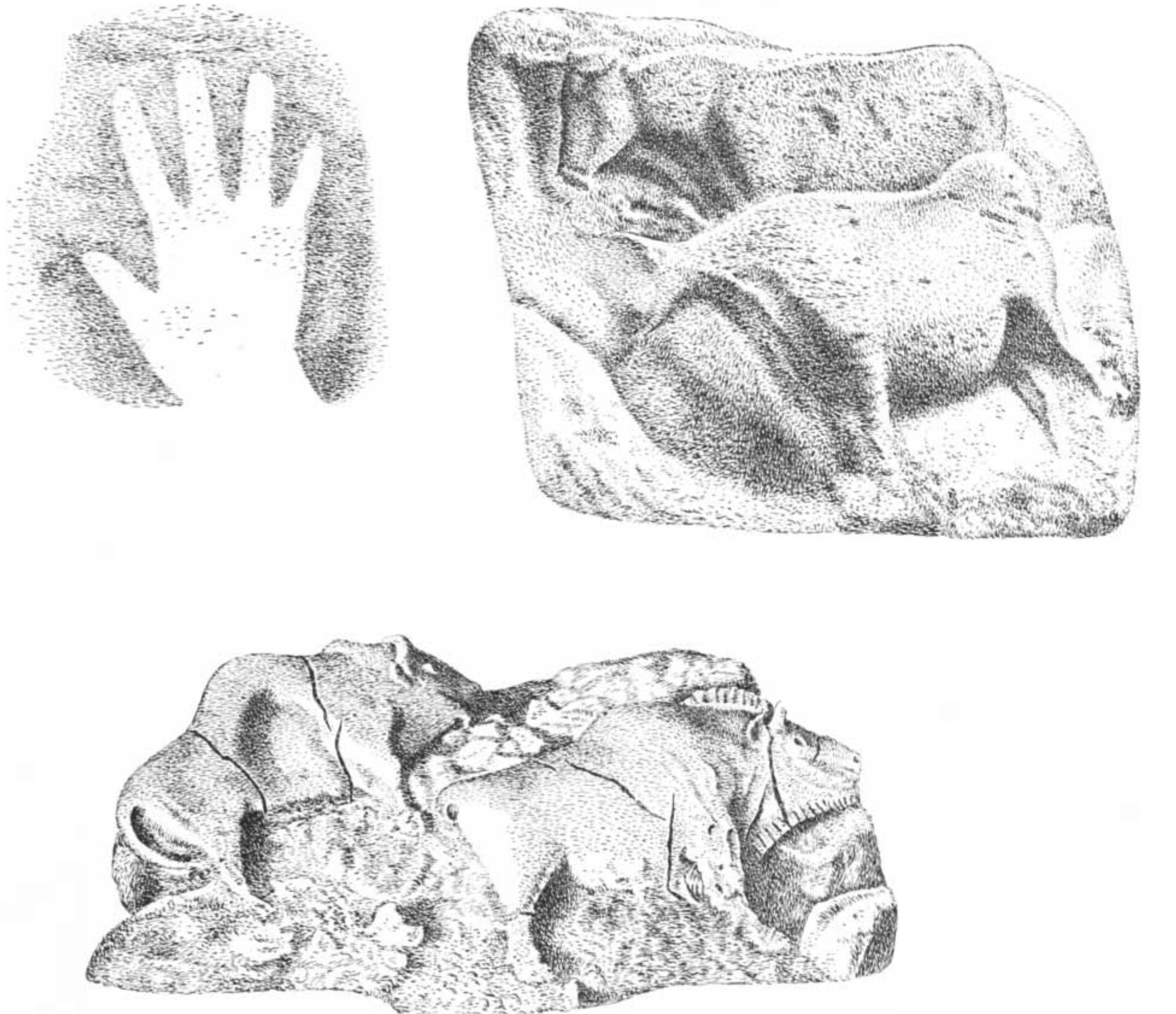
The art of the caves is often called "cave man's art" or "Cro-Magnon art," but neither description is satisfying. There are very few indications that its creators actually lived in the caves; they normally camped either on the terrace in front of the cave or in the shelter of an overhanging rock. The so-called Cro-Magnons were only one of several races of Homo sapiens inhabiting southern and western Europe at the time. To attribute all the cave paintings to them is more than an oversimplification: it is wrong.

Every form of art reflects the culture of the people who created it—the economic basis of their subsistence, their social organization, their ceremonial life. Since the remains of more than one Upper Paleolithic culture which produced talented artists are found in southern and western Europe, it is hardly surprising that the time and the region should be represented by more than one style of art. But the fact that numerous styles of artistic expression can be distinguished is not generally appreciated. The famous French prehistorian Henri Breuil has found that the art styles of the Upper Paleolithic can be grouped in two principal cycles named after the cultures with which they are associated: (1) the Aurignacian-Périgordian and (2) the Magdalenian. Where do these cycles fit into the time scale provided by the natural sciences?



PRINCIPAL REGIONS in which cave art is found are shown in color. The areas covered with vertical lines show the maximum extent of glaciers.

THE GREAT ANTIQUITY of the cave art was established beyond any reasonable doubt before the close of the 19th century. It was obvious that, if the bone, ivory and stone objects of the *art mobilier* were unearthed in direct association with other remains of an ancient culture, they were contemporary with it. Indeed, it was the understanding and appreciation of the *art mobilier* that led the 19th-century investigators to turn their attention to the wall art. The antiquity of both forms was emphasized by the fact that many of the animals they depicted—the mammoth, woolly rhinoceros, reindeer, saiga antelope, bison, wild



PRINCIPAL FORMS of cave art in addition to painting are finger tracings (*"macaroni" pattern at lower left*), engravings (*lower right*), bas reliefs (*upper right*) and sculpture (*center*). At upper left is stenciled hand.

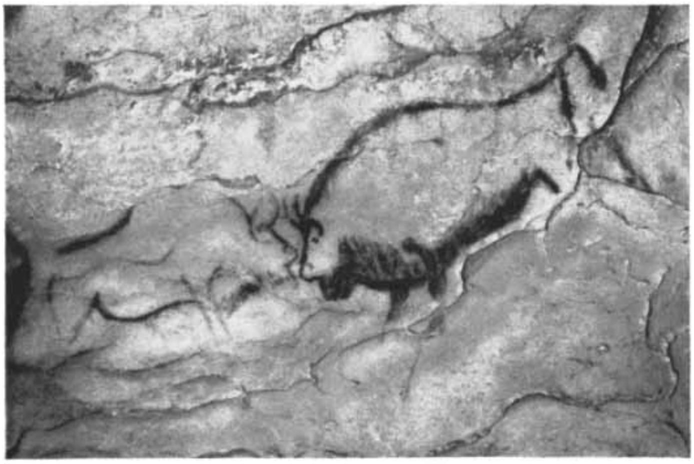
ox, wild horse, cave lion and cave bear—were either extinct or had emigrated to other parts of the earth. There was much other evidence. Was it not sufficient proof of high antiquity, argued the early archaeologist Edouard Piette, that certain of the engravings found in southern France had been executed on mammoth ivory and reindeer antler which had later been turned to stone by the processes of fossilization? Emile Rivère demonstrated that the cave of La Mouthe in the department of Dordogne, the walls and ceilings of which were adorned with many fine drawings, had been sealed by deposits similar to those in which the remains of the Magdalenian culture were found. While excavating an Upper Périgordian layer in the cave of Pair-non-Pair in the department of Gironde, François Daleau found that it covered a large number of wall engravings, apparently of Aurignacian age.

As indicated by the chart on page 34, Paleolithic archaeology deals with an enormous span of time extending from the emergence of man as an erect-walking, tool-using mammal to shortly before the beginnings of written history. This period of perhaps a million years covers the entire Pleistocene epoch of geology, when vast ice sheets advanced and retreated four times, much of the land was reshaped, and the flora and fauna of the earth were profoundly changed. The four great glaciations were separated by interglacial periods in which the earth's climate was even warmer than it is at present.

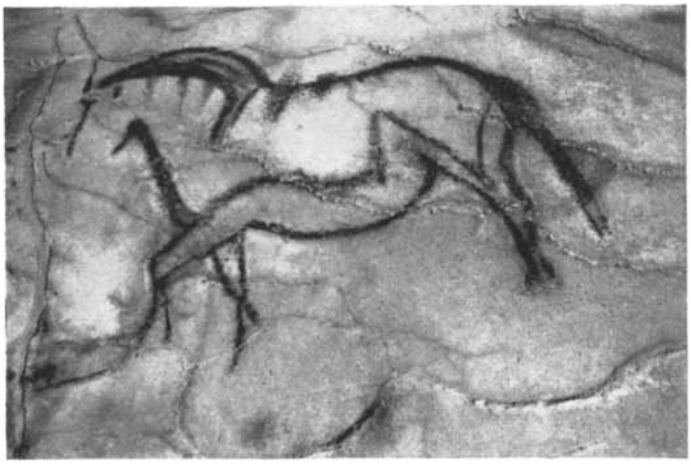
Throughout the entire span of the Paleolithic period man was a food-gatherer depending for his subsistence on hunting wild animals and birds, fishing and collecting wild fruits, nuts and berries. The stone tools that were made by these men fall into three main "traditions." One is the core tradition, in which the tool was made by chipping flakes from a "core." The second is the flake tradition, where the flakes themselves were used as tools. The third is the blade tradition, in which the flake was specially shaped before it was detached from the core. It is the blade tools that are characteristic of the Upper Paleolithic cultures in western Europe. Since cave art is found in association with blade tools, it is placed in the Upper Paleolithic. Indeed, there is no evidence whatsoever to suggest that art of any kind is older than this period.

The Upper Paleolithic period is divided into the Lower Périgordian, the Aurignacian, the Upper Périgordian, the Solutrean and the Magdalenian. Although the oldest art is definitely identified with the Périgordian and Aurignacian, it is difficult to date these stages of cultural development. To say that they began 20,000 years ago is merely a reasonable guess. For the age of the Magdalenian culture, in which the cave art reached its climax, we have much better evidence. Because its culmination was contemporary with the final stages in the retreat of the European ice sheet, we can say that it goes back about 12,000 years. All the art of the Upper Paleolithic falls between these two limits.

It is not so easy to correlate figures painted or incised on the exposed wall or ceiling of a cave with the culture that gave rise to them. Sometimes engravings of animals unearthed in a clearly identifiable cultural stratum are almost identical with other representations on the walls of the same cave. In the cave of Hornos de la Peña in northern Spain, for instance, a piece of bone was found engraved with the hind quarters of a horse; this representation closely resembled a wall drawing in another part of



Facing bison in the cave of Portel (France)



Horse in the cave of Portel

Goat and pig in the cave of Niaux

Horse's head and deer in the cave of Niaux the cave. The resemblance is so striking that the engraving could well have been the artist's preliminary sketch before he committed himself to the larger "canvas"! In other places fallen blocks with paintings or engravings on them have been discovered in known cultural horizons. In the Aurignacian and Upper Périgordian hearths of the Labattut and Blanchard rock shelters in the Dordogne, paintings have been unearthed whose style can be related to the figures painted on the walls and ceilings of caves in the same region. Of course such fallen blocks can only be older than the layers of earth that contain them. But this does not tell us how much older they are.

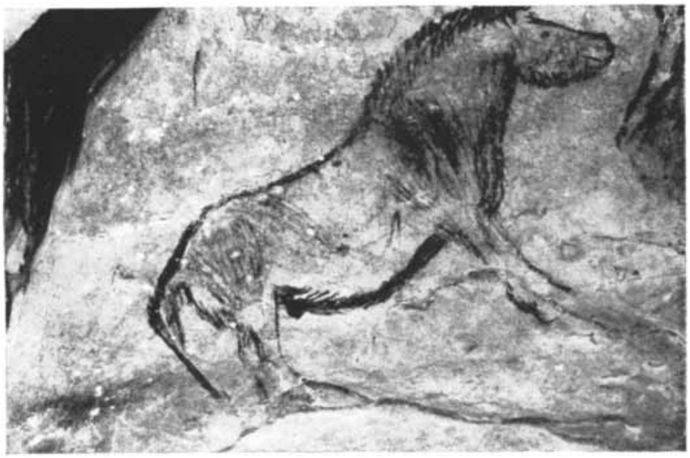
JUDGMENTS concerning the age of primitive art that are based entirely on stylistic considerations can be very misleading. The Abbé Breuil has nonetheless suggested that the perspective of Upper Paleolithic art can be employed to establish its period. Some of the drawings utilize what is called *perspective tordue*, or contorted perspective, in which the horns and hooves of certain animals are turned so that they face the observer. Breuil believes that this perspective is characteristic of the Aurignacian-Périgordian cycle. Beginning in Upper Solutrean time and extending throughout Upper Magdalenian, the perspective is thought to resemble the more realistic modern convention.

Following a similar line of reasoning, several experts maintain that sculpture must have preceded the earliest line drawings. Because of the fundamental difficulty of rendering a three-dimensional object on a two-dimensional surface, these workers believe that the earliest representations of three-dimensional shapes must have been exact copies in sculptured form. Although this theory is plausible, it is only partly supported by the facts. It is true that sculpture in the round occurs more commonly in the portable art of the first cycle of the Upper Paleolithic than in the second, but at the same time simple line engravings and finger drawings have been identified with the very earliest horizons.

The oldest convention of all is represented by finger tracings in the layer of damp clay found on the walls of certain caves. These tracings describe meandering, interlacing patterns, including the so-called "macaroni" patterns. They also form drawings of a primitive sort. Often superimposed on the finger tracings are the earliest engravings—simple outline drawings in which the eye is frequently omitted. These look as though the shadow of the animal had been projected on the cave wall and a shallow outline scored around it with a burin, or graving tool. When one considers the economy of these naturalistic drawings, their vigor is all the more remarkable. Associated with these first attempts at true design are vague geometrical patterns the true significance of which is not clearly understood, although most scholars agree that they are magical symbols. Also dating from very early times is a series of human hands, frequently with mutilated fingers, which stand out as negative paintings against a red or black background. Positive tracings of hands likewise occur, and it is generally thought that these stencil drawings represent Upper Paleolithic man's first attempts to use color.

The oldest true paintings of animals are in simple areas of color or are merely colored outlines in red, yellow or black that are stylistically related to the earliest engravings. Then the artist's mastery of his medium begins to become apparent. The rudimentary sil-

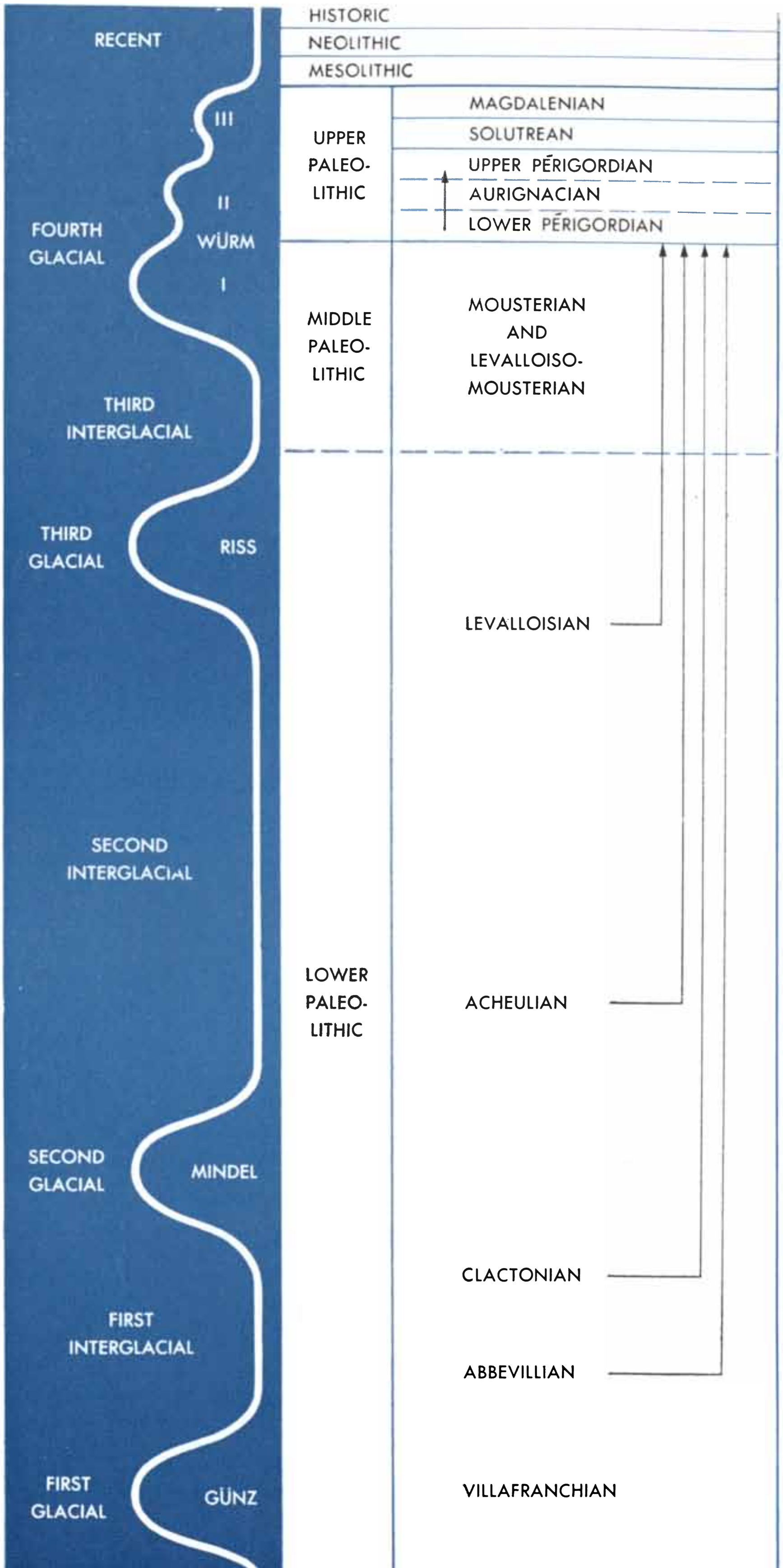
Horse in the cave of Portel



Horse in the cave of Niaux (France)

Bison in the cave of La Pasiega (Spain)

Bison in the cave of Altamira (Spain)



PALEOLITHIC CULTURES (*right*) **are correlated in time with the advance and retreat of the Pleistocene glaciers** (*white line in colored area at left*)**. The cave art was produced by the cultures of the Upper Paleolithic.**

houettes assume a greater precision of form, and are executed in a more refined manner. In the early representations each animal was depicted with only two legs. As the artists ventured further into realism, the animals were shown with four legs. Even now, however, the hooves of ruminants such as the bison are turned with the cleft facing the observer. The horns are similarly drawn in *perspective tordue*. The drawing is nonetheless lively and possesses a tremendous illusion of movement. Next the paintings become delicately modeled, sometimes even in two colors; often the contours are accentuated by incised lines. A great many of the paintings are done in black or red line, but others utilize a wide range of colors from a delicate yellow to the darkest brown. In the two-color paintings black and red were normally employed.

The engravings of this stage reflect two very interesting developments. In one the outline of the animal is discontinuous, composed of short and more or less parallel dashes that are often inclined at an angle to the main direction of the outline. These apparently depict the animal's hair. In the other development the body of the animal is partly filled in with long parallel striations representing the hair but cleverly arranged to suggest shading. Although the technical skill of Magdalenian art is considerably greater than that of the Aurignacian-Périgordian, all the fundamental artistic concepts of the later period were established in the earlier. In the Magdalenian these principles came to full flower with the development of true perspective and paintings rendered in many colors.

WHAT were the means by which the Upper Paleolithic artists achieved these rich expressions? We have very little knowledge of how they made sculptured figures on blocks and bas-reliefs on the limestone walls of the caves. Presumably the stone was chipped away with a flint chisel or pick held in one hand and hit with a stone hammer in the other, but this has never been confirmed. More is known about the technique of engraving. Both in the case of the wall art of the caves and the *art mobilier* these were unquestionably made with flint burins, which are found in great quantities in the archaeological deposits of the localities where engravings have been discovered. In a cave in the Pyrenean region of southern France one of these tools was actually found on a small ledge just below a very fine engraving of a cave lion.

Upper Paleolithic man collected and used several kinds of pigment in preparing the colors of his paintings. Naturally occurring ochres were most commonly employed, and small caches of this material are often found in the deposits of his dwelling sites. The ochres consist of iron oxides mixed in various proportions with earth, clay and other substances. They range in color from the various reds of the oxide known as hematite to the chocolate, orange and yellow of limonite. Manganese oxide yielded a blue-black pigment. Jet-black was obtained from carbonaceous matter such as burned bones. Unless colors of vegetable origin that have long since disappeared were prepared, no other pigments are known to have been employed by the Upper Paleolithic artist. For this reason the cave paintings are in a wide range of red, yellow, brown and black shades; no true blues, greens or whites have ever been observed.

It is believed that the pigment was first ground to a fine powder, and then placed in shells or in small tubes made from hollow segments of long bones stopped up at one end. At several cave sites these tubes and shells have actually been found with traces of ochre in them. They are associated, moreover, with flat stone palettes on which the pigments were ground. Next the powdered material was mixed with some fatty substance, easily obtained from the animals regularly killed in the hunt, and the paint applied to the cave wall. We do not know exactly how the paint was applied. Although there is no reason to deny the possibility that some kind of brush was used, no such object has ever been found. In any case, the necessary materials were available: many of the contemporary animals had long hair or wool, an adaptation to the cold climate of late glacial times. Apparently some sort of wooden or bone stamp covered with skin was also used; in many paintings the outline of the animal has been rendered by a series of punctuations shaped as if they were made by a stamp dipped in coloring matter and pressed against the cave wall.

The paintings and engravings are often located a considerable distance from the entrance to the cave. To view these galleries, which are sometimes situated deep in the interior of hillsides, the visitor requires either a large miner's acetylene lamp or a powerful electric torch. Upper Paleolithic man must also have needed some kind of artificial light, not only when he wished to create his art but also when he wanted to visit it. Surely he did not enter the cave merely by seizing a burning brand from his fire—he required proper lamps. Lamps of stone, similar to those still used by the Eskimos, have indeed been found. Carbonaceous matter inside them indicates that the fuel was probably either animal fat or marrow, and the wick some kind of moss. Animal skulls and slabs of stone with irregular basin-shaped depressions were also used for this purpose. Although the illumination from such lamps must have been poor, it would have lasted for several hours at a fairly constant intensity.

PERSPECTIVE TORDUE, or contorted perspective, is illustrated by this copy of a painting in the cave of Lascaux in the Dordogne. The hooves of two bison are twisted so that their clefts face the observer.

WHEN we ask why Upper Paleolithic man went to such trouble, and why indeed he created his art at all, we must remember that he lived in a rigorous and demanding environment. To him success in the hunt was the difference between plenty and near or actual starvation; this we know from the lives of primitive hunting peoples existing in similar climatic conditions today. Such peoples do not draw merely for the sake of expressing themselves, or creating a beautiful picture, or making records of the animals they hunt. Art to them is a means of propitiating the spirits of the animal world. This is borne out by the fact that almost without exception Upper Paleolithic cave art is found in places that are perpetually dark; the artists even preferred the most inaccessible corners of the caves. Thus it seems clear that the pictures were not solely for decorative purposes. We can further appreciate that we are not dealing with art for art's sake when we consider the engravings and paintings which are virtually hidden and can only be found with the greatest effort.

It is also likely that certain crannies of the caves were particularly sacred, and that the spells cast there were thought especially effective. This possibility is enhanced by the fact that, even when there was plenty of wall space in a cave, the artists repeatedly used the same panels, piling their pictures one upon the other like palimpsests, not hesitating to destroy older ones of great artistic merit. Since paintings and engravings are by no means found in every Upper Paleolithic cave, it further seems possible that certain caves were regularly dedicated to magical and religious ceremonies. As far as we can determine there were in each region a few places of the same age that should probably be considered true "sanctuaries."

Thus it seems that from prehistoric times groups of people at the hunting and gathering level of subsistence have practiced ceremonial magic to ensure either abundance of game or success in the hunt. Even today the Australian aborigines paint figures of animals and other signs on cave walls which have significance in connection with hunting ceremonies; it is probable that similar rites were performed in western Europe during Upper Paleolithic times. On this basis one can imagine that the remote galleries of these dark underground labyrinths once witnessed witchcraft and ritual dances accompanied by the songs and cries of men in a state of ecstasy. Such an hypothesis of the magical and religious significance of Upper Paleolithic art explains a whole series of facts the meaning of which would otherwise be obscure. One may speculate that the stenciled or negative hands on the cave walls reflect possession or power, that the darts or arrows piercing certain animals signify the casting of a spell on the game.

BUT this aspect of a stage in man's prehistoric cultural development has forever vanished, and we can do no more than speculate about it. In the final analysis the only reality is that our feeble attempts at reconstruction are, to quote the French investigator Annette Laming-Emperaire, "far behind the living reality as it was felt, thought and experienced by our very distant forefathers, with all that this implied in beliefs, faith and creative force." Nor should we, in assessing the significance of Upper Paleolithic art, neglect the natural creativeness of the individual artist. For in dealing with man and his works one must never lose sight of their essential humanity.

Soil Conditioners

The wonder chemicals that burst upon the agricultural world last year have now been tested in the experiment stations. An account of what the tests have indicated

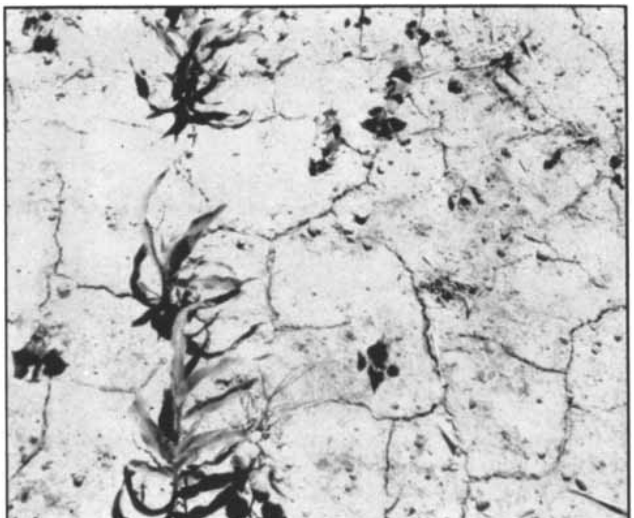
by C. L. W. Swanson

AMAZING CLAIMS have been made for the new soil conditioners. Some hail them as wonder chemicals which, sprinkled on the ground, turn clay or sand to rich, loose topsoil in a few hours, removing all need for organic matter and the back-breaking labor of digging and cultivation. More modest statements are that the chemicals stick clay particles in soil together into crumbs or aggregates, thus changing hard, cloddy and crusted soil into one more suitable for crop growth. But the soil must first be worked to get it into suitable tilth; then the chemicals must be applied and mixed thoroughly into the broken up soil; finally, it must be wetted to make the chemical act on the clay particles, "fixing" the mellow condition of the soil. These claims eliminate no work but do maintain that a favorable physical condition is produced lasting over the growing season and possibly longer. But are the soil conditioners really practical, or just a glamorous novelty? Enough tests have now been run to begin to strike a balance.

The great German chemist Justus Liebig discovered more than a century ago that chemicals could aid the growth of plants. Using sulfuric acid on bones to release their phosphorus as plant food, he founded the vast chemical fertilizer industry which today is said to be responsible for about 20 per cent of our greatly increased crop yields. If chemicals can thus supplement the natural fertility of our soils, why not a chemical to substitute for the humus and clays which in the best soils are bound together in loose clumps, thus improving soil structure? This was the question which the Monsanto Chemical Company asked its research staff, and which led to the organic compounds now used as synthetic soil conditioners. It is a discovery that may well rank in importance with chemical fertilizers. But it must be viewed in the perspective of what soil conditioners are, how they work, how they are best applied, and exactly what they can and cannot do.

SOIL CONDITIONERS continue to multiply on the market, but nearly all belong to one of three classes of materials: polyacrylates, polyvinylites and, smallest in volume, cellulose derivatives. Other materials being investigated are lignins, silicates and the versatile silicones, all of which improve soil structure but have such drawbacks as high alkalinity, waterproofing effects or difficulty in application. Another conditioner recently introduced from Europe is a ferric ammonium compound, claimed to be especially useful in alkaline clay soils. Low in cost, it will probably be limited in use to some of our western soils.

The two synthetic conditioners most widely available are a modified hydrolized polyacrylonitrile (yellow in powder form) and a vinyl acetate and maleic acid compound (white). These are sold under many trade names in powders, flakes or liquids. Being able to take up water, they are usually mixed with an inactive diluent in strengths of 25 or 40 per cent to reduce deterioration in storage as well as to facilitate application in the proper small amounts. Chemically they are long-chain polymers, with molecular weights in excess of 50,000, related to the synthetic fibers and plas-



CRACKING OF SOIL planted to corn at the Connecticut Station was prevented by soil conditioner. At left is an untreated Cheshire fine sandy loam; at right, the same soil with 1,000 pounds of conditioner per acre.

tics. One of them, in fact, is a basic raw material for Orlon, Dynel and other acrylic fibers. Since these materials have no nutrient value, their first limitation is that they cannot serve as fertilizers.

Functionally the conditioners are water-soluble polyelectrolytes, which simply means that in solution their molecules have many electric charges. These charges attract clay particles in the soil like a magnet, forming many small lumps or aggregates. This, indeed, is the way in which natural soil conditioners, the decomposition products of such organic materials as manure, compost and other plant residues, bind soil particles together. (In addition, of course, many natural conditioners are also fertilizers.) The resulting structure improves soil aeration, moisture balance and the ability of plants to take up foods. But whereas the natural conditioners are readily broken down by bacteria and must often be replenished at the end of a season, the synthetics are much more stable. Once added to the soil they "set" quite rapidly, resist bacterial attack and do not leach out. In tests to date their effects have lasted as long as three years.

This advantage, however, leads to another limitation. Research by W. P. Martin and his associates at the Ohio Agricultural Experiment Station shows that 24 hours after application most of the chemical has acted on the soil. Within 48 to 72 hours chemical action is essentially complete. This lag can cause trouble in greenhouse potting. If the conditioner and soil are mixed and wetted immediately before potting, some of the conditioner will act on the walls of the pot, causing the soil to stick to them. In outdoor applications, if it rains before chemical action takes place, the soil will be dispersed by the beating rain and the chemical will set the soil in this dispersed condition, leaving it poorer than before. Tillage may break up such dispersed or slaked soils, but it is then doubtful whether the conditioner will be of as much use.

MANY DISAPPOINTING results in using soil conditioners probably stem from a misunderstanding of how they act. They *stabilize* the existing soil structure pretty much as they find it. Hard, lumpy, sandy, slaked or "run together" soils cannot be made into soils of good tilth simply by the application of the chemicals. If not worked in, the conditioners act only on the top eighth of an inch or so of soil. Once applied, they do not, like nitrogenous fertilizers, work down in the soil as the season progresses. If a soil is in poor tilth, the conditioners will "fix" this poor tilth. Actually, of course, it is almost impossible to add conditioners to a soil without disturbing it in some way, whether by spading, hoeing, harrowing or disking, which in themselves improve tilth.

Therefore the method of application is extremely important. This past season the Connecticut Agricultural Experiment Station ran some tests to determine the amounts required, the ease of application and the efficiency of various soil conditioners in powder *v.* liquid form. One test, for instance, took place on plots of snap beans in Cheshire fine sandy loam, using varying amounts of five soil conditioners.

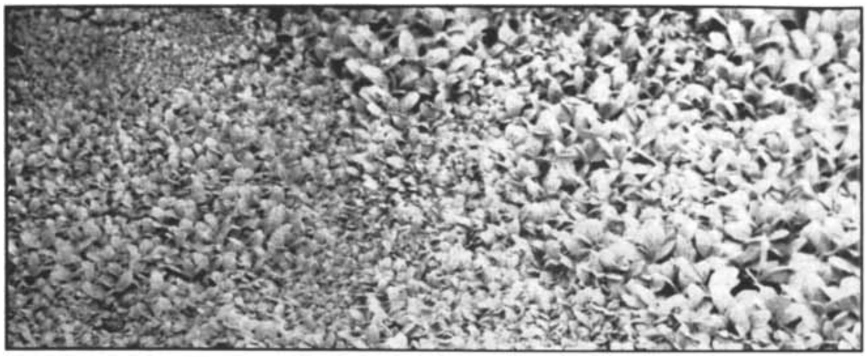
Regardless of form, it was found that if the chemicals were put down in excessive amounts—the largest quantity used here was 3,125 pounds per acre to a three-inch depth—they retarded germination, repressed plant growth and produced lower yields than the untreated plots. Being essentially plastics, the conditioners literally plasticized the soil. Part of the chemical remained on the surface, binding it into a gummy mass which hardened into clods on drying, like a wet plowed field in spring. Better results and yields are obtained by applying much smaller amounts. These range from 500 to 1,000 pounds per acre to a three-inch depth, depending on type of soil. This works out to about one to two pounds per 100 square feet. In this Connecticut test, possibly because the clay content of the soil is low compared with test plots elsewhere, the lower of these amounts worked best.

Sometimes the recommended amounts are too small. When the specifications of some manufacturers were followed, it was found that the application was too thin, covering too large an area with too little chemical. More disconcerting was the failure of some packagers to indicate the percentage of active ingredient, which one needs to know in order to increase or decrease the rate of application as conditions warrant. Some formulators seem deliberately to recommend dilute, unsatisfactory applications to make their product appear more efficient than others.

Generally the powder forms were found to be more practical and easier to apply than the liquids. They can be distributed by the usual fertilizer equipment, though they tend to blow about in windy weather. The liquids are hard to handle: they are slippery, slimy, sticky materials to mix and apply. Some are more soluble than others, but all require large amounts of water. At a rate of 1,000 pounds per acre the least soluble types plug up spray nozzles. For large areas, application in solution is not practical and in the higher concentrations it is nearly impossible.

Liquid conditioners may have a place in such specialized uses as surface treatment of seed rows to prevent crusting and to improve emergence of seedlings. M. T. Vittum and N. Peck of the New

ABSORPTION OF LIGHT was also improved by conditioner. On February 24 the cracked, wet, untreated soil at the left absorbed some 50 fewer foot-candles of light than the dark, crumbly, treated soil at the right.



TOBACCO SEEDLINGS were adversely affected under some conditions. The seedlings at left were treated with conditioner; those at right, with peat.

York State Agricultural Experiment Station at Geneva have developed machinery to do this which sprays a two- to four-inch band of conditioner from a nozzle mounted just behind the planter shoe of a tractor-planter. It can be accurately controlled to spray concentrations varying from .02 to 2 per cent. Knapsack sprayers may also be used. Fast emergence of seeds and improved stands are reported on carrots, beans, peas, beets, cotton, lettuce, radishes and tomatoes. Such use is practical because treatment involves only the top quarter-inch of soil, and liquid sprays can be more uniformly applied here than powders, which are difficult to work into shallow depths. The cost of such narrow-band applications is said to be as low as $5 per acre, which would make them more economic than treatments running into hundreds and thousands of dollars.

THE EFFICIENCY of soil conditioners is harder to assess than the rate and ease of their application. It seems to vary with the soil, crop and amount of conditioner appropriate to each. Some tests have shown increased yields, others decreased. Soil scientists are still experimenting to find the answers. In general, lettuce, snap beans and carrots have shown increases in the Connecticut Station tests. But other crops, such as tobacco seedlings in loamy sand, grew faster and more vigorously in peat-treated rather than synthetically conditioned soil. These tests were on soils different from the one reported earlier and they required higher rates of application for best results.

Lettuce was planted in three Connecticut soils: Carver loamy sand, low in clay (4 per cent); Enfield very fine sandy loam, intermediate and highly erosive; and Buxton clay loam, the state's most clayey soil (30 per cent). Four rates of dry conditioner (200, 1,000, 2,000 and 4,000 pounds per acre) were tried on each soil to a depth of three inches and these were compared with manure applications and with untreated plots. The same amount of commercial fertilizer was added to each. In all cases except two, where plant disease retarded and killed some plants, the chemical conditioners increased yields. Oddly the biggest percentage increase (325 per cent at the 4,000-pound rate) was in the Carver soil, a result which runs counter to prevailing research showing that soils low in clay are least improved by conditioners. Actually, however, on a weight basis the best improvement shown was in the heavy clay of treated Buxton soils, which produced two or three times more lettuce than untreated plots. Manure increased yields, but not as much as the heavier rates of conditioner. In every case increasing amounts of conditioner improved tilth or aggregation.

The Pennsylvania Agricultural Experiment Station has reported increased yields of sweet corn, potatoes, tobacco seedlings and greenhouse roses in structurally poor soils treated with conditioners. The West Virginia Station, testing for tomatoes, beans, cabbage, corn, carrots and cucumbers, found that only bean yields were increased. The Ohio Station obtained no significant increases of potatoes and sugar beets on a Brookston silty clay loam, but on this same soil marketable carrots were increased 21 per cent. Corn and red beets likewise showed marked increases on treated Paulding clay, and field corn on a Miami silt loam subsoil yielded 15 bushels per acre more than on similar untreated soils. The U. S. Salinity Laboratory at Riverside, Calif., testing alkali soils, increased production of sweet corn and found that conditioners greatly improved both saline and non-saline soils under irrigation.

Some tests have been made on conditioners combined with fertilizers in order to apply both in one operation. Ohio Station research indicates that such mixtures are not entirely compatible, tending, particularly in the mixture of fertilizer with polyacrylates, to deter soil aggregation. However, field tests show that this effect is not too significant, since aggregation as well as corn yields were improved in soils so treated. Plant tissue analyses showed that conditioners, in turn, have no effect on the uptake of fertilizer elements.

In general, greater aggregation and better results have been obtained in fine-textured soils rather than coarse. Some research also shows that the chemicals work more effectively on clays that are low in cations, but this is not conclusive. Other factors such as organic matter, salt content and soil reaction probably also enter into it. Treated soils warm up earlier in the spring because their loose structure causes them to dry out faster, become darker and absorb more of the sun's rays. Measurements in Connecticut last February 24 show 50 foot-candles more light being absorbed by conditioner-treated soils. Earlier spring planting is feasible in these more friable soils.

OTHER SPECIAL advantages accrue from soil conditioners. They may prove useful in combatting erosion. Tests by H. L. Borst of the Ohio Station show that, in a three-month period, treated agricultural soils lost five inches less water and 3,400 pounds less soil per acre than untreated soils. They may be particularly useful in holding soil on raw banks and slopes until vegetation develops. The Connecticut State Highway Department finds that conditioners control erosion fairly well in such places and to some extent aid grass growth. Though they are not equal to hay mulch for these purposes, they do not blow away on steep slopes and they allow less mulch to be used. For the straight growing of grass, soil conditioners are not of much use on old lawns but they may improve new lawns, especially if the soil is clayey, and providing they are mixed well into the soil before seeding.

All preliminary data indicates that there is a long road of research ahead before these new chemicals may be said to be practical on a wide scale. Research so far suggests that there is an optimum tilth or aggregation to be achieved for each soil to promote the best plant growth. Chemical conditioners offer a tool for ascertaining this optimum. Not enough research has been done to indicate conclusively that any one chemical is better than the others. Some report that the polyvinylites are more effective. The Connecticut Station tests thus far, on the other hand, gave the edge to the polyacrylates. The chemicals just have not been evaluated sufficiently to rate them as to their relative effectiveness.

THEY can never in their present form fill the role in the soil of organic matter. While organic matter decomposes and loses its aggregating effects quicker than the chemical soil conditioners, it provides food for the microorganisms without which a soil cannot be productive. However, the tests here recited show that all the soil-conditioner chemicals tested do stabilize the soil, provided sufficient amounts are used and are thoroughly worked in. This is a notable and useful achievement capable of further development.

Kodak reports to laboratories on:

a roundup of materials for color photography . . . our recent contribution to the improvement of bread . . . better inspection of electron tube assemblies

Color

A color photograph speaks more eloquently than one in black-and-white. Here, then, is a rundown of the products we offer for imparting this eloquence and the additional informational capacity it adds to photography.

Kodachrome Film everybody knows about. Comes in 16mm and 8mm for movie cameras and 35mm for still cameras. "You press the button, we do the rest"—our old slogan.

Kodacolor Film is for roll film cameras. We process to a negative without additional charge, and then from your Kodak dealer you order prints or enlargements. No projection, no holding up against the light.

Beyond these two that are familiar to millions of amateurs there is *Kodak Ektachrome Film*. It comes in roll and sheet film form, and you (or a local lab) convert it to a transparency. If you'd rather have a print to look *at*, we can make you a *Kodachrome Enlargement*, provided your original is 4″ x 5″ or less. If it's larger, we suggest a print by the *Kodak Dye Transfer Process*. This you can undertake yourself or leave to a commercial laboratory for a creation of smashing visual impact.

(If smashing visual impact is more important to you than strict objectivity, you can work the *Kodak Flexichrome Process*. This starts from any good black-and-white negative and allows you to assign the colors by hand.)

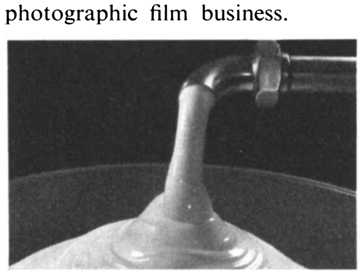
Finally, if you'll be wanting several duplicates at minimum cost, particularly of exhibition size and with the color brilliance so easily achieved in a transparency, make your original negative on *Kodak Ektacolor Film* and your duplicates on *Kodak Ektacolor Print Film*.

Your Kodak dealer sells all these items and also the Kodak Color Handbook *($4) that delves deeply into the details. Write Eastman Kodak Company, Rochester 4, N. Y., if you have any difficulty finding out what you want to know.*

Bread

Ever since the first neolithic housewife baked the first loaf of shortening-bearing bread, substances known as monoglycerides have been formed by the splitting of fats in the baking process. Your own digestive system carries this splitting even farther, since it converts 30 or 40 per cent of any fat you eat into monoglycerides.

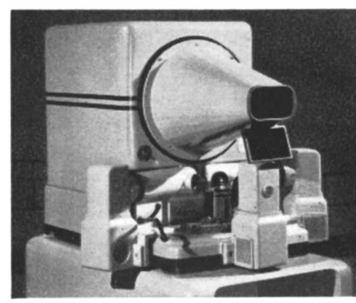
The interesting thing is that if *before* you bake a loaf of bread you add about 1/40 of an ounce of pure monoglycerides to the shortening that goes into it, you significantly improve the tenderness, texture, volume, and crumb structure of the product. Monoglycerides have been manufactured for this purpose for some years, but they have really come into their own only recently when our high vacuum stills began concentrating them from reaction mixtures which previously constituted the only available commercial form of monoglycerides. Now the shortening for several of the best known bread brands in the land is enhanced with our new *Myvatex Food Emulsifier*—a 50-50 mixture of our distilled monoglycerides with prime lard. It would have been hard to predict this as the culmination of certain experiments in producing high vacuum undertaken years ago to solve a minor problem of the photographic film business.



Myvatex Food Emulsifier *looks like this. If you happen to be in the baking business and are looking about for an emulsifier permitted under the new Federal Brand Standard, by all means send for a sample and technical data from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Tube inspection

We want to make sure that everybody interested in the manufacture of electron tubes knows about this machine. Stands to reason it should have a beneficial effect on the probability that a given tube at a given point in a given circuit will function at a given instant as the designer intended it to. Why? Because it permits the gals who inspect tube assemblies to do their inspection in comfort at high magnification. All they have to do is look into the box to see any part of the assembly magnified 20 times. It isn't just a shadow the gal sees either, but the



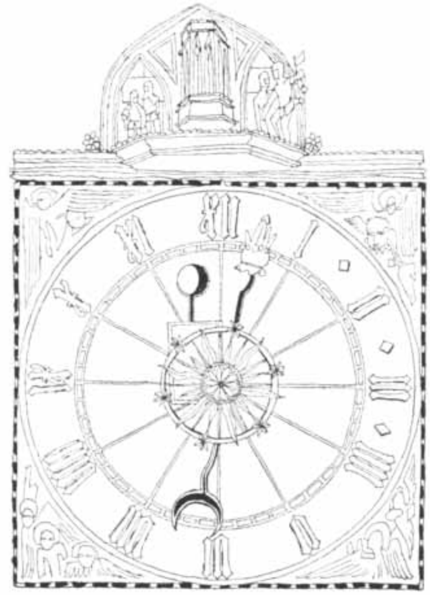
actual surface appearance. As she rotates the tube assembly on the fixture, she can in a matter of a few seconds check grid and cathode spacing and uniformity and the condition of the various welds. Without refocusing, she can come down to 10X and a wider field of view by means of the gearshift-like lever at the left. A handwheel at her right hand brings different planes of the assembly into focus. A picture of ease she sits, and so she should be, if her eyesight and alertness are to play fair with the finished product rejection rate and the firm's quality reputation.

This is a special tube-inspection version of the Kodak Contour Projector. *Quotation and full details from Eastman Kodak Company, Special Products Sales Division, Rochester 4, N. Y.* Kodak Contour Projectors *also do a fine job for those whose minds these days are on transistors instead of subminiature tubes.*

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*

Kodak
TRADE-MARK

SCIENCE AND



Where the Money Goes

MORE than half of all scientific research and development in the U. S. is now sponsored and paid for by the Federal government. The National Science Foundation has analyzed the current Federal research subsidies to non-profit institutions and published a report which was summarized in a recent issue of *Science*.

Of the $1.9 billion disbursed for research and development by the Government (mainly the Defense Department and Atomic Energy Commission) last year, $338 million went to non-profit institutions, mostly large universities. A total of 225 schools did Government work, but five institutions accounted for 55 per cent of it; one institution (not named) got $70 million in Government funds for the year. Half the money went to "research centers," such as the Los Alamos Scientific Laboratory and The Johns Hopkins Applied Physics Laboratory. The NSF pointed out that work done in these centers is almost entirely military in character.

Some $71 million of the $338 million was allotted to basic research. Applied research took $170 million, and development work, $77 million. The physical sciences got the lion's share, 72 per cent, while 19 per cent went to biological science and 3 per cent to social science.

The NSF analysts raised these questions: Should universities do so much military research? Should the Federal funds be spread among more institutions? Is too much being spent in the physical sciences and too little in the biological and social?

Materials Wanted

THE layman, reading almost every day of the invention of another "wonder" fiber or "miracle" metal, may suppose that engineers now have more materials than they know what to do with. The engineers see the matter differently: they find themselves frustrated at every turn by the limitations of their materials. Last month the magazine *Materials & Methods* published a catalogue of the outstanding needs. Some of the items:

Materials which will behave well at extremely high and low temperatures. In jet engines, new power generators and some new high-temperature chemical processes, efficiency demands new materials which will not lose strength or corrode under great heat.

More basic knowledge about the behavior of metals. Metallurgy is still an empirical science which cannot predict such qualities as fatigue resistance or impact strength in a new alloy but can only discover them by testing.

Metals of higher purities than are now commercially available. As an example of what can be accomplished, the British are now producing 99.999 per cent pure aluminum, with which they make electrical capacitors having 10 times the shelf life of previous units.

New alloys to substitute for stainless steels, because of the critically short supply of nickel. Ceramic coatings of low-alloy steels are becoming popular but they are too thick and too brittle for many purposes.

Better conductors and heat-resistant insulators for miniature circuits in electronics.

Improvements in welding and soldering for such metals as aluminum, magnesium and titanium. The wonderfully stable new fluorocarbons also will be more useful to engineers when ways are found to bond them to themselves and to other materials. In general the profusion of new alloys and plastics has run ahead of the ability to join them to one another.

New Chairman for AEC

LEWIS L. STRAUSS, financier, has been chosen by President Eisenhower as chairman of the Atomic Energy Commission to succeed Gordon Dean. He began his career as private secretary to Herbert Hoover when the latter headed the U. S. Food Administration in Europe after the First World War. Strauss later joined the investment banking firm of Kuhn, Loeb & Company and was made a partner in 1928. During World War II he served in the Navy and on the Interdepartmental Committee on Atomic Energy, retiring in 1946 with the rank of rear admiral. He was then appointed by President Truman as one of the original Atomic Energy Commissioners. Often in conflict with the other AEC members, he opposed the sending of radioactive isotopes to Norway and the exchange of atomic information with the British.

Dean, the retiring chairman, is understood to be planning to join the banking firm of Lehman Brothers.

Bronk to Rockefeller Institute

DETLEV W. BRONK has been elected president and chief executive officer of the Rockefeller Institute for Medical Research. He will resign the presidency of The Johns Hopkins University but continue as president of the National Academy of Sciences and of the American Association for the Advancement of Science. He said he had accepted the new position "because it will provide unusual opportunities to devote much of my time to research . . . while developing a unique international institution for the furtherance of science and for the advanced training of scientific investigators."

The Rockefeller Institute will merge its scientific and policy direction under its new president. It plans to "increase its facilities for training talented young investigators and for working more intimately with universities."

AD-X2 Again

THE controversial battery additive AD-X2, which set off an upheaval in the National Bureau of Standards, is to be looked into by a distinguished panel of chemists appointed by Detlev W. Bronk, president of the National Academy of Sciences. Headed by Zay Jeffries, retired vice-president of the General Electric Company, the committee includes E. K. Bolton of E. I. du Pont de Nemours & Co., Inc.; W. G. Cochran of The Johns Hopkins University; J. G. Kirkwood of Yale University; Victor K. LaMer, of Columbia University; L. G. Longsworth of the Rockefeller Institute for Medical Research; Joseph E. Mayer of the University of Chicago and John C. Warner, president of the Carnegie Institute of Technology.

The Senate Small Business Committee, which had said it would not hold hearings on the additive for fear of "beclouding" the issues, nonetheless held some last month. The first witness was Jess M. Ritchie, manufacturer of AD-X2. Ritchie refused to disclose his "secret formula" for the material, which, he said, he had hit upon accidentally after 1,600 trials. He said that besides the chief ingredients, sodium sulfate (Glauber's salt) and magnesium sulfate (Epsom salt), it contained "a couple of other agents" or "trace elements." "I don't know too much about what's in it myself," the inventor remarked.

Allen V. Astin, director of the National Bureau of Standards, testified that the Bureau knows what is in AD-X2 to an accuracy of five parts per million. The magnesium and sodium sulfate in a $36 carton of the product would cost five cents at wholesale, he said. As to the trace elements, they are found in proportions of one hundredth of 1 per cent or less and "usually come in sodium and magnesium sulfate as you buy it." Astin reiterated his confidence in the Bureau's testing procedure and in the worthlessness of AD-X2 for extending the life of batteries under conditions of normal use.

Worcester Tornado

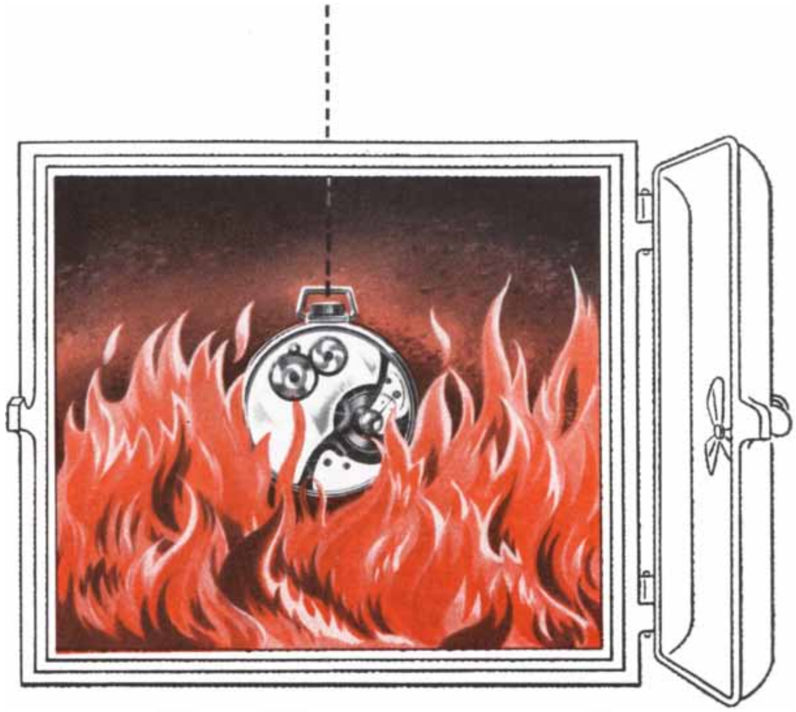
THE New England tornado of June 10 was spotted on a radar screen at the Massachusetts Institute of Technology while it was still in its formative stage some 45 miles outside of Worcester. The M.I.T. observers traced the storm on its destructive course and probably had more detailed data on it than anyone else. The one thing they did not know was that they were watching a tornado.

As Hal Foster noted in his article on "Radar and the Weather" in *Scientific American* last month, radar does not distinguish between thunderstorms and tornadoes. The only clue that the watchers in Cambridge had to the unusual ferocity of the blow was the height of the disturbance as measured on their range-height indicator. Thunderheads have never been seen to rise higher than 45,000 feet, but the top of the storm over Worcester was well above the 50,000-foot limit of the M.I.T. scope. Reports from various sources after the storm gave its approximate height as 14 miles.

The radar instrument, built by the Raytheon Company, is being tested by M.I.T. for the U. S. Army Signal Corps. With further development of the apparatus and the technique of reading its signals, the investigators hope to be able to tell a tornado from a thunderstorm.

Electron Interferometer

THE old disputed question as to whether light had the nature of waves or particles gave rise to two classic tests for identifying waves. One is diffraction: the breaking up of a beam of light by a very narrowly spaced grating so that its waves alternately reinforce and cancel one another and thereby form a diffraction pattern of light and dark bands. The second test is the interferometer: an instrument in which a beam of light is split in two, one of which travels a longer route than the other, so that when the two beams are reunited their waves are out of phase and the



Want to "hang a Watch" in a furnace...and make it run?

Something as technically difficult *is* being done now. For instance, the "buckets" (paddles) and turbine rotor assemblies we make for aircraft jet engines.

These buckets have to stand up against 10,000 revolutions a minute and a flame 1400° hot. Yet, they are made to closer tolerances than many of the parts in your watch and your automobile.

To accomplish this, the Jet Division developed a special technique to finish-forge unusual tougher-than-steel alloys to accurate curves even smoother than glass...with no final machining required! And we helped develop the alloys.

You're probably planning a new product . . . or how to make a present one better, stronger, at lower cost. *Now is the time to call on the Jet Division for recommendations and technical advice.*

We offer you our experience in making more jet-engine "buckets" and turbine rotors than any other producer.

JET DIVISION

Thompson Products, Inc.

DEPARTMENT JS-8 • CLEVELAND 17, OHIO

result is a pattern of interference fringes.

Twenty-five years ago C. J. Davisson and L. H. Germer showed that electrons, like light, have the nature of waves by the first of these tests. They produced a diffraction pattern by passing electrons through a crystal as the grating. Now a group of physicists at the National Bureau of Standards have achieved the second, clinching proof that electrons really are waves: they have constructed an electron interferometer with which a split beam of electrons produces interference fringes just as light does.

The wavelength of electrons is only about one 100,000th that of light waves. Hence the electron interferometer must be a much more refined instrument. The electrons are passed through a succession of three copper crystals only about four 10-millionths of an inch thick. The beam is split and then recombined; when it emerges from the third crystal it contains a pair of differently diffracted rays. The difference in length of path of the two rays can be controlled by moving the first crystal back and forth or by exposing the electrons to electric or magnetic fields as they pass through the crystal array.

The instrument was designed by L. Marton, J. A. Simpson and J. A. Suddeth. They hope that when they have perfected it, it will serve as an extremely accurate measure of length, electric and magnetic field gradients and electron wavelengths.

The Electricity of Viruses

How viruses attach themselves to the wall of a bacterium before they invade it is a question that greatly interests virologists. Theodore Puck and Bernard Sagik, biophysicists at the University of Colorado, have performed an ingenious experiment which supports the idea that it is a simple electrical process.

The targets for the viruses in their experiment were not living bacteria but ion exchange resins. It has been known that bacterial viruses attach themselves to cells only when positive ions are present. This suggested that both viruses and cells normally are negatively charged, and that the positive ions make it possible for them to get together by neutralizing the repulsive force of the like charges. The Colorado experimenters found that viruses readily attached themselves to positive resins, and would not stick to negative resins unless positive ions were added. They proved that cells, like viruses, also are negative: they attach to positive but not to negative exchangers.

When certain bacterial viruses attach to a resin, they begin at once to separate into a protein and a nucleic acid fraction. This parallels exactly their behavior in cells, where the nucleic acid is injected into the cell and the protein "coat" remains outside. Puck and Sagik, writing

18th dynasty Egyptian glass amphoriskos, made in 1500 B.C., looks as new as the day it came into being.

How to give your product

A "new look" that lasts

When archeologists opened the tombs of the ancient Pharaohs, they were able to visualize the world of 1500 B.C.

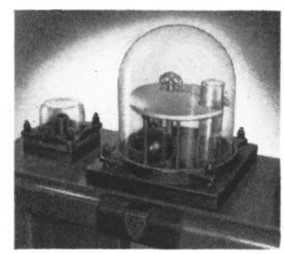
Vividly, too—for the glass cosmetic jars, vases, bottles and beads they found looked as new as the day they were made.

The fact that glass will not rust, fade, deform or discolor can be important to you, too. It means that you can use glass to help keep your product looking new and help assure its lasting quality and value.

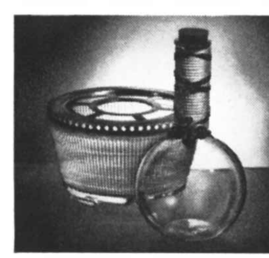
But glass does more. It modernizes your product, too. Much of the fresh, new look of today's architecture, automobiles and appliances comes from extensive use of glass.

If you have a product idea, no matter how big or small, it will pay you to get the facts on this versatile material. Its "new look," its transparency, corrosion resistance, light transmission, or electrical properties may make glass just the material you need. You'll find a host of ideas in the 12-page illustrated booklet, "Glass, Its Increasing Use In Product Design."

Attractive, three-dimensional dials and nameplates . . . tubular glass handles . . . glistening PYREX brand oven windows . . . modernize and keep ranges looking new for years.



As components of machines, glass can give you corrosion resistance, visibility or many other properties at economical cost. It may be blown, pressed or drawn to your requirements.



Sparkling glass by Corning adds sales appeal to houseware articles. Women like its ease of cleaning—and they know and trust the PYREX trade-mark.

PYREX

CORNING GLASS WORKS

CORNING, NEW YORK

Corning means research in Glass

CORNING GLASS WORKS, 78 Crystal Street, Corning, N. Y.

Please send me your 12-page illustrated booklet, "Glass, Its Increasing Importance In Product Design."

Name ______________________

Company ______________________

Address ______________________

City ______________ Zone ______ State ______

PYREX is a registered trade-mark in the U. S. of Corning Glass Works.

in *The Journal of Experimental Medicine,* suggest that the splitting is the result of simple electrostatic forces.

Chemical Genetics

If you ground up two animals of the same species and subjected the remains to chemical analysis, could you tell them apart? The Italian geneticist Adriano A. Buzzati-Traverso has been investigating this question—a question of the connection between chemistry and genetics. He squashes fruit flies on filter paper and analyzes their composition by paper chromatography. His tentative conclusion is that genetically identical flies are also chemically identical, but their chemical constitution is recognizably different if they differ by so much as a single gene.

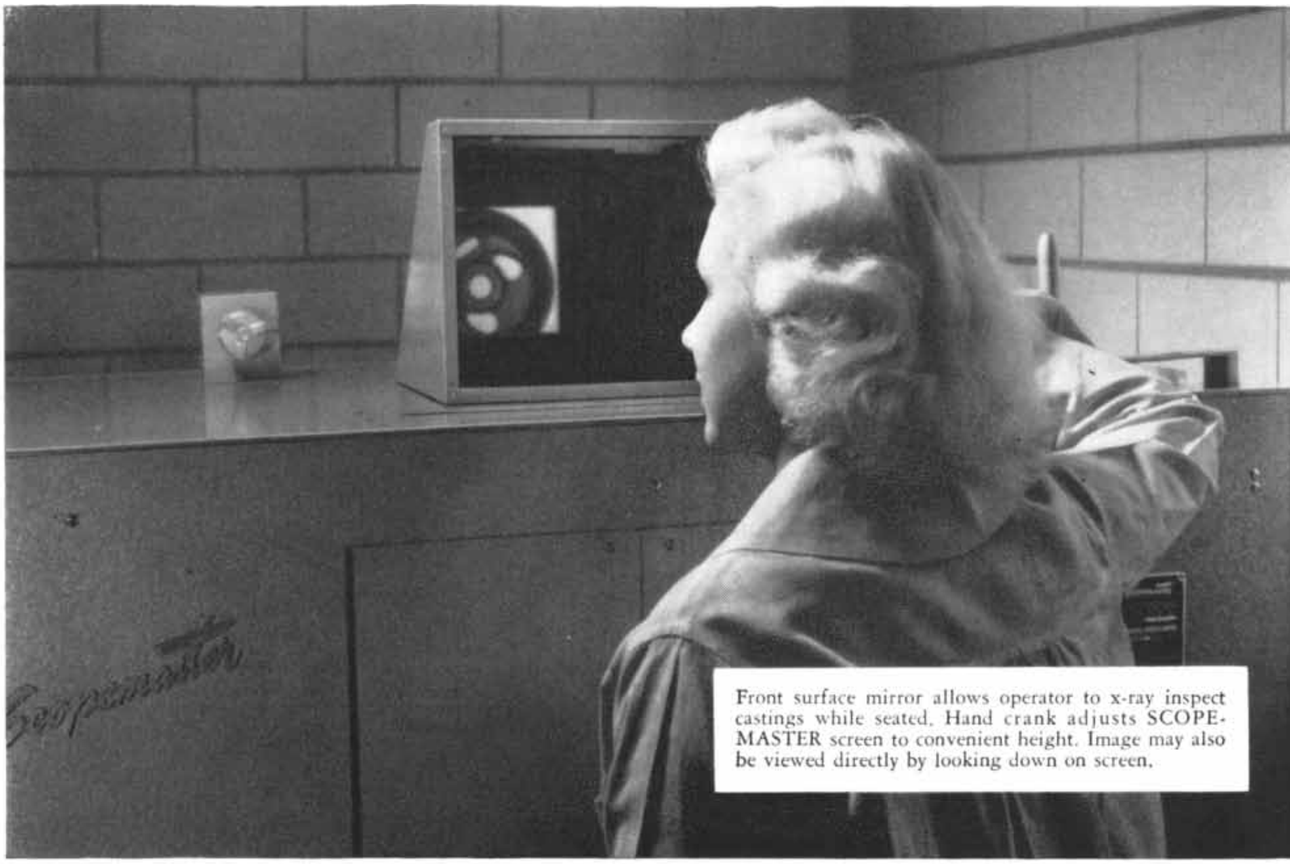
Buzzati-Traverso performed his experiments at the University of California, where he is a visiting professor. He reports in *Proceedings of the National Academy of Sciences* that members of a genetically pure strain of *Drosophila melanogaster* yielded a remarkably uniform array of spots in a chromatograph, regardless of differences in the insects' diet. Males, however, differ in composition from females, and females change somewhat with age.

Buzzati-Traverso cut off the flies' heads and worked only with differences in form, such as wing shape or size. Flies with different wing shapes gave different chromatographic patterns. The chemical analysis even disclosed recessive genes: a fly with one dominant and one recessive gene for a certain character showed a different pattern of spots from an identical-appearing fly with two dominant genes. Thus chromatography can uncover hidden genetic differences.

Buzzati-Traverso has not yet tried to identify the compounds that make up the spots. He hopes that biochemists will soon tackle this job. He has, however, taken one preliminary step toward finding out what type of compounds he is dealing with. He decomposed fly tissue in water before analyzing it and found that the differences in the patterns disappeared. This he interprets to mean that different individuals build the complex compounds of their bodies out of the same starting materials, but that the way in which they put the compounds together is governed by the genes.

Tagged Cortisone

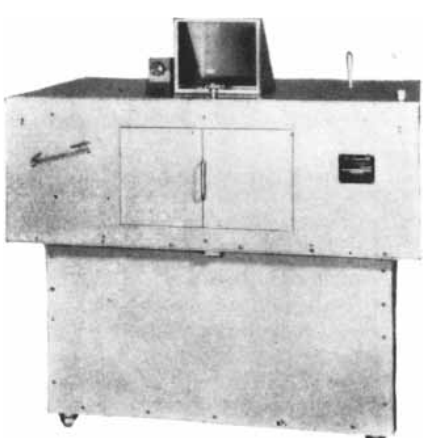
Scientists studying the biochemical action of cortisone now have a powerful new research tool. For the first time the hormone has been prepared in radioactive form, making it possible to trace its course through the body. The molecule has been labeled with an atom of carbon 14 in place of normal carbon at the "number 4" position. The synthesis was a cooperative accomplishment by



Front surface mirror allows operator to x-ray inspect castings while seated. Hand crank adjusts SCOPEMASTER screen to convenient height. Image may also be viewed directly by looking down on screen.

Reduce costs! Use GE Scopemaster for 100% visual x-ray inspection

Provides more than ample sensitivity in high-speed examination of light-metal castings, molded plastics, intricate assemblies, etc.



SCOPEMASTER's screen-object distance can be varied to magnify image, and a single control moves the sample longitudinally or transversely. Unit is fully protected for stray radiation.

100% fluoroscopic x-ray inspection can prove a valuable tool in your plant. Pioneered for the aircraft industry, the GE SCOPEMASTER saves producers and users of light metal alloy castings time and money in catching defective parts. The accuracy of its inspection is attested by its use on airframe castings where failure could cause a serious accident. It is vastly superior to sample inspection by other means, and costs are far lower than with any other method of comparable thoroughness.

Other jobs on which x-ray fluoroscopy has been successful include checking small electrical components for incomplete or improper assembly. In the molded plastics industry, it has helped establish manufacturing technics. And in the production of small ordnance items, it replaced destructive spot tests — salvaged 90 to 98% of lots that previously would have been rejected in their entirety.

The SCOPEMASTER is another example of how General Electric is harnessing x-ray to the needs of industry. If there's a testing or inspection trouble spot in your plant, x-ray may be the answer. Ask your GE x-ray representative for an evaluation, or write your requirements to X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Rm. TT-8.

GENERAL ELECTRIC

the U.S. Public Health Service, the Sloan-Kettering Institute for Cancer Research, the Worcester Foundation for Experimental Biology, the Upjohn Company, and Charles E. Frosst and Company of Canada.

New Work in Birth Control

RESEARCH on contraception by physiological rather than mechanical methods is making considerable progress, according to a recent report in *Science* by Paul Henshaw of the Planned Parenthood Federation of America. Some of the new approaches are far enough advanced to justify pilot studies by volunteer couples, he says.

The studies have two objectives: (1) to improve the fertility of childless couples, and (2) to develop a reliable and convenient form of contraception by pill, injection, timing or a combination of these methods.

Seven different approaches are being investigated. One is research on hormones and enzymes that affect fertility. A second is a study of spermatoxins and related substances. A third is an investigation of bacteria, yeasts and other organisms that cause temporary infertility. A fourth is investigation of the fluid media that carry the sperm and eggs. A fifth is the effects on fertility of vitamins, metallic ions and other elements of food. A sixth is study of the psychic and sensory stimuli that affect the endocrine system. A seventh is research on the rhythm of ovulation.

One promising method seems to be the use of an inhibitor against the enzyme hyaluronidase, which helps the sperm enter the egg. The inhibitor, phosphorylated hesperidin, has been given in tablet form to 300 couples. It was reported that no conception occurred while they were taking the prescribed treatment and that 220 of the couples had normal offspring after stopping it. Laboratory studies of the desert tea herb *Lithospermum ruderale*, used by American Indians of the Southwest, also have been encouraging. The plant contains a factor which acts on the pituitary and prevents the release of a hormone controlling the production of germ cells.

The Girl Next Door

DO modern city dwellers marry neighborhood sweethearts? J. R. Marches of the University of Maryland and Gus Turbeville of the University of Minnesota recently examined the marriage statistics in the city of Duluth and reported their findings in the *American Journal of Sociology*.

Analyzing 300 marriage licenses, they found that: 5.67 per cent of the couples lived at the same address; 20 per cent lived within five blocks of each other; 42 per cent lived within 20 blocks.

Get *All* the New TV Channels With a Mallory Converter

No tampering with your set
No sacrifice of VHF channels

To receive *all* channels, both old and new, in any area . . . the simple, practical means of converting any TV set is with a Mallory UHF Converter.

Unlike the "tuning strip" method of conversion—which requires a service installation for each new station—the Mallory Converter covers any and all channels. What's more, it is easily connected—in just a few minutes.

The Mallory Converter has proven itself, wherever it has been installed, since the first UHF station went on the air. It is but one of the many contributions Mallory has made not only to television but to the fast-growing electronics industry. Mallory Batteries power tiny transistor hearing aids . . . electronic instruments . . . walkie-talkies. Mallory Capacitors, Vibrators, Switches and Resistors are vital components in communications equipment.

In the metal working field, Mallory Resistance Welding Electrodes have brought new economy to the fabrication of automobiles, steel pipe, pots and pans. Special Mallory Alloys answer the need for better materials in many different forms . . . from electrical contacts to gyroscope rotors.

If you have a problem within the scope of our activities, perhaps we can help you find ways through Mallory components to reduce costs . . . improve performance . . . better your products. Write us today.

WE'RE CASTING IN SECTIONS

Why do a race-driver's eyes light up when he talks about aluminum engine blocks and heads? "Sweet, cool running . . . improve high-compression performance . . . the engine weighs 150 pounds less."

For these reasons, auto makers have wanted to use aluminum blocks and heads in passenger cars. But costs have been too high. So, it was big news to the industry when we said, "We have a new way to make aluminum blocks. The cost—slightly higher than iron ones!"

Engineers in our Development Division knew that the water passages in engine heads make casting expensive. Delicate, intricate cores are used to form these holes (Fig. 1). They often break. Frequently, they shift as the molten metal is poured around them. This ruins the casting.

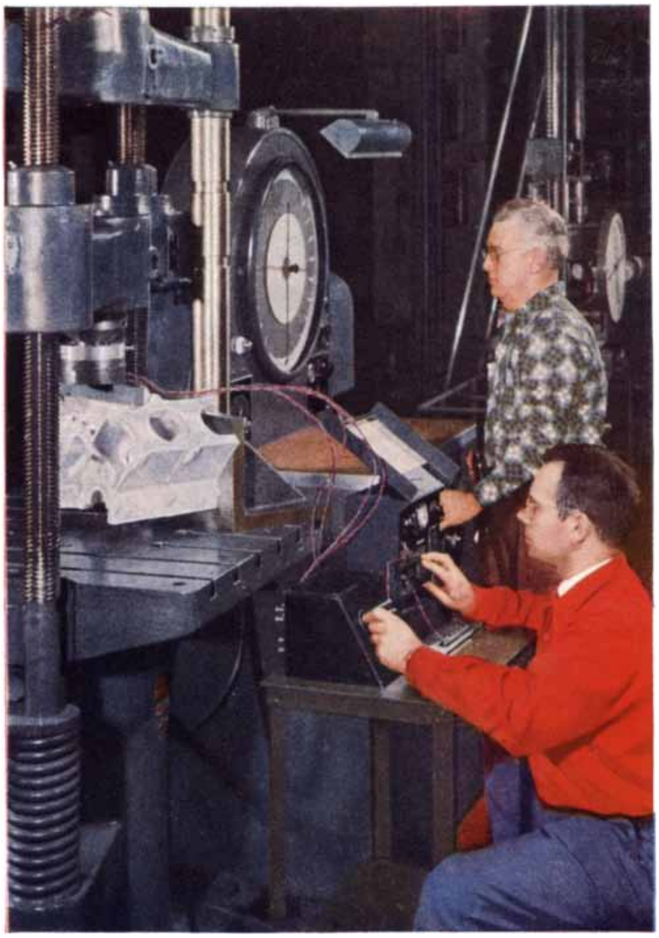
Our idea was to design an engine in sections . . . like a sliced loaf of bread (Fig. 2). These small castings would be easier and less expensive to make. Then we would stack them up with

Alcoa Aluminum

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

ENGINE HEADS IN CLEVELAND



gaskets of brazing metal between.

A pass through a brazing furnace and presto, the casting would fuse into a complete head. No cores. No rejects. No clogged passages.

Putting the idea to work wasn't that easy. Alloy selection took time. Brazing temperatures were tricky. Even when we got sound castings, our job wasn't finished.

Perhaps the castings were too strong in some places, too weak in others. To find out, we coated them with brittle lacquer and assembled a complete engine (Fig. 3). We loaded it until the lacquer cracked and showed where stresses lurked. Castings were tested on tension-compression machines, using electric strain-gages to duplicate the pressures of actual operation (Fig. 4). Shaving a little metal here—adding a little there—we made the castings still stronger, more efficient.

The engines are now on test. Reports are downright spectacular.

MORAL: This problem has something in common with your product or process . . . the *way* it was solved. Did you notice that it was divided into four parts? First, the *Alcoa engineer* with automotive experience knew the problems of the industry. Then basic *Alcoa research* suggested alloys and procedure. *Alcoa testing equipment* proved the theories of basic research—made further refinements. Lastly, *Alcoa's process development labs* suggested ways to mass produce it.

Alcoa engineering, research, test and development can put your product or process head and shoulders above competition. Now is the time to call your local Alcoa sales office, or write: ALUMINUM COMPANY OF AMERICA, 2182-H Alcoa Building, Pittsburgh 19, Pennsylvania.

P. S. Ask for a copy of "Road Map to a Better Product." It shows in detail the facilities at your disposal.

The idea that was piped all through industry!

Lengths of Republic Electric Weld Casing are rapidly joined together and lowered hundreds or thousands of feet into an oil or gas well to line it with tough steel—to protect its walls against the tremendous pressures that otherwise might cause collapse of the hole.

TWENTY YEARS AGO, Republic engineers and metallurgists gave the oil and gas industries a *new kind* of steel tubular product. It was electric weld pipe—casing, tubing and line pipe—with advantages of uniformity never before attained in mass production.

This new pipe was made by a process of electric resistance welding *developed* by Republic Steel. It was uniformly round, uniform in wall thickness and uniformly strong throughout every inch. These qualities have improved pipe performance far beyond the oil industry, in fact—throughout all industry. Millions of feet of casing and tubing and thousands of miles of line pipe in service have proved the dependability of the process.

Since its beginning, Republic Steel has kept alert to the changing needs of steel users. It has pioneered, not only in steelmaking, but in the fabrication of steels. Out of this has come Republic's present-day 3-FOLD SERVICE FOR STEEL USERS:

1. The production of the best possible steels and steel products in ever-increasing variety.
2. The recommendation of specific steels and steel products based upon thorough study of the need.
3. The assistance of trained engineers and metallurgists whose job it is to see that you get the results you want from Republic Steel Products.

This does not mean we make any pretense at knowing all your answers. But we do know steel—and we fabricate steel into many products. From this dual experience, we have been able to assist many customers to more profitable results. Perhaps we can help you, also.

REPUBLIC STEEL

GENERAL OFFICES • CLEVELAND 1, OHIO

REPUBLIC STEEL

WORLD'S WIDEST RANGE OF STEELS AND STEEL PRODUCTS

Cell Division

Called mitosis, it is the process by which units of living matter duplicate themselves. Its delicate apparatus is now investigated by the remarkable feat of isolating it from the rest of the cell

by Daniel Mazia

IT SEEMS to be a necessity of the biological world—though exceptions exist—that any living mass of more than microscopic size be composed of cells. The capacity of cells to grow, in the sense of adding to their content of chemical substances that do not exist in the inorganic world, is limited. In general—though again there are exceptions—a cell can only double its mass. Thus any significant growth requires the production of new cells, and this involves the process of cell division. We can add continuously to the amount of living matter only by multiplication, and the multiplication takes place by division.

All this is commonplace today, but it seemed so unreasonable a century ago that it was not even accepted by Theodor Schwann and Matthias Jakob Schleiden, the two German biologists who are generally credited with the founding of the cell theory. Cell division had actually been seen and described many times by skillful microscopists. But an observation is seldom acceptable if its consequences seem unreasonable, and the dictum that every cell must arise by the division of a pre-existing cell did seem unreasonable. Schwann and Schleiden were much more reasonable when they proposed that new cells arise by a process analogous to the formation of crystals in a solution. They were merely wrong.

We now understand the reasons why cells must always arise from cells and by a process that seems excessively complicated. It is because the history and capabilities of a cell are determined by the threadlike chromosomes in its nucleus, and the various forms of life can maintain their historical continuity only if the chromosome patterns are transmitted from cell to cell. If the biological world is essentially conservative in its tendencies, it is because the chromosomes are so stable. The elaborate process of cell division that we call mitosis perpetuates them in all their stability.

Of all the activities that we can see in the cell, mitosis is the most complicated, and its machinery is about the most elaborate that a cell can manufacture. Hereinafter we shall refer to this machinery as the mitotic apparatus. Anyone who has ever attempted to make a satisfactory diagram of the process, or teach it to a class of normally unresponsive freshmen, will grant that its complexity is real. A machine of beautiful geometric perfection is temporarily created out of the seeming formlessness of the cell and operates with exquisite coordination.

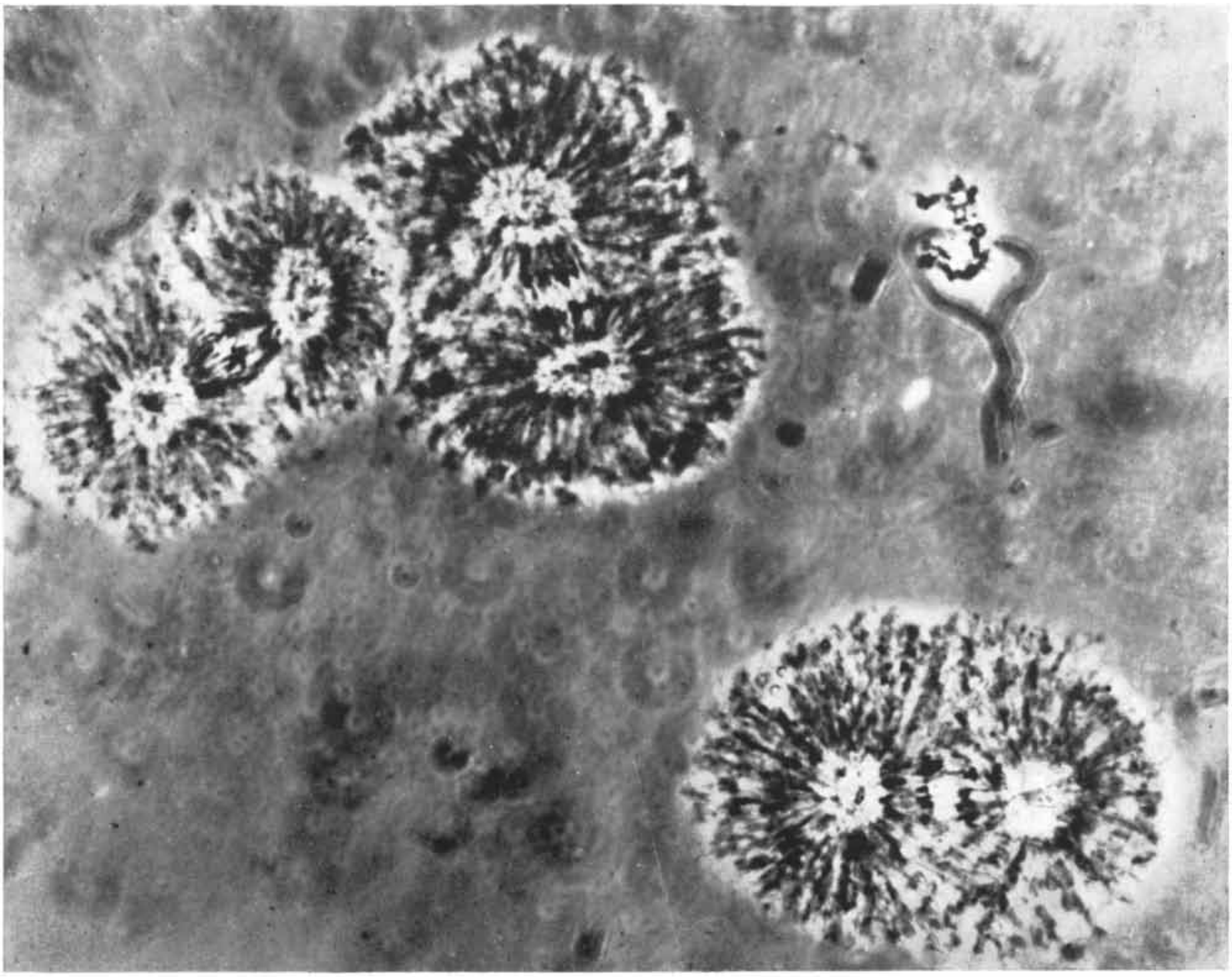
The Strategy of Mitosis

Let us consider what happens. We begin with the so-called "resting cell," a cell that is busy enough in other ways but has not yet gone through the travail of giving birth to two daughter cells. The chromosomes are contained in the nucleus and look like nothing at all. We know they are there from chemical and genetic data, but the lovely compact threads that we always visualize when we think of chromosomes usually are visible only during mitosis. In the resting cell there is no evidence of the mitotic apparatus, except that in favorable cases a small body appearing either single or double sometimes is detected near the surface of the nucleus. This is what we call the centriole or centrosphere.

What happens when this resting cell begins to divide may be regarded in two phases. First, the mitotic apparatus is formed. The centrioles divide, separate, and as they separate throw out what seem like radiating systems of fibers, appropriately called asters. These appear to find their way to opposite poles of the cell and to be connected by fibers running from one centriole to the other. This group of fibers is called the spindle. Meanwhile the previously invisible chromosomes are becoming visible as slender threads while the nucleus fades away. Then the threads become more compact. In a most remarkable way the chromosomes find their way to the equator of the spindle; that is, a plane exactly midway between the two centrioles and at right angles to a line connecting them. Here we have the culmination of this remarkable set of preliminary maneuvers. Now the mitotic apparatus is fully formed. At some point along the way it becomes possible to observe that each of the chromosomes has doubled. More precise evidence suggests that the real duplication process has occurred much earlier than the visible appearance of twin threads. In fact, it is now thought that the duplication takes place during the resting stage, which would mean that mitosis was a process for distributing the products of a reproductive step that had already been completed.

The second and perhaps more dynamic stage of mitosis is the movement of one complete set of chromosomes to each pole, and, coordinated with this, the division of the whole cell so that each set of daughter chromosomes goes to one of the daughter cells. It is here that we see the mitotic apparatus in action, moving the chromosomes apart, often pushing the cell out of shape, and somehow controlling the location of the wall that will finally separate the daughter cells. Finally we have two daughter cells, each with half of the mother's substance and each with a complete set of chromosomes seemingly identical with those of the mother. These daughters go back into a resting stage by a process that roughly resembles a movie of the first steps of mitosis run backward. The chromosomes disappear from view and a nucleus is formed.

The process has many variations. In plant cells we ordinarily do not see asters. Animal cells divide by what looks like a process of pinching in two; plant cells build a new wall. In both cases the barrier between the two daughter cells is formed exactly where the equator of the spindle was located. Some single-celled animals have bizarre systems of mitosis. In the bacteria the very existence of the mitotic system of cell division was doubted until recently. Edward DeLamater and Stuart Mudd of the University of Pennsylvania have reported that they



ISOLATED MITOTIC APPARATUS of the sea-urchin egg is revealed in a photomicrograph made by John D. Roslansky of the University of California. There are three specimens: two at the upper left and one at the lower right. The two round light areas in each apparatus are the centers; surrounding them are the asters.

can see in dividing bacteria what look like typical mitotic figures. Some students of microorganisms are not convinced; the difficulty rests on the sheer smallness of the cells and of the alleged mitotic figures. It is nonetheless significant that the trend is toward a unified picture of how cells divide.

The discovery of mitosis in the years around 1880 is a remarkable chapter in the history of biology, if only for its lack of drama. There was no one discoverer, although Walther Flemming of Germany may be credited with unifying the observations that he and others had made. There were no brilliant laboratory accidents here, but only powers of observation and imagination which awe the biologist of today. These men knew nothing about the significance of chromosomes; they had to observe the individual stages out of proper sequence and most often in dead cells. One wonders whether there are microscopists today who with this kind of information could piece together the logical sequence of mitosis in space and time.

Mitosis may be a rapid affair. It is not unusual for cells to go through the whole process in 30 minutes, and it is unusual for it to take more than a few hours. The preparatory phases take the longest; once the mitotic apparatus is fully formed, the actual process of division may take only a matter of minutes, almost as though the cells had snapped apart once the apparatus was there.

So much happens in this process that it would scarcely make sense to ask the question: "What is the mechanism of mitosis?" Knowing as much as we do of what takes place at the level of the microscope, and as little as we do of what happens below the level of the microscope, we will be wise to restrict our questions to the material nature of the mitotic apparatus, to the way in which it is formed and to the forces involved in the crucial movements of cell division.

Movement and Mechanism

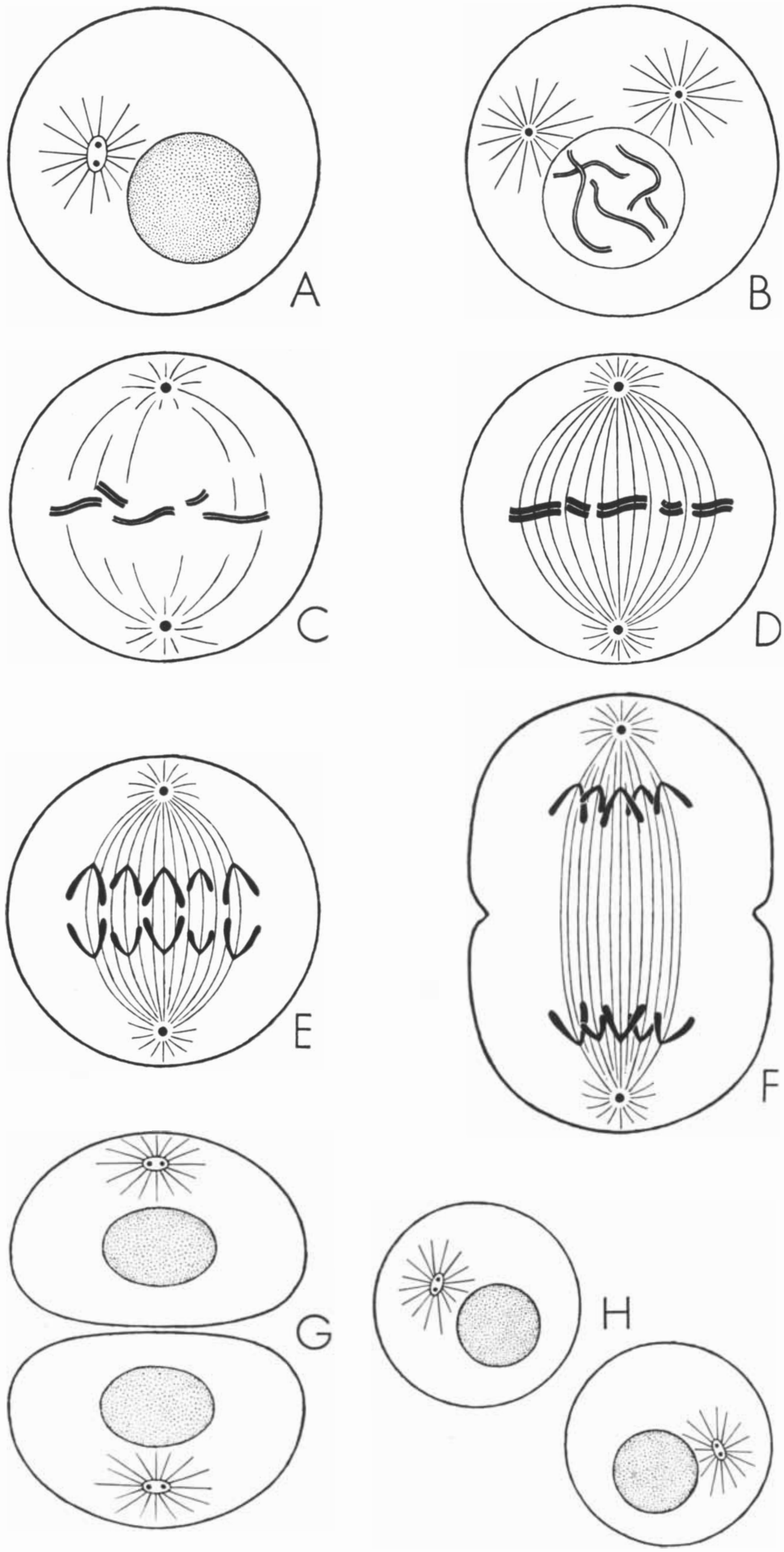
The symmetry of the mitotic apparatus inspired a number of interesting physical models based on the operation of electrical and magnetic forces. In most cases it would appear that the chromosomes are being pulled through a liquid by special fibers which run from the poles and are attached to a definite region of each chromosome. This region has been called by various workers the centromere, kinetochore or simply "the spindle fiber attachment." The convincing reasons for this "contractile fiber" hypothesis are two. First, each chromosome generally takes the form of the letter V or J or a rod, with the point facing the pole. This is what we would expect if a limp thread were dragged through a liquid. Second, the point of attachment is always the same for a given chromosome. If the point is eliminated when the chromosome is broken by X-rays or another agency, the chromosome does not move at all. There are, however, disturbing exceptions. Some years ago Charles W. Metz, now at the University of Pennsylvania, described a case in the fly *Sciara* in which the chromosomes pointed the wrong way! This has never been explained in terms of the contractile fiber hypothesis.

Various mechanisms have been proposed to explain the division of the cell mass, especially in those cases where a pinching, or "furrow" is involved. One hypothesis involves the so-called "contractile ring." This hypothesis suggests that, at the time of division, a layer around the equator of the mitotic apparatus actually contracts and pinches the cell in two. It is based in part on some interesting experiments by Douglas Marsland of New York University. A contractile ring would have to be a rigid layer of colloid in the gel state. Such a gel, Marsland predicted, would become soft and liquid under high pressure, on the order of 500 atmospheres. Beneath the surface of cells there is a thin layer of gel called the cortex, and Marsland was able to show that the application of high pressure did make this layer more liquid. Experiments on dividing cells revealed that pressures which liquefied the cortex also prevented the cell from dividing. Whether or not the contractile ring hypothesis proves to be true, these experiments demonstrate that a semirigid cortex plays an essential part in cell division.

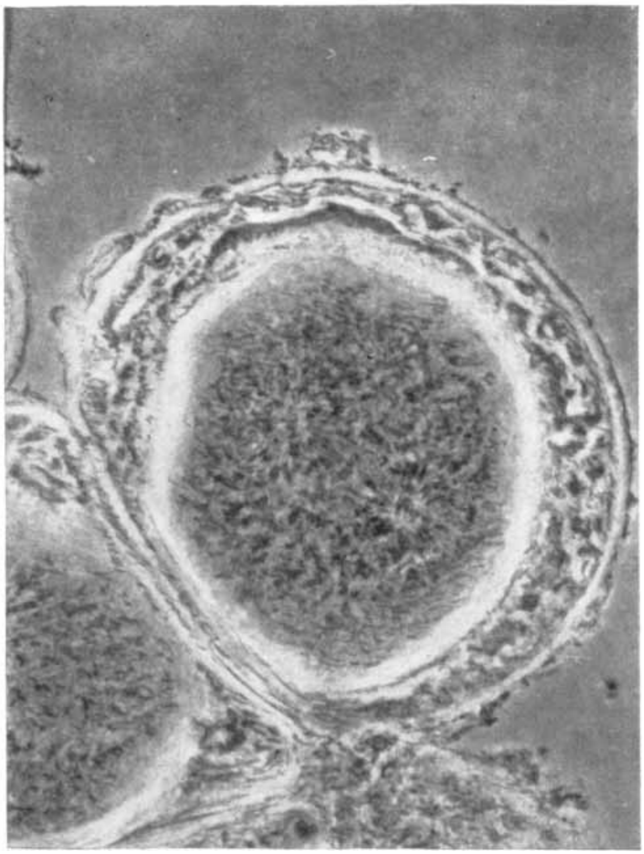
A more detailed hypothesis on the mechanics of cell division in cases where asters are present and a furrow is formed has been elaborated by Katsuma Dan of Tokyo Metropolitan University in Japan. Some years ago Dan devised a very simple means of following the movements of the cell surface during division. He applied tiny particles of clay to the surface of cells, and some of these adhered. Then, with great patience, he measured the distance between two particles during cell division. His results were most unexpected. At the region of the furrow, where the surface would be expected to stretch, the distance between the particles actually decreased.

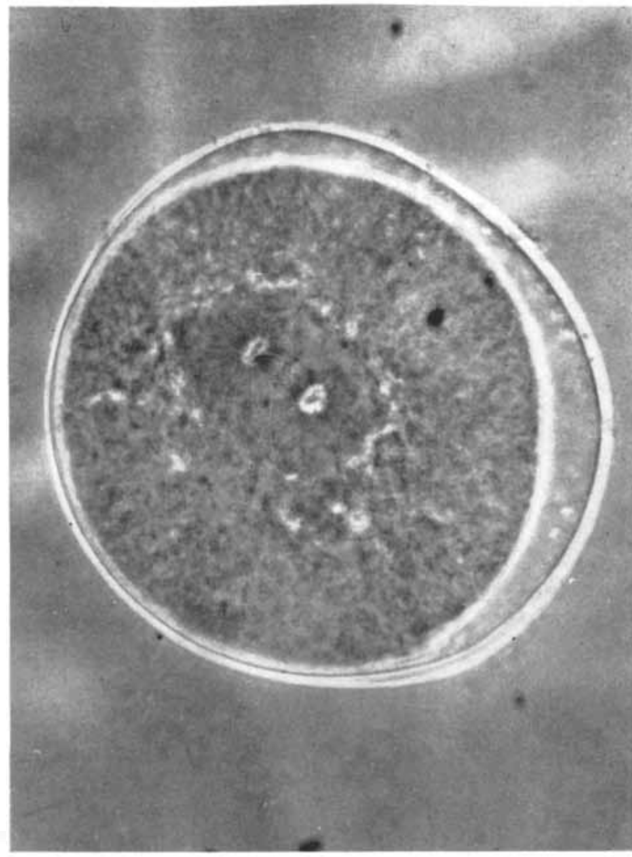
As the furrow forms, the cell elongates. The spindle, too, is longer from pole to pole. Dan pictures the spindle as a stiff body that pushes the centers apart. At this point the rays of the asters, growing in all directions, appear to have joined the surface of the cell. The rays of the opposite asters cross at the equator. Dan's ingenious proposal is that, when the asters are pushed apart, the tips of the rays are brought closer together in the region where they cross. If, as he imagines, the tips are attached to the cell surface, their movement will collapse it at a point midway between the centers.

Ordinarily the asters are of equal size, and the center of the spindle is the equator of the cell; thus we expect the cell to divide into equal halves. But if one aster is much larger than the other the midpoint of the spindle will be displaced from the equator toward the smaller aster. In this case Dan predicts an unequal division, with the smaller daughter cell containing the smaller aster. This is



PROGRESS OF MITOSIS is outlined in schematic form. As the cell prepares to divide, chromosomes appear in its nucleus. The mitotic apparatus then forms and draws the divided chromosomes apart. The cell finally pinches in two and gives rise to two new cells, drawn in smaller scale.





ISOLATION of the mitotic apparatus is depicted in the four photomicrographs on these two pages. The first photograph shows a dividing sea-urchin egg in cold alcohol, which is used in the initial stage of isolation. The second photograph shows an egg that has been treated with the detergent digitonin; the cell is

confirmed by observation, and is a strong point in favor of his view.

In Dan's theory the work of cell division is accomplished by the push of the lengthening spindle at the time the cell is seen to divide. Last year two biologists at Cambridge University in England, M. M. Swann and J. M. Mitchison, proposed a mechanism which is a compromise between the contracting-ring theory, in which the mitotic apparatus has no role in the division of the cell mass, and Dan's theory, in which the role of the mitotic apparatus is paramount. According to Swann and Mitchison, the furrow is due to an active stretching of the cell surface by the unfolding of molecules that were previously rolled up and did not occupy as great an area. They consider that the mitotic apparatus may determine the position of the furrow and guide it inward as in Dan's model.

The Nature of the Apparatus

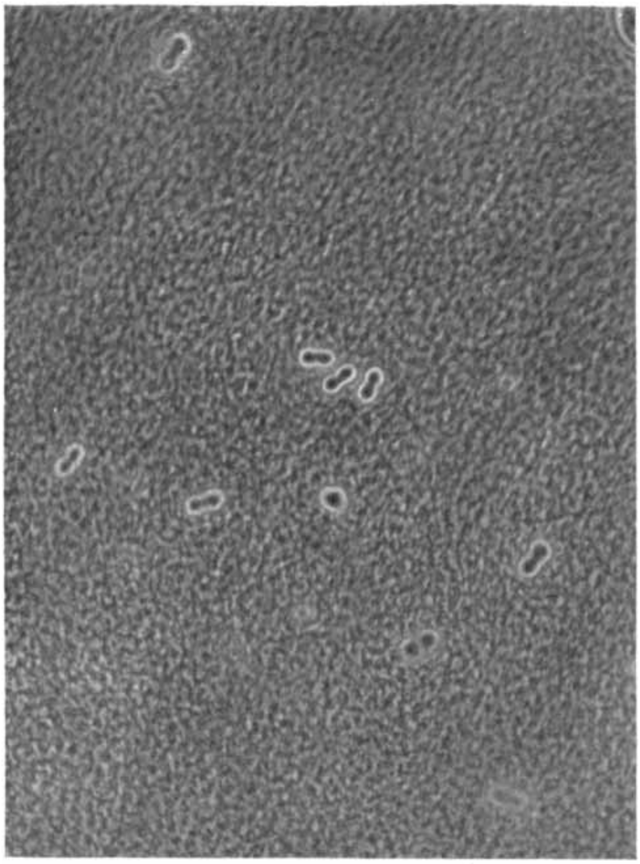
But neither through microscopic observation nor ingenious physical models can we achieve a feeling of intimate contact with the realities of cell division. The formulation has lacked substance, which in the biology of 1953 means a treatment in terms of identifiable molecules undergoing reactions translatable into the language of chemistry. What is the stuff of the mitotic apparatus and how are its constituents assembled into this beautiful little gadget? Answers to these questions solve no problems of mitosis, but put flesh between the bones of physical speculation and the clothing of microscopic appearance.

In the past year an opening toward the answers to these questions has been found in experiments conducted at the University of California by Dan and the author. The direct way to obtain the answers is clear enough. One should isolate the mitotic apparatus from dividing cells in pure form and in quantity and study its chemistry and its structure. Other bodies in the cell—nuclei, chromosomes, mitochondria—have been isolated and studied with great profit. But the problem here is a little more difficult. The mitotic apparatus is a temporary structure. It appears in the cell only when it is dividing, and changes continuously in the course of division. It is not freely suspended but is embedded in the substance of the cell. What is worse, it is extremely unstable in its living environment. If a dividing cell is damaged mechanically or treated with one of a number of chemicals, the mitotic apparatus simply disappears.

In order to experiment on the isolation of the mitotic apparatus in quantity, it was obviously necessary to work with a large population of cells, all of which were dividing synchronously. Dan and I were fortunate to have on hand, in the tide pools of the Pacific shore, the material of choice. For many years students of cell division have worked with the eggs of sea urchins, which may be induced to divide by fertilizing them with sperm cells. If a very large number of eggs are inseminated at a given time, all will divide synchronously. The whole mitotic process from the time of fertilization may take an hour or so, but so uniform is the cell population that 90 per cent of the cells will be seen to be forming division furrows within a period of 5 to 10 minutes. Thus we could experiment with masses of cells which represented for the most part any desired stage of the mitotic process.

Because the mitotic apparatus is so unstable it was necessary to find a means of stopping the process with the least damage and the least chemical change. After many experiments, very cold (minus 10 degrees centigrade) dilute ethyl alcohol proved to be suitable.

Attempts to isolate the mitotic apparatus by the conventional method of mechanical disintegration of the cells were so discouraging that we turned to a fresh, though not necessarily original, approach. If the mitotic apparatus were chemically different from other things in



not broken but its cytoplasm has begun to dissolve. The third photograph shows the apparatus of several eggs after they have been broken with digitonin; the apparatus is isolated but it is still surrounded with the dispersed cytoplasm. The fourth photograph shows the isolated apparatus at a magnification of 400 diameters.

the cell, could we not find some means of "dissolving" the cell in such a way as to liberate the apparatus?

We knew of agents that dissolve (solubilize is the more precise word) cell structures without excessive damage to the molecules of which they are composed. Foremost among them are the detergents, substances with a soaplike action. At first we worked with synthetic detergents of the varieties commonly encountered in the dishpan and the laundry tub. We found that Duponol (sodium lauryl sulfate) was effective in solubilizing the cytoplasm of the dividing sea urchin eggs, but that it dissolved the mitotic apparatus as well.

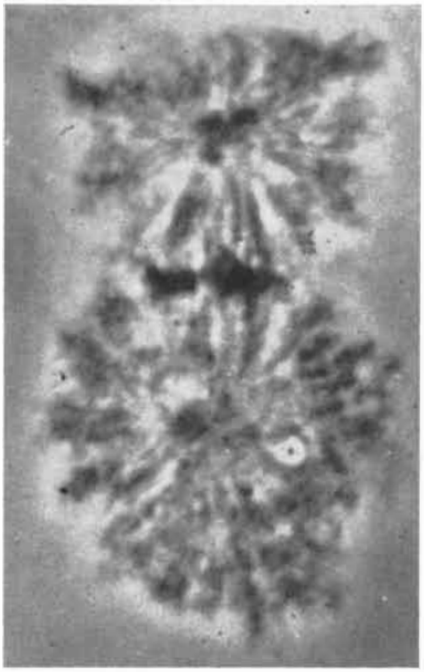
Looking at the research in retrospect, it is evident that we should then have tested gentler detergents; it was perhaps fortunate that instead we attempted to analyze the conditions that determined whether or not a body would be solubilized by a detergent. Our approach may serve as an illustration of the role played by informed guesswork in research. First, we imagined that the mitotic apparatus was composed of proteins, an assumption for which there was slight factual basis. The cell generally employs proteins in the establishment of structure, and especially does so in the elaboration of fibrous structures. How are protein fibers formed and what are their properties? One mechanism of fiber formation is the establishment of the so-called disulfide (S-S) bridges between molecules. Protein molecules contain sulfur in the form of sulfhydryl (SH) groups. If, on two adjacent protein units, the hydrogens are removed (which is another way of saying that oxidation has occurred), the sulfur atoms of the two molecules may be linked in a disulfide bridge. Thus may fibrous chains be formed.

The disulfide bonds are very strong, so it is difficult to dissolve structures formed by them. In 1935 David Goddard and the late Leonor Michaelis, working at the Rockefeller Institute for Medical Research, showed that the reason why wool and similar proteins were so stable and insoluble in chemical solution was because they contained so many disulfide bridges. If, by the addition of an agent such as thioglycolic acid, the disulfide bonds were converted back to sulfhydryl bonds (a reversal of the oxidation described above), wool became soluble.

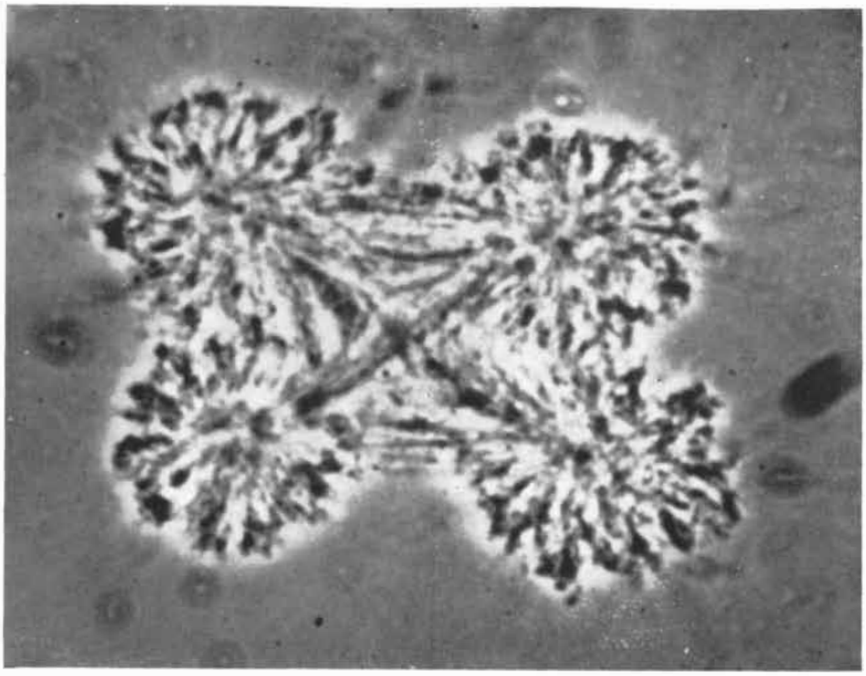
What does all this have to do with the mitotic apparatus? If the apparatus dissolves in Duponol or other strong detergents, the logical conclusion would be that the fibers of the spindle and asters are *not* formed by disulfide bridges. We drew the less logical conclusion that there were too few disulfide bridges to make the fibers sufficiently resistant. We then guessed—there is no other word that would be entirely honest—that there might be a larger number of *potential* disulfide bridges (SH groups) which could be converted to actual bridges (S-S bonds) by the addition of an oxidizing agent. On this assumption we treated the eggs briefly with a solution of hydrogen peroxide before adding the detergent.

The experiment—every step of which was based on inference as to how the cell *might* make the fibers of the mitotic apparatus—worked. The detergent dispersed everything in the cell except the mitotic apparatus, which was left intact! The contaminants could then be removed by letting the heavier mitotic apparatus settle out under a small centrifugal force. By repeated washing in this manner, a sediment composed of "pure" mitotic apparatus could be collected. The method set no limits on the number of dividing cells that could be used; it was possible to isolate enough of the mitotic apparatus for relatively large-scale chemical analysis.

The microscopic study of the isolated mitotic apparatus immediately supplies interesting information. Whatever the stage of mitosis, the whole apparatus may be isolated in one piece containing



UNEQUAL DIVISION involves a large aster and a small one. This is the isolated apparatus of a clam egg.



ABNORMAL DIVISION of the sea-urchin egg gives rise to an isolated mitotic apparatus with four poles instead of the usual two. In this apparatus, isolated by an older method, the chromosomes cannot be perceived.

all the elements that entered into the description of mitosis. This proves that the cell does make a physically integrated apparatus for carrying out the cell-division process. An interesting result is obtained when one isolates the mitotic apparatus from clam eggs or other cells which do not divide into daughter cells of equal size. In these cases the asters are also of unequal size, the larger aster being at the end where the larger cell will form. Thus observations of isolated mitotic figures confirm Dan's theory as to how the plane of cell division is located. In general, observations of the isolated mitotic figures confirm the picture that had been obtained by earlier microscopists, but everything is much clearer and observation does not depend upon violent killing and staining procedures. The most interesting result of observing the isolated figures is the fact that they are isolated at all. This signifies that the dividing cell performs some chemical act, common to all parts of the apparatus, that makes it chemically different from everything else either in the dividing or the resting cell. This is a logical consequence of the fact that the isolation procedure works. While the procedure does not solve the "secret" of mitosis, it assures us at least that there is one, and one that can now be studied.

We now know something about the chemistry of the apparatus. It is composed mostly of protein, as was originally guessed. There is present a small amount of ribonucleic acid, and, of course, the contents of the chromosomes. Other constituents are suspected but not yet proved. The "weight" of a single mitotic apparatus has been determined: it is found that the apparatus involves about 2 per cent of all the protein in the egg at the time of its first division. This will certainly vary as cells of different kinds are investigated.

To what extent was the guess that the mitotic apparatus is formed by the linking together of protein molecules through sulfur bridges a legitimate one? A logical way to test this is by attempting to reverse the process. If the guesses were accurate—and the success of an experiment does not in itself prove that the assumptions which led to it were correct—then the mitotic apparatus should become soluble in detergent if the S-S bridges were reduced to unlinked SH groups. The experiment would be comparable to that by Goddard and Michaelis on the solubility of wool. The same reagent, thioglycolic acid, was used—and the predicted results were obtained. After treatment with this reagent, the mitotic apparatus was soluble in detergent. Therefore the idea that the fibers are formed through sulfur bridges is a tenable one. Once the protein of the mitotic apparatus is in solution, further information may be obtained. By the use of the ultracentrifuge, which measures how fast molecules settle under very strong gravitational forces, one can observe the size of the molecules. It appears that most of the apparatus consists of molecules about the size of "ordinary" proteins, such as the albumin of egg white. This might be considered the unit which the cell strings out by sulfur bridges to form the fibers of the mitotic apparatus.

While much could be learned from the mitotic apparatus isolated by peroxide and Duponol, the method was still a rough one. By the standards of the biochemist, peroxide is a rather violent reagent, and the isolation involved the creation of unnatural sulfur bridges which did not exist in the original cells. Following the same line of reasoning, now fortified by experiment, the problem could be simplified. If the "natural" mitotic apparatus depended upon disulfide bridges but contained relatively few, could we not use a detergent that was just strong enough to solubilize the other materials of the cell and just weak enough *not* to solubilize the mitotic apparatus? If such a detergent were available the peroxide could be omitted and the whole treatment would be gentler. After some trials such a detergent was found. It is a natural detergent: digitonin, which is obtained from the common foxglove. George Wald of Harvard University had used this substance some years ago to solubilize the visual pigments of the eye without damaging them chemically. Recent experiments in our laboratory have shown that digitonin alone will disperse the cell content and liberate the mitotic apparatus.

There is every reason to think that the isolated mitotic apparatus is now closer to its natural condition. Its structure remains intact down to fine details. A merit of the newer method is that the chromosomes, which were often difficult to see when isolated by the old method, are preserved. But again we must raise the question: was the reasoning that led to the successful isolation correct? If it was, the isolated mitotic apparatus could have fewer S-S groups and still be more soluble in thioglycolate than was the apparatus prepared by the old method. This proved to be the case.

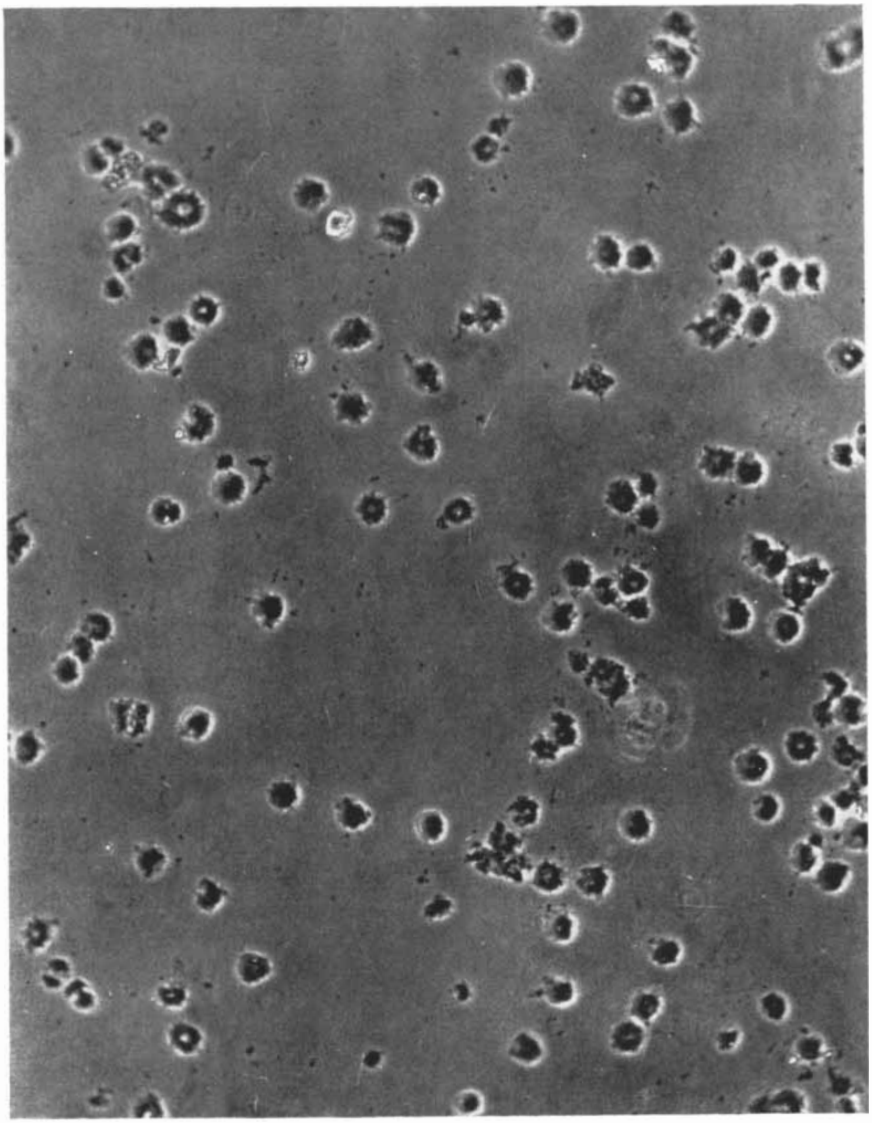
The Centers

Now a new and challenging fact emerges. Let us consider, for this soon becomes the heart of the problem, how the beautiful geometry of the mitotic apparatus might be achieved. On visual evidence alone the old masters of microscopy believed that the centrioles were in fact centers which formed the fibers of the mitotic apparatus. Since the appearance of these bodies varies so much from cell to cell, let us use the general term "center." The fibers do seem to grow out of the centers. No alternative hypothesis has been proposed, although it is often suggested that one group of fibers, those connecting the chromosomes to the poles, may originate in the chromosomes. Translating into chemical language, we may set up the working hypothesis that the form of the mitotic apparatus is determined by centers at which fibers are made by a process involving the formation of disulfide bonds. The peculiarity of these centers would be that they provide conditions favoring such a polymerization. Recent observations on the mitotic apparatus isolated by the digitonin method lend some support to such a line of thought. If the mitotic apparatus is given a very mild exposure to thioglycolic acid, everything dissolves but the spherical central region of the asters. This seems to be in fact the region where the S-S bridging of the proteins is strongest. We are a long way from understanding how the mitotic apparatus is formed, but the availability of the isolated apparatus and now the isolated centers should permit us to feed chemical information into the theory of mitosis as it evolves.

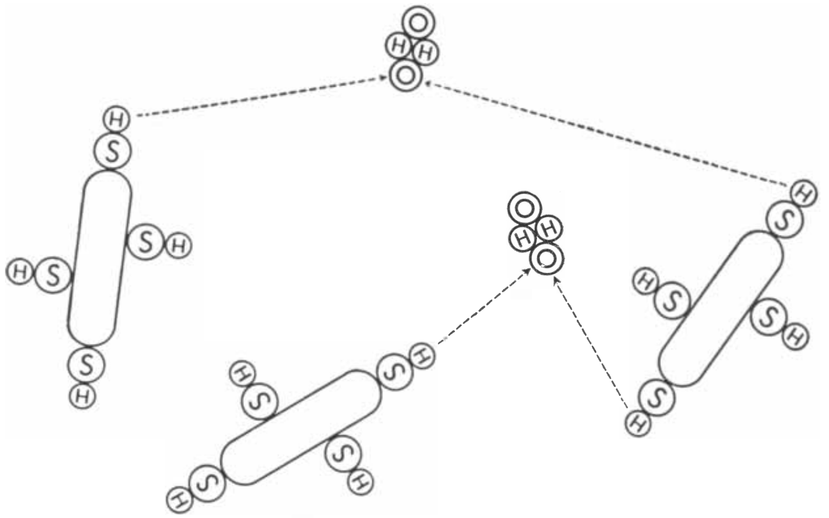
Optical Tools

Mitosis cannot be understood merely as a series of chemical transformations. It is a dynamic mechanical process, a matter of push and pull, stress and strain. What tools have we to study this aspect of the problem? The most refined tool, and one that is being used most effectively, is the so-called polarization microscope. Where molecules are oriented, and take on other than random arrangements, they influence the speed and direction of beams of polarized light passing through them. The orientation may be the result of the architectural operations of the cell, as in the formation of the mitotic apparatus, or the result of mechanical stresses. The influence of an object composed of oriented units on a beam of polarized light is measured as its birefringence. Birefringence is actually the difference between the speed of a beam of polarized light through the object when the light waves are vibrating parallel to an axis of the object, and the speed of a beam vibrating at right angles to this axis. The axes are obvious in the case of an object such as an elongated fiber. What is important is that the birefringence may measure the degree of orderliness in the arrangement of the molecules or the extent to which the molecules themselves are non-symmetrical. In the case of a fiber composed of long and slender units, the birefringence will increase if all the molecules are made to lie parallel to one another. It will decrease if for any reason the individual molecules become shorter or fatter.

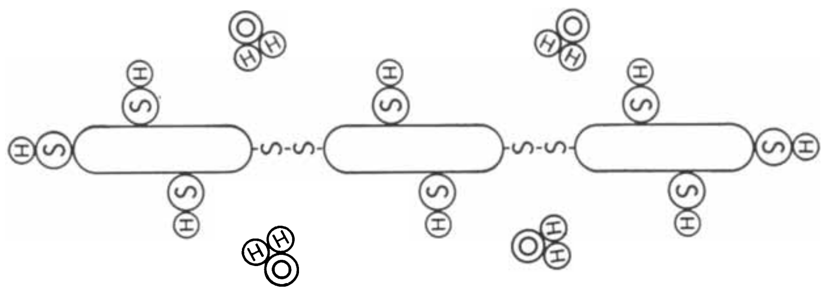
Researchers whose main interest has been the problem of mitosis have in recent years refined the polarization microscope to the point where we may now hope for a real surge of information about the arrangement of molecules in the mitotic apparatus. A few examples will illustrate the kinds of information that we can expect. Some years ago a German pioneer in the field, W. J. Schmidt, showed that the mitotic spindle was birefringent, and that the birefringence decreased when the chromosomes were separating. This demonstrated that the fiber system of the spindle had as its basis a system of fibers of molecular dimensions, aligned more or less parallel to the visible fibers. The decrease in birefringence indicated either that fewer of the molecules were aligned along the axis of the spindle or that the molecules were contracting. Schmidt's methods were not sufficiently sensitive to detect small-scale changes. Recently Swann and Mitchison have refined the microscope so that much smaller degrees of birefringence can be measured, and the measurement can be made on a movie of the dividing sea-urchin egg. They were able to show that the decrease in birefringence as the chromosomes moved



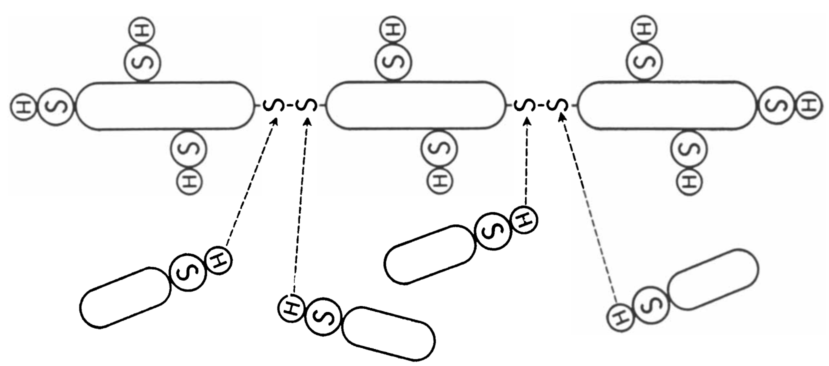
CENTERS of the mitotic apparatus are isolated by treatment with thioglycolic acid. These centers are from the dividing eggs of the sea urchin.



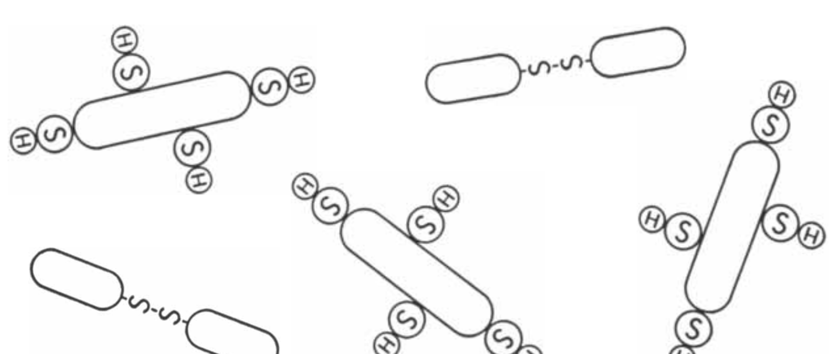
MOLECULES ARE OXIDIZED with hydrogen peroxide (H_2O_2) to remove hydrogen (H) from the sulfhydryl groups (SH) of the mitotic apparatus.



MOLECULES ARE LINKED by disulfide bonds (S-S) after the hydrogens of the sulfhydryl groups have been removed. Water molecules (H_2O) remain.



REACTION IS REVERSED with thioglycolic acid, which has a sulfhydryl group. The hydrogens of these groups join with sulfurs of disulfide bonds.



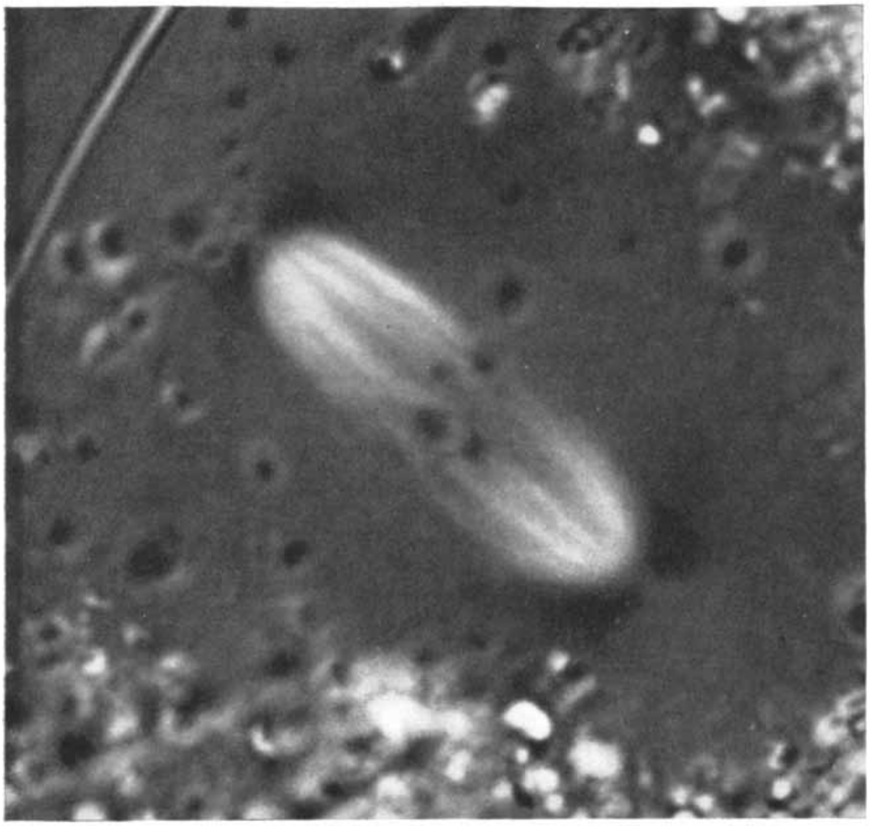
BONDS ARE BROKEN by reduction back to sulfhydryl groups. The molecules of the thioglycolic acid, however, are now joined by disulfide bonds.

apart was not uniform, but began near the chromosomes and spread toward the poles. Swann has proposed that the changes that take place in the spindle during chromosome separation are initiated by one or more substances produced by the chromosomes. An engaging feature of this hypothesis is the way in which it demonstrates how a few facts (even when incorporated into a hypothesis that is difficult to prove) may resolve a seeming contradiction. For years cytologists have debated whether the chromosomes are pulled toward the poles or themselves provide the momentum for their migration. Swann's experiment reveals that both the spindle and the chromosomes may play an active part. This is often the outcome of such "either-or" controversies.

Microscopic research on mitosis has been both stimulated and plagued by debates as to whether this or that part of the mitotic apparatus was real or was an "artifact" produced by the technique of preparing the cell for observation. At one time the reality of even the chromosomes was debated; the question of their existence was only resolved by the ultimate court of appeal—observation in the living state. The controversy as to the reality of the fibers in the mitotic apparatus has continued to rage, though observations of the fibers in living cells have been reported by Kenneth Cooper of the University of Rochester and by others. In the opinion of the writer, the polarization microscope has solved this problem. Shinya Inoué, a young graduate student working under Cooper at Princeton University, designed and built a polarization microscope capable of detecting and measuring smaller degrees of birefringence than had previously been possible in biological material. With this instrument he has studied the mitotic figures in many kinds of living cells, and in every case he has been able to detect distinct spindle fibers. The fibers, which contrast so poorly with the background material in ordinary light, stand out vividly in polarized light by virtue of the arrangement of the molecules in them.

The reader is sure to ask about the contributions of the electron microscope to the study of mitosis. Living material cannot be examined in this instrument because the beam of electrons with which it resolves very small objects must be focused in a vacuum. Thus the application of the electron microscope to the study of mitosis is already beset by arguments as to whether the observations made with it are real or artifacts.

The difficulties could have been predicted from the troubles of pre-electron microscopists. "Seeing" depends on contrast, and the electron microscope, however great its magnifying power, depends on a rather high degree of contrast (difference in density of matter between an object and its surroundings) in order



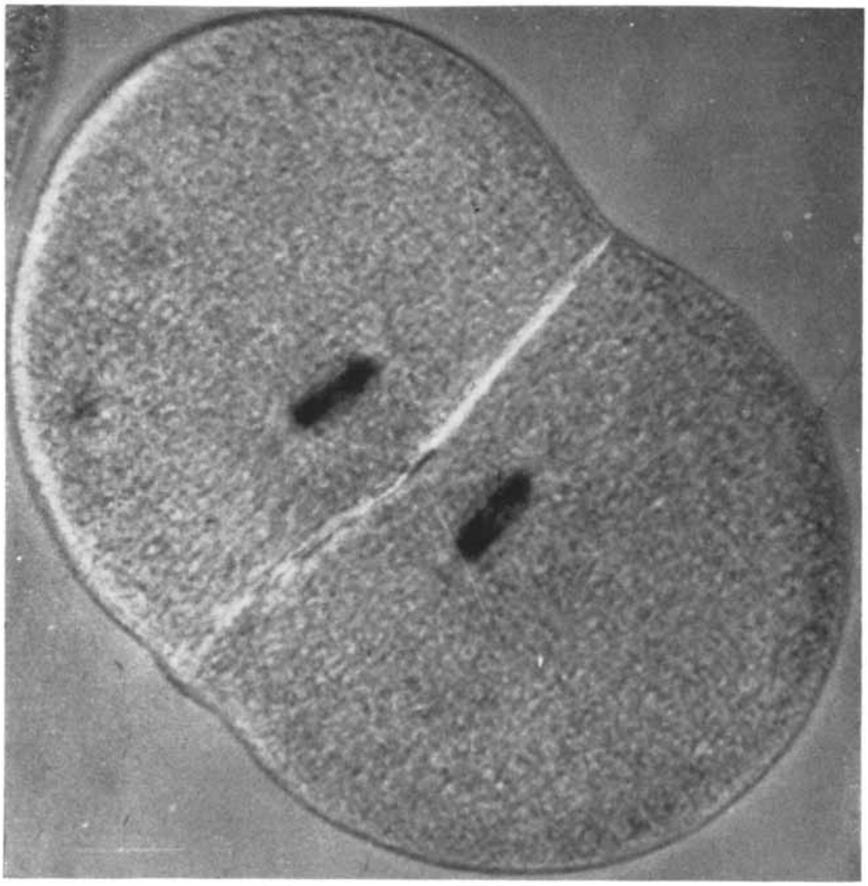
POLARIZED LIGHT PHOTOMICROGRAPH made by Shinya Inoué shows the mitotic spindle in a living cell of the worm Chaetopterus.

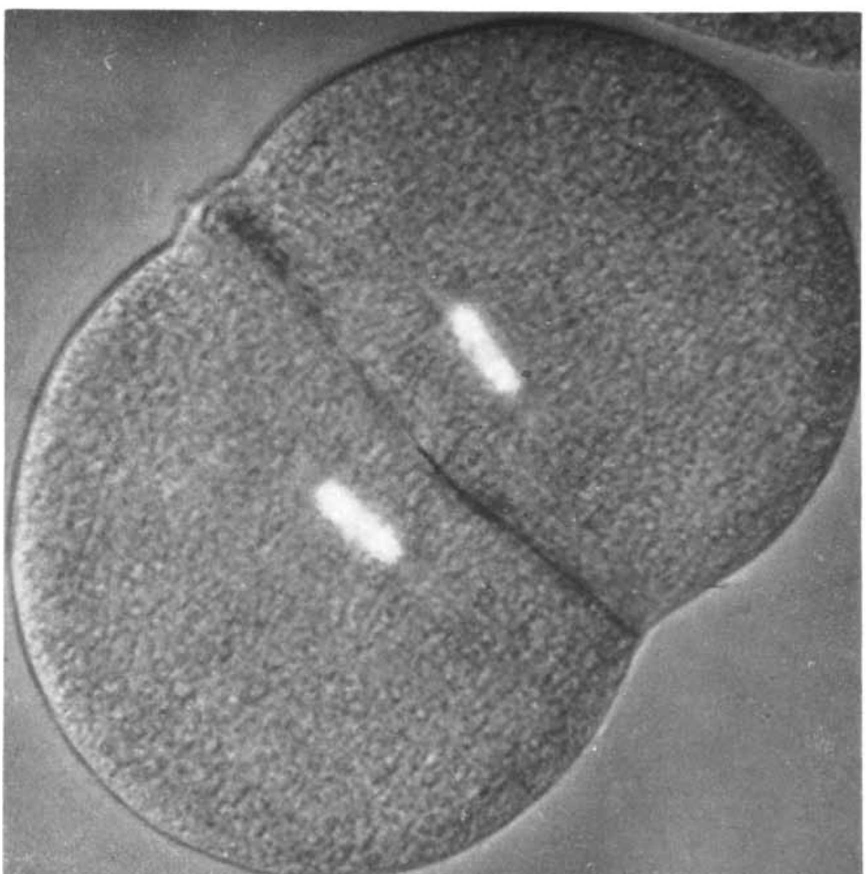
to show an object at all. It is perhaps for this reason that the mitotic apparatus, observed while it was embedded in the other constituents of the cell, has seemed so structureless even to skilled electron microscopists. On the other hand, the isolated mitotic apparatus promises to show a great deal of structure. Patricia Harris of our laboratory has made photographs of the isolated mitotic apparatus which, even at the relatively low powers employed thus far, reveal a number of interesting details. It seems, for example, that the spindle fibers are not straight and continuous from pole to pole, but appear to be formed by an end-to-end union of fibers from either pole at the equator. As everyone would have predicted, the fibrous appearance of the spindle is not due to distinct fibers with nothing between them; the spindle is more like a sheaf of threads with a tendency to lie side by side. What will be seen as the full resolving power of the electron microscope is brought into play cannot yet be predicted. So powerful is this tool that we are forced to proceed slowly toward the highest magnifications, using each step to provide the landmarks for the next.

Exceptions

If we survey the whole living world, we see that mitosis is the most common mechanism for distributing the hereditary birthright, and the most fundamental features of mitosis are the formation of a "plate" of doubled chromosomes and the formation of a spindle which will guide each of the daughters of chromosome doubling to the opposite pole. There are important exceptions to this typical pattern. In the growth of our own muscles, for example, nuclei may reproduce by mitosis without the formation of new cells around them. Growth keeps pace with the number of nuclei, and the result is huge cells with many nuclei. There are instances where, after the division of nuclei alone has given rise to a large cell, the cell suddenly builds a wall around each nucleus so that we end up, after all, with as many cells as there are nuclei. This process is of great practical importance, for the formation of infectious spores in many microorganisms is due to it. How new cells can be marked out without a mitotic apparatus to guide the process we do not understand at all.

As mentioned earlier, we cannot detect asters in many cells, especially those of plants. Nor have the centers toward which the chromosomes of plants migrate been identified visually as the distinct bodies called centrioles. In some very common instances, such as the division of white blood cells and other cells that crawl like amoebae, the division is accompanied by lively movements. Such divisions look for all the world as though, once the forming daughter cells decide that they are daughter cells, they try to crawl away from their sisters and thus





LIVING MITOTIC APPARATUS is revealed in sea-urchin eggs by polarized light photographs. In the top photograph the apparatus is dark; in the bottom one it is light because the polarizing filter has been rotated.

aid the division process. In many but not all of the protozoa, the one-celled animals, there is a peculiar kind of mitosis in which the nuclear surface does not break down. The spindle forms inside the nucleus, which elongates as the daughter chromosomes part, and finally pinches in two. Even here, where we can see neither asters nor mitotic apparatus outside the nucleus, the cell "knows" where the equator of the peculiar spindle is, for it pinches into two at the midpoint. We also have, in such diverse instances as mosquito gut cells and certain plant cells, "endomitosis," which involves neither cell division nor even the separation of the daughter chromosomes into new nuclei. The chromosomes simply divide and remain together in the same nucleus.

The advance of biology is an interplay of generalization and exception, and attitudes toward exceptions tell us more about biologists than they do about biology. To the writer it seems that the diverse patterns of cell multiplication will emerge as variations on a simple design once we learn something of what lies beneath the surface.

Applications

In the full context of nature the biological world is characterized by continuous growth, limited only by the resources and hazards of the physical world. But, just as human beings fancy themselves as being more than mere descendants and ancestors, so the life of an organism is largely a vacation from the propagation of its kind. Even single cells do not add to their store of living matter during division, but only between divisions. In higher organisms the pattern of development is a counterpoint of division and organization. In the embryo the frequency of mitosis decreases before the forms and specializations of the adult come into being. When a group of cells reverses this pattern, we have a cancer. What sets mitosis into motion and what stops it? We have only a few scattered facts to marshal against these questions. In general, the mass of a cell must reach a critical maximum value before it begins to divide. If we keep amputating part of an amoeba so that it never reaches full size, it never divides. We also have learned in the last few years that mitosis is a process which distributes equally between the daughter cells chromosomes which have doubled before mitosis begins. It is conceivable that the control of mitosis involves restraints on the synthesis of new chromosome material.

What artificial restraints can we place on mitosis, short of simply murdering cells? We know several kinds. One is to suppress the synthesis of the nucleic acids of the chromosomes. This is what happens when we expose cells to mild doses of X-rays or other ionizing radiation from which they generally recover. Heavier doses of radiation upset mitosis by breaking up the chromosomes. So far as we know, most biological effects of radiation involve the formation and the integrity of the chromosomes. Chemicals that duplicate these effects are called radiomimetic—mimickers of radiation. On the other hand, ionizing radiation seems to have little effect on the mitotic apparatus apart from the chromosomes, but many chemicals do. Substances such as the plant derivative colchicine prevent the formation of the mitotic spindle, but do not affect the chromosomes. The chromosomes go through their complete mitotic cycle, but cannot be separated because there is no mitotic apparatus. The result is a single cell with a double portion of chromosomes. Such antimitotic agents have been used successfully in the palliation, but not the cure, of cancer, and have been useful where it was desirable to breed organisms such as food plants with twice the parental ration of chromosomes. It goes without saying that a reasonable approach to the problem of controlling mitosis will depend on understanding mitosis itself.

Biology has few generalizations that can be dignified by the word "law," and to most of these there are exceptions. But no exception has been discovered to the law that every cell must arise from another cell. This generalization makes sense once we have discovered the essential accomplishment of mitosis: the deployment of the chromosomes so that each daughter cell is assured a full representation of all the chromosomes in the mother cell.

The essential meaning of mitosis can be learned from microscopic observation alone, and was learned many years ago. Now we begin to see some progress toward a deeper understanding of what actually is happening in the dividing cell. Through the combined efforts of those who study virus reproduction and those who investigate cell division, we may hope to have some insight into the mechanism whereby the chromosome material is duplicated before mitosis begins. But there are aspects of the mitotic process that do not lend themselves so well to analysis by current means. The problems that are being attacked successfully are those which fit pretty well into current trends of biophysical and biochemical research which any steady reader of this magazine will recognize. But if we ask how the chromosomes come to align themselves in the correct geometric plane before they separate and how sister chromosomes find their way to opposite poles, we discover that we are dealing with an order of problems that does not fit into current methods or ways of thinking about biological events. While we are learning a great deal about the chemistry of cells, we are a long way from understanding how any part of the cell knows where it is.

Francis Hauksbee

In a series of ingenious experiments this uneducated artisan first established a connection between electricity and light and lay the groundwork for new discoveries in electrostatics

by Duane and Duane H. D. Roller

THE NAME of Francis Hauksbee is not associated with any of the landmarks in the history of electrical theory. But Hauksbee, who performed his experiments in the first decade of the 18th century, asked disturbing questions, toppled obstructive theories, perfected equipment for more ambitious research and in general set the stage for spectacular advances in the knowledge of electricity that came later in the century.

One of the most fruitful tasks that can engage the historian of science is to retrace the steps by which some imaginative pioneer of an earlier era worked his way toward new knowledge. It is not necessary that the pioneer should have reached his goal; indeed, his failures may be as instructive as his successes. Hauksbee is an admirable subject for this kind of biography. Although little is known of his life or personality, the record of his experimentation is remarkably complete. From these carefully illustrated documents one can readily follow the logic of his investigations.

It has been said of Hauksbee that he started to study a new optical phenomenon and found himself studying electricity. Up to the end of the 17th century there was apparently not the slightest notion of a connection between electricity and light; no one supposed, for instance, that such familiar and striking phenomena as the aurora, lightning and St. Elmo's Fire were electrical in origin. At the time Hauksbee was beginning his work—he was most productive from 1703 until his death in 1713—"electricity" still meant little more than "the ability to attract straws and other small objects that is acquired by any one of about two dozen substances, such as amber and glass, upon being rubbed." By the time his work was ended, the connection between light and electricity was evident, though the governing principles were not yet understood.

THE optical effect which attracted Hauksbee's attention was called "barometric light." It had been discovered in 1675 by the French astronomer Jean Picard, who observed that a glow or flash of light appeared in the space above the mercury in a barometer tube when he moved the instrument. Picard reported the phenomenon to the French Academy; it attracted much attention, and for a time there was considerable controversy as to its nature. By Hauksbee's day, however, scientists were generally agreed that the light came from sulfur or a "phosphorus" supposedly present in the mercury.

The barometric light is explained today roughly as follows. When the mercury splashes and moves over the surface of the glass tube, both glass and mercury become electrified. This is an example of the familiar phenomenon called "electrification by friction": when two dissimiliar substances are brought very close together by rubbing and then are separated, they are found to be oppositely electrified; the one substance has lost electrons, leaving it positively charged, while the other substance has gained these electrons and thus is negatively charged by an equal amount. Now the air and mercury vapor in the top of the barometer tube contain some charged molecules (ions); also present are some free electrons. These various charged particles are set in motion under the influence of the charged glass and mercury; and, since the top of the tube is a partial vacuum, there are few collisions among gas molecules to slow this motion. The particles, especially the tiny electrons, therefore acquire sufficient speed to ionize additional gas molecules upon colliding with them. Thus the number of moving charges, and the electric current, increases. The flashes of light result when the charged molecules, by any of several processes, lose their charge or otherwise lose the energy which they gained as a result of the collisions.

Modern work on electric discharges in gases is usually done with a long glass tube containing the gas and equipped with two metal terminals at the ends. These terminals are kept oppositely charged by having them connected to a high-voltage source. So long as the gas pressure in the tube is atmospheric, practically no electric current occurs between the terminals. But if the gas is gradually pumped out of the tube, resulting in greater distances between the molecules, the current increases; then between the terminals there appears a thin streamer of light, its color depending on the kind of gas in the tube. With further pressure reduction, the light spreads out to fill the whole tube. This is characteristic of the familiar neon advertising sign. As more gas is removed, dark spaces appear in the column of light. Finally, at the lowest pressures, so few molecules remain to act as potential sources of energy that the light disappears entirely.

Much of this explanation depends on discoveries made long after Hauksbee's day, and he never reached any such coherent understanding of the phenomenon he studied. Nevertheless, he did show that friction was an essential factor in barometric light and that this effect was related to what in his time was called electrification. From there he was led to further experiments with electrical charges—both at normal air pressure and when the air was partly evacuated—which are an essential part of the groundwork on which the modern theory of electricity rests.

WE KNOW so little about Hauksbee's background that it is difficult for us to understand how he became involved in scientific experimentation. We gather that he was an artisan of little formal schooling; his writings show him to have been almost illiterate compared with other prominent scientists of the day. Nevertheless, he became a member of the Royal Society of London. One may guess that his skill at constructing instruments and his unusual genius for experimentation were what brought him into association with the members of that body. According to the official *Record* of the Society, "In 1707 Dr. Douglas and Mr. Hauksbee were . . . employed to prepare experiments, and were paid for doing so, but do not appear to have borne the title of curator." The facilities afforded Hauksbee by the Society must have been a factor in helping him become the most active experimentalist of his day.

But granting that Hauksbee was pursuing interests somewhat unusual for an 18th-century artisan, we can readily guess why he was attracted to the problem of the barometric light. In the preface to his book, *Physico-Mechanical Experiments on Various Subjects* (1709), he acknowledges his indebtedness to the great Robert Boyle. It was Boyle who, on hearing that the air pump had been invented by Otto Von Guericke in Germany, had various models of such pumps constructed for his own extensive vacuum researches. As one of Boyle's immediate and most active successors, Hauksbee perfected a double-cylinder pump that was to set the design for such devices for the next 150 years. With this skill and interest in vacuum techniques, Hauksbee would naturally have been drawn to the study of Picard's light. He may even have discovered the effect independently, for the first of all his published papers was "An Experiment, to show the cause of the descent of the mercury in the barometer in a storm" (1704).

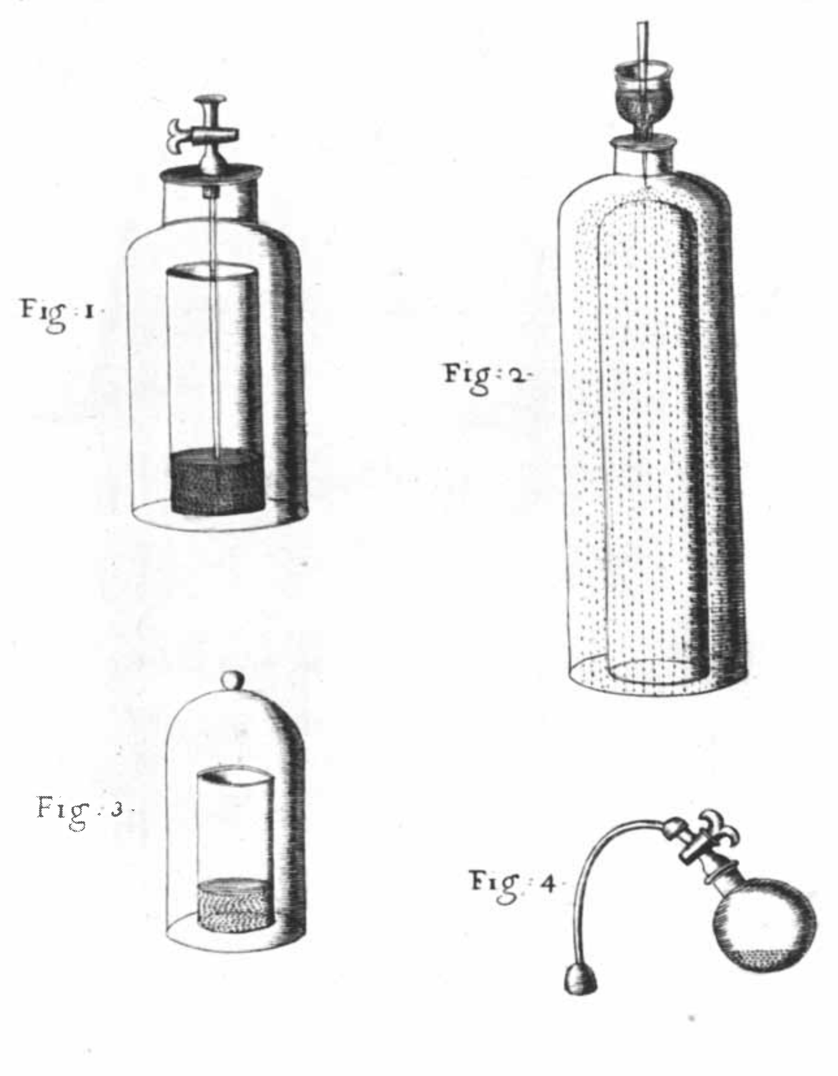
In any event we find him in 1705 reporting experiments on the capacity of mercury to produce light in a glass vessel. From the plan of these experiments we may suppose that he had already guessed the relevant factors in the production of the barometric light to be the motion of mercury over glass and the low pressure of the gas in the vessel. Although this working hypothesis may appear obvious to us, apparently no one else had phrased it, consciously or unconsciously, during the four decades following Picard's discovery.

Hauksbee tested the two parts of his hypothesis in turn. With the equipment depicted in the drawing at the right, he proved conclusively that the motion of the mercury over the glass is essential: The flashes of light occurred when drops of mercury slid down the glass, but never when they merely stuck to it. Then, to find what degree of vacuum was necessary for the effect, he varied the amount of air present in the vessel. No light flashes appeared until about half the air had been removed. As the vacuum was increased beyond that point, the light intensity gradually rose to a peak and then fell away until it seemed to disappear. This led Hauksbee to conclude that some air must be present if the phenomenon is to occur. In at least one experiment he attached to the pump a mercury pressure gauge (apparently an open-tube manometer). The lowest pressure he could obtain with his pump was roughly 1/60 of atmospheric pressure; but the light flashes occurred only at pressures between about 1/20 and 1/2 atmosphere. In truth, when the pressure was one atmosphere—that is, when the vessel was not evacuated at all—shaking the mercury around over the glass produced "little bright sparks"; but these, Hauksbee noted, differed markedly in appearance from the more diffuse light seen when the vessel was partly evacuated.

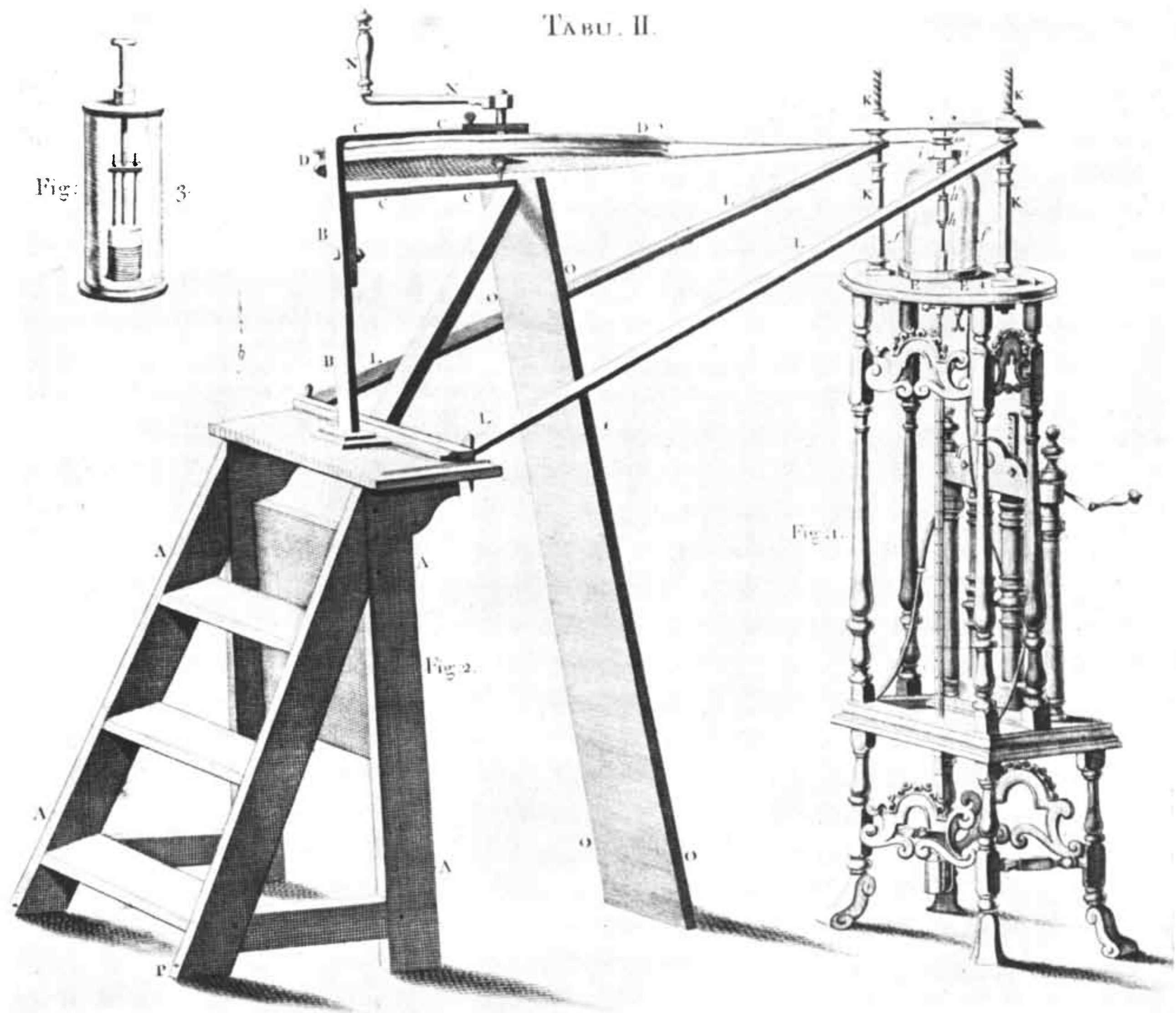
HAUKSBEE now broadened the problem by asking whether mercury and glass were the only substances that could produce the light flashes when rubbed together in rarefied air. Here he used a "machine for giving a swift motion to bodies in a vacuo." This device consisted of a wooden wheel with a large number of amber beads fastened around its rim and so mounted that when it rotated the beads pressed against a series of woolen pads. The wheel was placed within a glass vessel which could be evacuated; a hand-operated belt and pulley arrangement turned the rim of the wheel at speeds up to "something more than one third of a mile in a minute." Upon starting the air pump and setting the wheel in motion, Hauksbee observed flashes in the rarefied air.

He tells next how he replaced the beaded wooden wheel with a small glass globe; when the globe was rotated so as to rub against the woolen pads in the evacuated vessel, the light again appeared. He also rubbed glass against oyster shells, wool against oyster shells, and so on. In every case the light appeared in the rarefied air, although with varied intensity. Thus he had proved that the nature of the substances rubbed together was not crucial to the experiment; the governing factors were the friction and the rarefaction.

After a brief diversion to unrelated experiments on the specific gravity of water



BAROMETRIC LIGHT apparatus used in Hauksbee's early experiments is reproduced from the *Philosophical Transactions* for 1705. Outer vessels in Figures 1 and 2 were evacuated, and the mercury agitated in 1 by bubbling air through the reservoir and in 2 by pouring the liquid from funnel over inner vessel. At bottom are other arrangements of mercury in vacuum.



FRICTION IN A VACUUM was produced in the jar atop the stand at right. The spindle within the jar turned in a tightly-fitted leather gasket; below was a pump which maintained the vacuum. The object to be rubbed was mounted on the spindle and pressed against woolen pads that were attached to a stationary bracket.

and the rise of water in capillary tubes in a vacuum, Hauksbee returned to the problem of light produced by rubbing. He now employed his productive imagination to design a modified machine that was much easier to construct and handier to use. Instead of enclosing the rotating glass globe in an evacuated vessel, he evacuated the globe itself, sealing it so that the air could not re-enter. With the container thus eliminated he could use a larger globe, one of about nine inches diameter; moreover, he could rub the spinning globe simply by laying his "open and naked hands" lightly upon it. When he did this the light appeared inside the sphere. By placing his hands so that they touched as much as possible of the globe's surface, he produced a light so bright that, in a darkened room, "words in capital letters were clearly legible by it."

Hauksbee now turned back to the original problem of the light in the barometer. Suppose that one did not shake the barometer, but rubbed the upper, evacuated part of the tube with the hand. He tried this and the light ensued. At this point, in the summer of 1706, Hauksbee may have begun to feel confident that the barometric light was closely related to the electrification produced by rubbing glass and other substances. That he had reached this point in his reasoning is certainly suggested by the fact that he next took up a study of "the extraordinary electricity of glass." He began with reactions that were already well known in his day: A glass tube that had been rubbed with paper, say, would attract pieces of brass leaf or other light objects; and these objects, upon striking the tube, would sometimes adhere to it and at other times be violently repelled. He spoke of the "effluvium" that reaches out from the tube to the brass leaf, thus indicating that he had some knowledge of earlier electrical work; for it was by postulating a material but invisible effluvium, which supposedly connected any electrified body with surrounding objects, that investigators for more than a century and a half sought to explain electrical attraction.

Soon Hauksbee's electrical experiments became more novel. He held a rubbed tube close to his face and his cheeks felt as if "pusht with the points of a considerable number of weak hairs." In this discovery of the "electric wind," as it is now called, he saw new proof that electrified bodies emit a material effluvium. Today the electric wind is known to be a stream of charged air particles that are repelled by the electrified body.

Now the air pump came back into play. Hauksbee evacuated the glass tube and, upon rubbing it, observed the familiar light. But even when rubbed most vigorously the tube no longer drew the brass leaf to itself, "notwithstanding it was held within a quarter of the distance at which it had been attracted before." He did notice some slight motion of small parts of the brass leaf, but suspected that even this attraction would have disappeared if the last traces of air could have been removed from the tube.

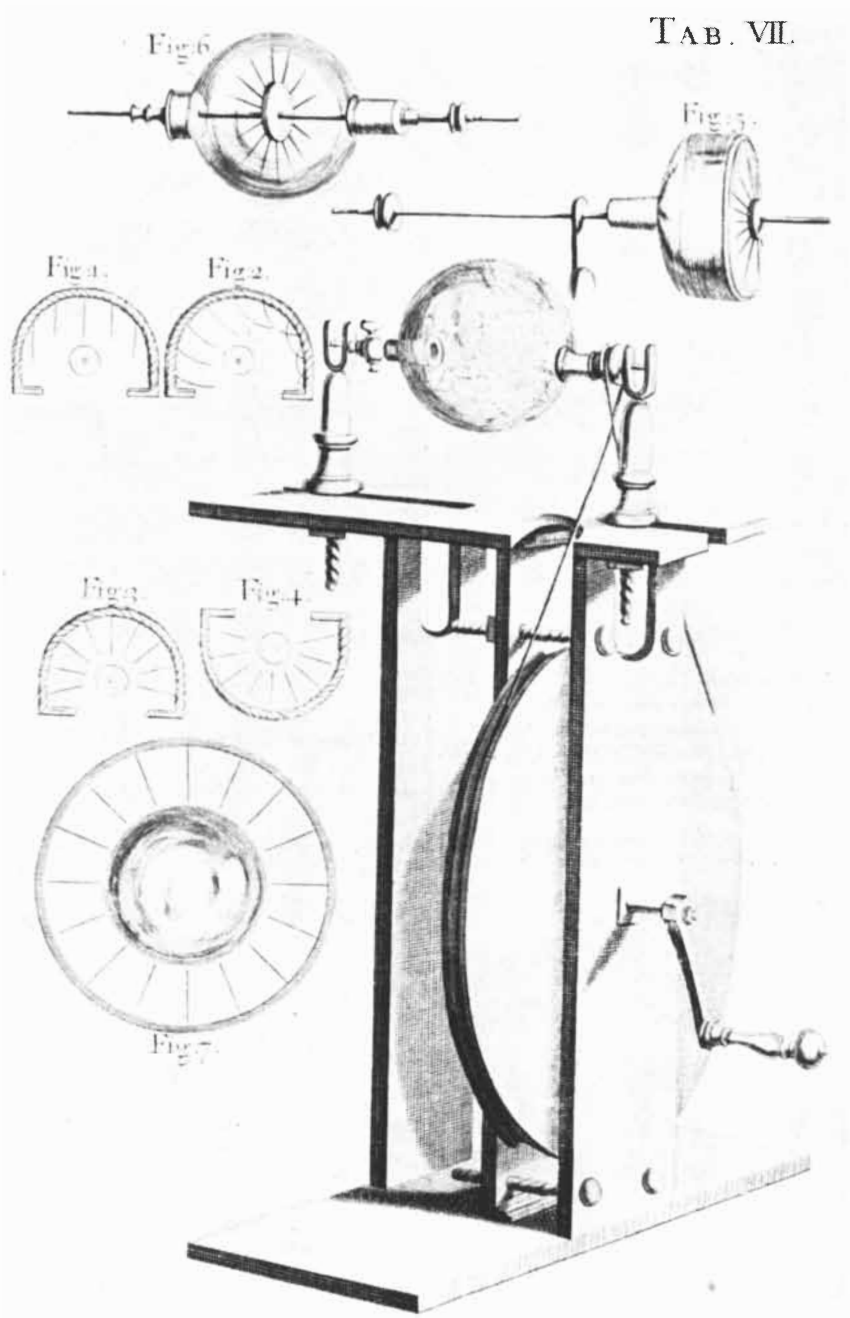
Hauksbee deserves much sympathy here, for he was dealing with very complex phenomena. He had clearly embarked on these electrical experiments in the belief that electrification by friction (triboelectrification) and the production of the light by friction were in some way related. Yet, after obtaining good electrical results with his glass tube, he evacuated it to produce the light and found its attractive property greatly weakened. He was justified at this point in suspecting that the tube, if perfectly evacuated, could not be electrified at all. Since at this time electrification was defined as the ability of a rubbed object to attract or repel other objects, there could be no question of electrification in the absence of attraction or repulsion. We shall see later that it was Hauksbee himself who, in effect, extended the definition of electrification to include the ability to produce light in rarefied air and sparks in the open air.

At this stage of his work Hauksbee changed his mechanical rotator into "a machine of a new contrivance" by shifting the axis of the spinning glass vessel from the vertical to the horizontal position. This development is illustrated by the engraving at the right. Upon evacuating the vessel and setting it spinning under his open hands, he found that it again "succeeded in respect to the light produced."

His next step was especially important to the investigators who followed him. He let the air back into the glass vessel and proceeded to use the machine for the usual electrical experiments of attraction and repulsion. From antiquity up to that time (1706) all such experiments had been performed by holding a piece of amber, glass or other similar substance in a fixed position and rubbing it by hand—a slow, awkward and usually laborious process. Hauksbee, by placing his hands on the spinning glass vessel, could effect the rubbing at a tremendous rate and with comparatively little effort. In brief, he had invented what is often called the triboelectric generator.

THIS INVENTION has in the past been generally credited to Von Guericke, who in 1672 described a large ball of sulfur mounted on an axle to which was attached a crank. Laying his bare hand on the rotating ball, he had observed a number of phenomena that we now know were electrical. However, Von Guericke's interest was in developing a new theory of the earth's rotation, and the sulfur ball was intended as a model of the rotating earth. Thus he did not devise it as an electrical generator or use it for investigating electricity. Moreover, his device and the experiments with it seem to have been unknown to electrical experimenters in England and France until nearly three decades after Hauksbee had published his work. Since Hauksbee built his generator to study electricity and since it had an immediate and important effect in that area, he should be regarded as the effective inventor of this early electrical machine.

Hauksbee now moved on to a new group of experiments, some of which were spectacular. He mounted a second glass globe within an inch of the one on the generator, but set up to spin independently. This second globe he evacuated, the one on the generator being left unexhausted. He then put both machines in motion and placed his hand on the generator globe, "the effluvia of which in a little time reaching the exhausted globe" immediately produced in



ELECTRIC GENERATOR was a spinning globe that could be rubbed by hand. In other experiments a cylinder with threads attached to its walls replaced the globe. Figure 1 shows the position of threads when cylinder is uncharged and stationary. In figure 2 the cylinder is rotating but is not yet charged. Figures 3 and 4 show the effect of charging the cylinder.

it a "pretty vigorous" light, "without the assistance of a touch from anything else to influence it."

Soon he found that it was unnecessary to rotate the second vessel. He noted, after merely holding an evacuated tube close to the generator globe, that it was "very surprising to see what large flashes of light would be produced in the long glass tube without its touching the glass in motion or itself being either moved or provoked by an immediate attrition."

In thus showing that light appeared in an exhausted vessel when it was merely held near an electrified globe, Hauksbee came very close to discovering the important principle that any object becomes electrified temporarily when it is in the vicinity of, but not touching, another object that is already electrified. This later came to be called charging by "influence" or by "electrostatic induction."

But although Hauksbee accurately observed and described charging by influence, he did not discover it as a new phenomenon because he managed to fit it into the old theories. He was of course puzzled when the light appeared in an unrubbed evacuated vessel, but he eventually hit on an ingenious explanation: the vessel was being rubbed by the effluvium issuing from the hand-rubbed generator globe. Thus he "saved" the prevailing notion that only rubbing an object could produce either electrification or the barometric light. At the same time, he missed the discovery that these phenomena are also produced by "influence."

If the effluvium can serve as a rubbing agent, then it must have a certain stiffness and act much like a solid body. Hauksbee was here following a false trail, but the experiments he performed were nevertheless most fruitful for his successors. Having noticed that bits of thread appeared to be "equally attracted" by all parts of an electrified body, he began a study of this phenomenon with the aid of an electroscope which he had specifically designed for the purpose. It was made by suspending short lengths of thread from a semicircular wire. This wire he fastened concentric with a glass cylinder mounted on his generator in the manner depicted on the preceding page. When the cylinder was rotated and was electrified by placing the hand on it, each thread moved until it pointed toward the axis of the cylinder. Upon replacing the cylinder by a glass globe, Hauksbee found that all the threads pointed toward the center of the electrified sphere.

FOR MORE THAN a century it had been known that bits of iron placed near a magnet on a table tend to arrange themselves in a definite pattern. Now Hauksbee was showing that threads suspended in the "field," as it is now called, of an electrified body likewise assume definite positions. His conjecture was that the threads were held in their radial positions by the substantial effluvium issuing from the electrified body.

What he next observed was also new and, moreover, quite complicated. While using his electroscope, he found that the loose end of a thread was repelled by his finger when both finger and thread were close to an electrified body and yet had not touched it. His explanation was that the finger displaced the "solid" effluvium surrounding the electrified body, and the effluvium, in turn, pushed away the loose end of the thread.

Then he moved his finger toward the fastened end of the thread and was surprised to see it attracting this portion, although neither finger nor thread had been rubbed to electrify them. This he could not explain. A satisfactory explanation had to await the discoveries, after Hauksbee's day, of charging by influence, electrical conduction and the existence of the two kinds of electrification, positive and negative.

Wondering whether the hollow glass globe of the generator emitted the effluvium in the inward direction, as well as the outward, he tied threads to a wooden disk mounted inside the globe in such a way that the threads did not touch the glass. The experiment did not work very well at first, but eventually he was able to show that these inside threads did assume radial positions when the globe was rubbed. Since only the outer surface of the globe had been rubbed, whereas threads supported either inside or outside were affected, he inferred that the effluvium was coming, not from the surface, but from the solid matter of the glass.

Upon bringing his finger close to, but not touching, the electrified globe, he saw it repel the loose ends of the threads inside, just as it had done when the threads were outside the globe. Seemingly the finger was pushing the "solid" effluvium through the glass. "But what is still more strange," he said, "[this effluvium,] although so subtle as seemingly to permeate glass, will not (as I have taken notice of in a former experiment) affect a thread through a piece of muslin. Now whether the muslin absorbs the effluvium, or what other laws it may be subject to, I cannot tell, but sure I am 'tis very amazing."

Eventually he hit on a way to adapt the effluvium hypothesis to these "amazing" results: the effluvium, though it behaves like a solid body, can pass freely through the substance from which it originates—here the glass—but not easily through other materials, such as muslin. If this hypothesis were valid, it would follow that the effluvium originating from, say, rubbed sealing wax, would not pass freely through glass. But upon holding a stick of rubbed sealing wax close to the glass globe, Hauksbee found to his disappointment that it attracted the loose ends of the threads inside. So did rubbed amber when held near the globe. The only way that he could find out of this difficulty was to suggest that there must be something much alike in the make-up of glass, sealing wax and presumably the various other substances which, in his time, were known to become electrified when rubbed. Otherwise, he could not "conceive how the effluvium of one can penetrate with such ease through the body of the other."

ONE final Hauksbee experiment should be mentioned because, when it was repeated by the French chemist Charles du Fay, it led him to discover "positive" and "negative" electrification. Hauksbee first observed that a piece of brass leaf, which had been attracted to and had touched an electrified glass tube, was thereafter repelled and could be "hunted about a room" with the tube. The floating brass leaf retreated, he explained, because it was pushed away by the stiff effluvium surrounding the tube. This behavior had been noticed by others, but what he next saw was really novel. As soon as the retreating leaf touched some unelectrified object, such as the wall of the room, it not only ceased to be repelled but also was attracted by the electrified tube. This sudden reversal of performance could not be accounted for by the effluvium hypothesis. New discoveries and concepts were needed, and these came several decades after Hauksbee's time. Then it could be explained that the brass leaf, upon touching the positively charged glass tube, itself became positively charged by conduction and was repelled by the tube. But when the leaf touched the room wall, it lost this positive charge and was attracted to the tube.

Lacking the concepts just mentioned, Hauksbee understandably could not fit all of his observations into a single conceptual scheme. Nevertheless, his continual effort to modify the notion of the effluvium bore fruit; it provided him with a succession of working hypotheses, each leading to new experiments and often to new factual knowledge.

At first glance Hauksbee's contributions to electrical science may seem to have been negative. So few facts and notions about electricity had accumulated in the preceding centuries that the subject appeared to be very simple. The new phenomena that Hauksbee uncovered were uncoordinated and at variance with existing notions; they raised questions that could not immediately be answered. Yet it is when traditional beliefs are thus challenged, when established theories are seen to be unsatisfactory, that vigorous inquiry gets under way. When the problems to which Hauksbee called attention were solved, a rapid advance in electrical science became possible. He opened a new frontier in an area of knowledge that had been comparatively inactive for 100 years.

ESSENTIAL OILS

The aromatic exudations of plants are essential to the ancient perfume and flavor industry and to modern chemical technology. Why plants make them, however, is still imperfectly understood

by A. J. Haagen-Smit

AN ORANGE PEEL, when sharply bent, ejects tiny oil droplets. These may be seen as flashes of fire in the flame of a match held nearby, or as oily spots on paper. Contrary to the behavior of fatty oils, however, these spots gradually disappear, carrying with them the odor of orange peel. In this simple experiment we have isolated an essential oil and learned about its typical characteristics: its volatility, plant origin and ability to carry the fragrance of a plant. We can guess why such oils are called "essential," for to the flavor and perfume industry they are the plants' essential parts or *quinta essentia,* as chemists of the Middle Ages called them.

A closer look at the orange peel shows numerous small pores easily distinguishable from the surrounding tissue. Cutting a thin slice of peel we observe under a microscope that the oil is contained in many spherical oil glands. Nature shows many types of such oil glands. In pine trees they have long canals from which essential oils and resins are released only by deep gashes in the tree. In many leafy plants they are external glands, covered only by a thin membrane which breaks at a touch. Often the heat of the sun is enough to evaporate substantial amounts of oil. The "burning bush," *Dictamnus albus*, is a spectacular example. During the day it releases so much oil that the whole plant can be ignited by a match held some distance away. Usually volatile oils are given off in much smaller amounts which can only be detected by microchemical methods. California sage excretes 10 to 20 milligrams of organic compounds per kilogram of plant per hour. These vapors, condensed by leading them through cooled traps, have the true fragrance of the plant.

Such procedures for collecting the essences of plants and flowers might be useful for a scientific investigation, but they are too expensive for a commercial process. For this the French perfume industry has a more practical solution called *enfleurage*, which makes use of a well-known and sometimes disagreeable property of fats to adsorb and hold odors rather tenaciously. Freshly picked flowers are spread out on glass plates covered with highly purified odorless fat. The plates are stacked on top of each other in wooden frames in such a way that layers are formed in which the flowers are surrounded by a thin film of fat. After the fat has adsorbed most of the odors, the essence is extracted with alcohol and the alcohol removed to leave a concentrated floral extract. These extracts are the famous absolutes of *enfleurage,* so true to the natural odor that they form the base of many expensive perfumes. From a thousand kilograms of tuberoses six to seven kilograms of absolute is obtained, of which only one kilogram is the true essential oil. Considering the low yield and the tremendous labor involved in handling, prices of a few hundred dollars per ounce are not astonishing.

An important feature of *enfleurage* is that the flowers keep on producing volatile substances while the adsorption in fats goes on. This is not true of solvent extraction, a second method for concentrating fragrances from flowers. This method immediately stops the flower's production of oils, hence yields are only one half to one third those of *enfleurage*. Nevertheless, since solvent extraction requires less hand labor, most floral extracts are now prepared by this method. The solvent used is generally a highly purified petroleum ether, free from any foreign odors. Allowed to penetrate the flowers in specially built extractors, it dissolves out the odoriferous substances together with some waxes and coloring matter. The solvent is then drawn off in a vacuum, leaving behind a concentrated flower oil retaining the delicate odor of the original. This is the process generally applied today in southern France—Grasse and Cannes—yielding oils of high quality from such flowers as jasmine, tuberose, jonquil, hyacinth, acacia, mimosa and violet.

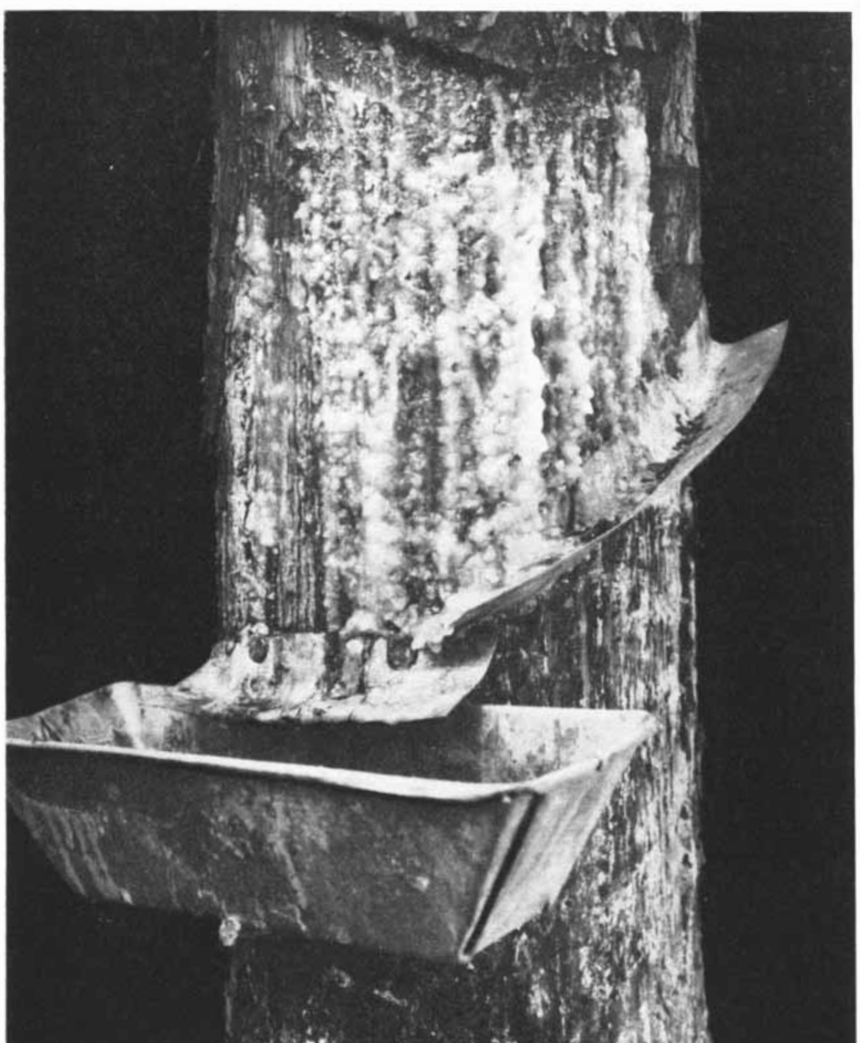
SOLVENT EXTRACTION is by no means a cheap process and is used only in obtaining the most delicate flower oils. When oils from leaves, stems, roots or seeds are extracted, steam distillation is used. Extensive descriptions of this classical process are given in the first handbook on distillation, printed in A.D. 1600. It contains directions for the preparation of oils of spike, turpentine, juniper and rosemary. A flask containing water and plant material is heated over a fire, and the steam produced carries over the volatile oils, which, after passing through a kind of fractionating column, condense in the receiving flask where the insoluble oil separates from the water. This simple procedure using the simplest of stills is employed by farmers in different parts of the world down to the present day.

In a more modern version of steam distillation the steam is produced in a separate still and is then blown through the plant material. This method produces the tremendous amounts of oils turned out by the naval-stores industry, a name surviving from the days when tars and pitch from the crude oleoresins of pine trees were used in the construction, repair and preservation of wooden ships. Today the industry has entirely different customers, but the term naval stores is still used for the steam distillate, turpentine, and the residual tarry and oily products of the pine. This industry, centered around Georgia, Florida and Oregon, produces about 25 million gallons of essential oil and one million tons of resins per year. These find their way into a multitude of uses ranging from solvents in paints and varnishes to frothing agents, sprays, polishes, disinfectants, deodorants, sweeping oils, writing and printing materials. The chemical industry uses many of the oil and resin components as starting materials in the synthesis of valuable products. For instance, pinene, the main constituent, is chemically converted to camphor, which goes into the making of celluloid and films. Other components are converted to polymers, terpenes, phenol resins and plasticizers.

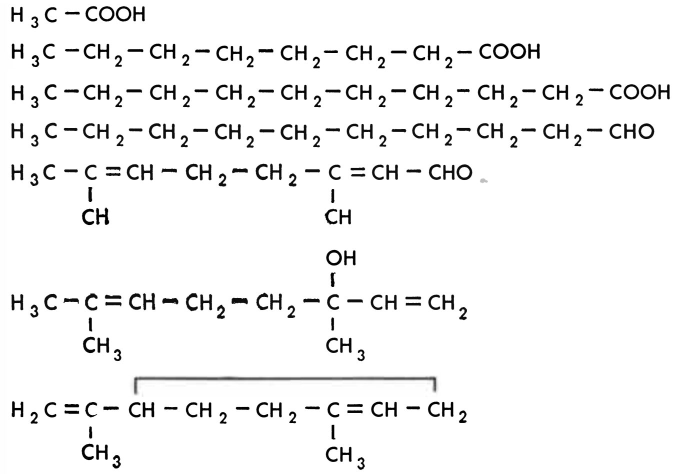
The rising modern demand for terpenes is fortunately met by the utilization of old pine stumps still remaining from cut-over virgin forests. Enlightened use of existing forests, coupled with an intensive reforestation program, promises a continuing supply in the future. The U. S. essential oil industry also supplies millions of pounds of oil used in the flavoring industry. Oils of peppermint, spearmint, orange, lemon, sassafras, bitter almond, mustard and wintergreen find their way into candies, ice cream or soft drinks. For medicinal purposes, small amounts of oil of erigeron, wormwood, wormseed and tansy are produced. To satisfy the demands of these industries dozens of oils are imported from all parts of the world.

TO FIND OUT what these oils really are, it might be well to return to our first experiment, wherein we pressed some oil from the peel of an orange. For chemical investigation we need at least a few ounces of oil, and we might follow the practice of the Italian orange presser, who squirts the oil on a sponge until it is saturated. Next he squeezes the oil from the sponge into a pail. We are probably not as skilled as the Italian farm boy, who handles some 3,000 oranges and collects about three pounds of oil a day. Nevertheless, after a few hours we shall have enough oil to start the analytical work. A fractional distillation shows that the bulk of the oil, boiling at 349 degrees Fahrenheit, consists mainly of one compound made up of molecules composed of 10 carbon atoms and 16 hydrogen atoms. It is identical with a compound, limonene, isolated from lemon oil. Further analysis shows that this main component is accompanied by small amounts of alcohols, aldehydes and acids.

Looking only at the carbon skeletons of these components, two groups emerge. One, which includes decyl aldehyde, octyl alcohol, caprylic, capric and acetic acid, has carbon linkages of different lengths, with the carbon atoms forming regular chains like strings of beads. The other group is quite different. All three compounds in this group consist of 10 carbon atoms, eight of which form a regular chain, while the remaining two are attached somewhere along this chain. Their position on the chain, however, is not haphazard, as a survey of the hundreds of similar compounds from differ-



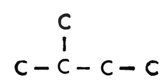
OLEORESINS from gashes in southern pine and from old pine stumps form the biggest essential oils industry: turpentine and certain terpenes.



ACETIC ACID
CAPRYLIC ACID
CAPRIC ACID
DECYLALDEHYDE
CITRAL
LINALOOL
LIMONENE

ORANGE OIL has many built-up isopentane (five-carbon chain) components. The major one is fragrant limonene, first identified in lemon peel.

ent oils shows. There is a recurrence of a five-carbon isopentane unit which is typical for these structures:



When two of these isopentane units are coupled, as in limonene or citral, the name terpene is used, a reminder that this type of compound was first discovered in turpentine. In this double-isopentane group we find valuable perfume and flavor compounds, such as geraniol from oil of roses and menthol from oil of peppermint. In the higher boiling fractions of the oils, the building principles of the terpenes is continued in compounds consisting of three isopentane units. Since they contain one and a half times as many carbon atoms as the terpenes, they are known as sesquiterpenes. They, too, are valuable perfume compounds, and among them are the odoriferous principles of sandalwood and lily of the valley. The occurrence of this isopentane pattern presents an interesting problem, especially in view of accumulated evidence that this type of structure is a building principle quite frequently seen in both plants and animals.

Still other members of the terpene series were found in the residues from the steam distillation of oleoresins. Resin consists for the most part of acids such as abietic acid, a compound with 20 carbon atoms belonging to the group of diterpenes. An important member of this group is phytol, which is part of the molecule of chlorophyll, the green pigment of plants. Interesting higher analogues consisting of six isopentane units are found in the saponins, present in soap root. Other triterpenes are squalene, found in liver, and lanosterol, a constituent of wool fat. Still higher polymers are found in the yellow and orange pigments known as carotenoids, present

STEAM DISTILLATION is the oldest method for getting essential oils from plants. A primitive Javanese distillation apparatus here extracts cananga oil.

IDEAS HAVE PROPELLED THE DETERGENT INDUSTRY through a period of soaring growth. Until recently, chemists were limited to a small group of basic materials around which to build their formulae. Now the detergent industry, with a wide range of "building blocks" at its disposal, can construct a variety of products to do specific cleaning jobs. That vast new markets have been tapped is evidenced by the estimated 1952 synthetic detergent production—over 1.7 billion pounds, or a 4-fold growth in a 5-year period.

IDEA-CHEMICAL

produces a versatile detergent that makes a laundry's washday simpler

Delicate fabrics . . . hard water . . . acidic wash solutions—these are problems facing commercial laundries, problems that demand maximum versatility in the detergents used as washing powders.

That's one reason why the detergent industry is turning with increasing interest to an Idea-Chemical from Du Pont—Lorol* 5 Fatty Alcohol—a mixture of saturated higher fatty alcohols ranging from C_{10} to C_{18}. One manufacturer, for example, uses this Idea-Chemical as a basic raw material in the manufacture of a washing powder reported to be "ideally suited to the varying conditions encountered in commercial laundries." Produced as the sodium salt of the sulfated fatty alcohols, this detergent is not affected by hard water and retains its cleaning power in acidic washing solutions. In addition, it thoroughly—yet safely—cleans nylon, rayons, silks and other fine fabrics.

But "Lorol" 5 Fatty Alcohol is only one of the Idea-Chemicals from Du Pont helping the detergent industry do a better job. Hydroxyacetic Acid—used in the formulation of mild but effective acid detergents for cleaning dairy equipment—is another example of how the industry is finding ever-increasing applications for these versatile chemical products.

*REG. U. S. PAT. OFF

Write for our new booklet on Polychemicals products for industry

These products for the detergent industry are typical. Polychemicals products for industry include amides, alcohols, esters, organic acids, solvents, resins and plastics. For more information about products which may be useful in your industry, send for our new booklet, "Products of the Polychemicals Department." You'll find descriptions, properties, uses, possible applications and other data. Write on your business letterhead for your copy. We will gladly cooperate with you on any applications for Polychemicals products you would like to investigate.

E. I. DU PONT DE NEMOURS & CO. (INC.) • POLYCHEMICALS DEPT. 598 • WILMINGTON 98, DEL.

DU PONT
REG. U. S. PAT. OFF
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY
Polychemicals
DEPARTMENT
CHEMICALS • PLASTICS

VACUUM STILLS fractionate fruit and flower extracts used in perfumes, which are obtained by modern steam or solvent extraction processes.

in orange peel and in many flowers. Finally we see the elementary unit repeated 1,000 times in such polyterpenes as rubber and caoutchouc.

MANY THEORIES have been given to account for this characteristic terpene pattern, and many intermediates have been postulated in their synthesis. The availability of isotopic material has made it possible to test some of these hypotheses, and it was found that the carbon atoms of isotope-labeled acetic acid are incorporated into the molecules of the terpenes. It was even possible to assign a distinct origin to each carbon, as arising from the methyl or carboxyl group of acetic acid. The pattern of synthesis finally emerging is as follows:

M — C — M — C — M — C — M — C —
      | |
     M   M

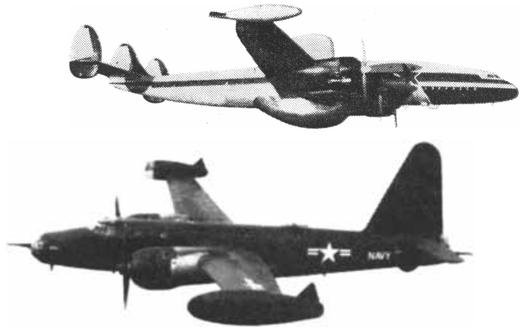
Here M represents the carbon of the methyl, and C that of the carboxyl group. Similar experiments in the biological synthesis of fatty acids have shown that these, too, are derived from the coupling of acetate molecules, in which the carbons of the methyl and carboxyl groups alternate. The formation of the terpenes is apparently related to the fundamental processes of fat synthesis, and the occurrence of both straight and branched-chain compounds in many oils is no longer surprising.

THE DIVERSITY of products contained in the oils raises the question whether they have some particular function in the plant. There is no doubt that some of the higher terpenes—phytol and carotenoids—take part in the assimilation processes leading to carbon dioxide formation. However, we are at a loss to account for most of the oil constituents. Some may serve as a means of attracting or repelling insects. Others may give protection against wounding or function as reserve food.

At best these explanations apply only to isolated cases. As a rule the oils accumulate during the lifetime of the plant, and after death the oil is found to persist. The guayule plant, which accumulates from 15 to 20 per cent of its dry weight in the polyterpene rubber, never makes use of this energy source. The naval stores industry draws largely from the supply of oils and resins left in stumps which have been in the ground hundreds of years. This resistance to decomposition might well be the reason for the accumulation of the oils in the plants. Their interfering action in many biological reactions may cause thickening of the surrounding cells and changes in the normal metabolism, resulting in the formation of cork and mucilaginous layers with low permeability to the oil.

The essential oil vapors do reduce the amount of water lost by the plant, and also decrease its movements toward light and in response to gravity. This rather non-specific effect may be of importance to the plant on hot and sunny days when excessive transpiration has to be avoided. However, at present it is as premature to endow the oils with certain functions as it is to regard them as mere waste products of plant metabolism.

In the past the chemical investigation of the essential oils has contributed materially to the development of organic chemistry, and it still continues to provide interesting examples of the synthesizing ability of plants and animals. Following the pattern set by nature, the perfume and flavor industries have learned to duplicate some of the natural materials by artificial synthesis, thus bringing good perfumes within the reach of many. This increased use has in turn created a greater demand for the natural oils, which are still indispensable in quality products.



Three reasons

why Lockheed in California

offers

better careers for engineers

1 *Diversified Production*

Huge luxury airliners, cargo transports, fighters, bombers, trainers and radar search planes are rolling off Lockheed assembly lines. Twelve models are in production.

2 *Diversified Development Projects*

The most diversified development program in Lockheed's history is under way—and it is still growing. The many types of aircraft now in development indicate Lockheed's production in the future will be as versatile as it is today—and has been in the past.

3 *Diversified Living*

You work better in Lockheed's atmosphere of vigorous, progressive thinking—and you live better in Southern California. You enjoy life to the full in a climate beyond compare, in an area abounding in recreational opportunities for you and your family.

This capacity to develop and produce such a wide range of aircraft is important to career-conscious engineers. It means Lockheed offers you broader scope for your ability. It means there is more opportunity for promotion with so many development and production projects constantly in motion. It means your future is not chained to any particular type of aircraft—because Lockheed is known for leadership in virtually all types of aircraft.

Lockheed's versatility in development and production is also one of the reasons it has an unequaled record of production stability year after year.

Lockheed

AIRCRAFT CORPORATION
Burbank, California

The Genetics of the Dunkers

In the hands, ears and blood of the members of this small religious sect a geneticist finds evidence for an important force in human evolution: genetic drift

by H. Bentley Glass

THE DUNKERS, a small, sober religious sect that originally settled in eastern Pennsylvania, possess a characteristic of great interest to human geneticists. They are a group genetically isolated by strict marriage customs in the midst of a much larger community. Their beliefs have kept them distinct for more than two centuries. When Milton S. Sacks, director of the Baltimore Rh Typing Laboratory, and I were searching for a group in which to study how present blood-type and other hereditary differences arose in human populations, we turned to the Dunkers. Not only were they ideal for the study but also they opened up a larger area of inquiry. In them it is possible to perceive how racial differences which today distinguish millions of men first emerged and became set, so to speak, in small populations.

For 20 years anthropologists and geneticists have been increasingly aware of the importance in evolutionary processes of population size. In prehistoric times, when man was a hunter and gatherer, the world was sparsely inhabited. Hunting tribes are never large—1,000 people or so at most—and each tribe must range a rather large area to secure food and clothing. To keep this area inviolate and the tribe intact, primitive social customs include a simple avoidance of outsiders as well as active hostility, head-hunting and cannibalism. Such customs tend to keep each tribe to itself and to make intermating between tribes quite rare. This was the period in human history when racial differences must have arisen and become set.

Such traits were probably established either by natural selection or by genetic drift, a term which may be explained as follows. In large populations chances in opposite directions tend to balance—*e.g.*, boy babies would generally equal girls in number—and the frequency of any genetic trait is expected to repeat itself generation after generation. But in small groups chance fluctuates more around the expected norm. No single family, for instance, is certain to have an equal number of boys and girls, and a predictable number of families will have all one or the other. If, in a small population, the initial proportion of brown eyes and blue were equal, the following generation might by chance have 45 per cent brown eyes and 55 per cent blue. This variation would then be expected to repeat itself by genetic law. However, the next generation might again by chance return to the 50-50 ratio or might shift to 40 per cent brown and 60 blue. If the latter were to happen, the expectation for the next generation would again be shifted, and this cumulative change by pure chance is what is meant by genetic drift. The phenomenon might continue until the whole population was either blue or brown eyed. Which ever way it went, once it had gone all the way it could not easily drift back. At that point it would be fixed in character until some mutation of the gene for eye color occurred. The chance of this in a small population is low, because the probability that a single gene will mutate is generally only one in 100,000 or even one in a million.

The actual operations of genetic drift are hard to pin down at this late date. Some present-day primitive peoples have been observed to have sharp divergences of inherited traits. The Eskimos of Thule in northern Greenland, where we are building a big air base, have a much higher frequency of the gene for blood group O (83.7 per cent) and a lower frequency of the gene for blood group A (9 per cent) than other Eskimos. They live far to the north and rarely mingle with the more populous Eskimo communities of the south. The Thule tribe numbers only 57. While its differences are probably due to genetic drift, we cannot rule out the possibility that some pressure of natural selection has operated more rigorously on blood-group genes in the far north than in the milder south.

A parallel case occurs in the aborigines of South Australia, whose traits have been studied for more than a decade by Joseph B. Birdsell of the University of California at Los Angeles. Among the South Australian desert tribes is the Pitjandjara, whose frequency of the gene for blood group A exceeds 45 per cent. To the west is a tribe of the same stock but having a much lower frequency of the group A gene (27.7 per cent); to the east is an apparently unrelated tribe with a frequency of this gene still lower (20 to 25 per cent). All three tribes are much more nearly alike in frequency of genes for the blood group MN. This is a situation to be expected from genetic drift, for it is not likely that in small populations chance will act on unrelated genes in the same way. But here again it is impossible to prove that genetic drift is the real agent. Each tribe has its own slightly different territory, customs and way of life: who is to say that it is not natural selection in a particular environment which has favored the marked increase of blood-group A in the Pitjandjara?

To get at the elusive drift in the frequencies of alternative kinds of genes, a small community of known origin is required, existing as nearly inviolate as possible in a larger civilization. After some discussion, it became apparent to Sacks and me that these requirements might happily be met right here among various German religious sects which immigrated to the U. S. in the 18th and 19th centuries. Not only are many of these sects still held together by strict rules regarding marriage, but also we have precise knowledge of their racial origins. This gives a starting point for comparison, since the present genetic composition of their homeland is also known. Moreover, they are now isolated in a much larger population, which provides an even more important basis for comparison. If natural selection or intermarriage were to influence their gene frequencies, these frequencies would shift from those of the homeland toward those characteristic of the large surrounding population. But if any sharp divergencies showed up, they would be attributable not to natural selection but to genetic drift.

After some exploration, a Dunker community in Pennsylvania's Franklin

DUNKERS of the study described in this article live in Franklin County, Pa. Although they seldom marry outside the sect and their dress differs from that of their neighbors, their customs are not otherwise unusual.

GENETIC DRIFT is depicted by disembodied eyes. The group labeled 1 represents a small population in which 50 per cent of the people have brown eyes (*dark in drawing*) and 50 per cent have blue eyes (*light*). Group 2 shows a second generation in which 45 per cent of the people have brown eyes and 55 per cent have blue eyes. Group 3 indicates a third generation in which, if the proportion of brown eyes to blue did not return to that of the first generation, the percentages might be 40 for brown eyes and 60 for blue.

County was settled upon. No small part in influencing the choice was played by Charles Hess, a young medical student at the University of Maryland and a Dunker. He became interested in the project and gave invaluable help in collecting information and blood samples and in winning the cooperation of the Dunkers, without which the project could not have been carried out.

THE DUNKER sect, more formally known as the German Baptist Brethren, was founded in the province of Hesse in 1708, with a second center arising at Krefeld in the Rhineland. Between 1719 and 1729 some 20 families from the latter place and 30 from the former completely transplanted the sect to the New World, settling around Germantown, Pa. Over the next century the Dunkers doubled in number, and nearly all of them were descended from the original 50 families. To marry outside the church was a grave offense followed by either voluntary withdrawal or expulsion from the community. By 1882 the sect had grown to 58,000 and spread to the Pacific Coast. Under this steady drain to the frontier the Pennsylvania groups remained fairly stationary in numbers. The Franklin County or Antietam Church community, the subject of this study, seems never to have grown larger than a few hundred persons up to 1882.

In that year a schism split the church and further contracted the size of this and other communities. For some time there had been trouble between those who wished to retain all the old tenets of the sect and those who wanted some relaxation of the more restrictive rules governing baptism, foot-washing, love feasts, head coverings for women, sober dress for men and the like. An open rupture finally separated the strict Old Order, as well as a Progressive group, from the main body, which went on to form the present-day Church of the Brethren. The Franklin County community studied by us remained in the Old Order, which from that day to this has numbered only about 3,000 people scattered in 55 communities over the country.

In all visible respects the Franklin County Dunkers live as their neighbors live. Most of them are farmers, though some have moved to the county's two medium-sized towns. They own cars and farm machinery; most have modest but comfortable frame houses; their food is typically American; the children attend public schools; medical care is good. Distinctions of dress are not conspicuous to the degree seen, for example, in the better-known Amish sect. Except for strict adherence to their religion, the Dunkers are typical rural and small-town Americans. In marriage pattern the community is not wholly self-contained. Over the last three generations about 13 per cent of their marriages were with members of other Old Order communities and about 24 per cent with converts, a factor taken into account in our study. Thus in each generation somewhat more than 12 per cent of the parents in the community came in from the general population. The equalizing force of this "gene flow" from outside would of course tend to make the Dunkers more like everyone else in hereditary makeup. The effects of genetic drift, if perceptible, would have to be large enough to overcome the equalizing tendency. Altogether the community now numbers 298 persons, or 350, if children who have left the church are included. For several generations the number of parents has been about 90. This, then, is exactly the type of small "isolate" in which the phenomenon of genetic drift might be expected to occur.

THE CHARACTERISTICS chosen for study in the Dunker group were limited to those in which inheritance is clearly established and in which alternative types are clear-cut, stable and, so far as is known, non-adaptive. The frequency records of these characteristics were available for both the West German and North American white populations, or at least the latter. Complete comparisons could be made for frequencies of the four ABO blood groups (O, A, B and AB) and the three MN types (M, MN and N). The Rh blood groups were almost as good. Although no Rh frequencies are available from West Germany, other European peoples have been studied, the English very extensively, and it is evident that all West Europeans are quite similar in this respect. Four other traits were examined in which the Dunkers could at least be compared with the surrounding American population. These were: (1) the presence or absence of hair on the middle segment of one or more fingers, known as "mid-digital hair"; (2) hitchhiker's thumb, technically called "distal hyperextensibility," the ability to bend the tip of the thumb back to form more than a 50-degree angle with the basal segment; (3) the nature of the ear lobes, which may be attached to the side of the head or hang free; and (4) right- or left-handedness.

The findings were clear-cut. They show that in a majority of all these factors the Dunkers are neither like the West Germans nor like the Americans surrounding them, nor like anything in between. Instead, the frequencies of particular traits have deviated far to one extreme or the other. Whereas in the U. S. the frequency of blood group A is 40 per cent and in West Germany 45 per cent, among the Dunkers it has risen to nearly 60 per cent, instead of being intermediate as would be expected in the absence of genetic drift. On the other hand, frequencies of groups B and AB, which together amount to about 15 per cent in both major populations, have declined among the Dunkers to scarcely more than 5 per cent. These differences are statistically significant and unlike any ever found in a racial group of West European origin. One would have to go to the American Indians, Polynesians or Eskimos to find the like. The ancestry of all 12 persons with blood groups B and AB was checked to find out whether their B genes had been inherited from within the community. Only one had inherited this blood factor from a Dunker ancestor in the Franklin community; all the others had either been converts or married in from other Dunker groups. Evidently this gene was nearly extinct in the group before its recent reintroduction.

The three MN types showed even more unexpected trends. These have almost identical frequencies in West Ger-

EAR LOBES either hang free or are attached to the head. Among Dunkers there are fewer attached lobes than among the U. S. population as a whole.

many and the U. S.: 30 per cent for type M, 50 for MN and 20 for N. In the Dunkers the MN percentage had diminished slightly, but frequencies for the other two types had deviated radically. M had jumped to 44.5 per cent and N had dropped to 13.5. One would have to go to the Near East or look in Finland, Russia or the Caucasus to find any whites with hereditary MN distributions like these. Only in the Rh blood groups do the Dunkers not differ greatly from their parent stock or adopted land. As against an average of close to 15 per cent for the Rh-negative type in both English and U. S. populations, the Dunkers show 11 per cent.

From the other traits in which comparisons were made almost equally striking conclusions can be drawn. Without going into details, the Dunkers had fewer persons with mid-digital hair or hitchhiker's thumb or an attached ear lobe than other U. S. communities. Only in right- and left-handedness, as in the Rh blood types, do the Dunkers agree well with the major populations used for comparison.

THERE SEEMS to be no explanation for these novel combinations of hereditary features except the supposition that genetic drift has been at work. To clinch the matter, the Dunkers were divided into three age groups—3 to 27 years, 28 to 55 years and 56 years and older—roughly corresponding to three successive generations. When the ABO blood types were singled out, it was at once apparent that their frequencies were the same in all three generations. It follows that the unusual ABO distribution is of fairly long standing and antedates the birth of anyone still living. When the same analysis of MN blood types was made, however, a very

THREE OTHER CHARACTERISTICS were studied. One was "hitchhiker's thumb" (*hand at top*), the ability to bend the end of the thumb backward at an angle of more than 50 degrees. The second was "mid-digital hair" (*hands at lower left*), or hair on the middle segments of the fingers. The third was right-handedness *v.* left-handedness (*hand at right*).

different story emerged. In the oldest generation the M and N genes were exactly the same in frequency as in the surrounding population. In the second generation the frequency of M had risen to 66 per cent and N had dropped to 34. In the third generation this trend continued, M going to 74, N sinking to 26. While other genes remained unaltered in frequency, these genes were apparently caught in the act of drifting.

Let us consider the phenomenon a little more deeply. There can be no doubt from these instances that genetic drift does occur in small, reproductively isolated human groups in which the parents in any one generation number less than 100. Drift is probably somewhat effective, though slower, in populations two or three times that size. Such were the tribes of man before the dawn of agriculture. How inevitable it was, then, that numerous hereditary differences, perhaps of a quite noticeable but really unimportant kind, became established in different tribes. It is my opinion, no doubt open to dispute, that most inherited racial differences are of this kind and were not materially aided by natural selection.

Some traits, of course, must originally have been fixed by selection. Dark skin is probably a biological advantage in the tropics, while pale skin may be an advantage in weaker northern light. The same may hold for kinky hair as against straight hair, for dark eyes as against light eyes, and the like. Many possibilities of this kind have been suggested in a recent book, *Races: A Study of the Problems of Race Formation in Man*, by Carleton S. Coon, Stanley M. Garn and Joseph B. Birdsell. I remain skeptical when I think of the prevailing hairlessness of man in many regions where more body hair would have helped to keep him warm. I am particularly skeptical of any selective advantage in blondness, "the most distinctive physical trait or group of traits shown by Europeans." It seems more likely that these traits confer no advantage to speak of, in Europe or elsewhere. I would add that if blonds had been eliminated by selection in other parts of the world, and if a blond type happened by genetic drift to become established in Europe, then it could have persisted and spread in large populations and given rise to the present racial distribution of the blond caucasoid or "Nordic" man.

THE STUDY of the Dunker community confirms the suspicion of many anthropologists that genetic drift is responsible for not a few racial characteristics. Further studies along these lines, together with studies of mortality and fertility in contrasted hereditary types, may in time tell us which racial traits were established because of selective advantage and which owe their presence solely to chance and genetic drift.

THE ORIGIN OF THE ATMOSPHERE

Air is the product of vast events in the geologic past. The knowledge acquired by many sciences may be brought together to provide a reasonable account of its history

by Helmut E. Landsberg

MOST of us take the Earth's mantle of air for granted and, except for slight annoyance at some of its weather, regard it as stable. Yet the atmosphere has undergone a dramatic evolution and it is still changing slowly. What it has evolved from and what it is changing to are matters for conjecture, with considerable leeway for scientific debate. But neither the first nor last stages of the Earth's atmosphere appear to be compatible with any life processes we know.

Before plunging into the speculations which support this view, it might be well to examine the present composition of the air we breathe. Here the facts are at least ascertainable, even if they have not all been ascertained as yet. At the Earth's surface air is a well-known mixture of oxygen and nitrogen, plus small amounts of carbon dioxide and the rare gases argon, neon, krypton and xenon. This mixture is almost constant in proportions, with only minute local and seasonal fluctuations. Other constituents of the lower atmosphere, especially water vapor and dust particles, are quite variable, changing rapidly with altitude. Above six to nine miles there is good evidence that water vapor is almost completely absent, and dust decreases rapidly the higher we go. The gassy constituents, however, remain fairly constant at least 44 miles up, though 99 per cent of the air mass is below 25 miles, while traces of air have been observed well above 600 miles.

In the uppermost 2 per cent of the air variations and reactions occur. At about nine miles photochemical processes begin to take place, the most prominent being the formation by short-wave solar radiation of ozone, the three-atom form of oxygen. At about 14 miles the ozone layer is at its maximum, and any sudden removal of this layer, which absorbs much of the burning ultraviolet radiation from the sun, could threaten all life on Earth. At about 44 miles samples of air recently brought back by rocket indicate that some change in equilibrium begins to occur, with lighter constituents increasing over heavier ones. The precise extent of this gravitational de-mixing of the atmosphere at high altitudes is not yet known. At still higher altitudes spectrographic studies identify such different constituents as nitrogen oxides, deuterium oxide and formaldehyde, while the proportions of other gases appear radically changed compared to surface values.

At the outer limits of the atmosphere, under the naked bombardment of solar and cosmic radiations, there is a veritable witches' brew of molecules and atoms, both in electrically neutral and ionized states. During the hours of darkness many photochemical reactions reverse themselves, causing a continual stirring and changing of physical form. These ionospheric phenomena are mainly of interest in studying radio propagation, but they also have an important bearing on the first problem to be met in considering the origin of the atmosphere, which is: Why hasn't the atmosphere streamed off into outer space?

The escape of gases from the Earth is governed by two sets of factors. One is their temperature and density at the perimeter; the other is the size, mass and gravitational pull of the Earth. To overcome the latter, a body shot upward must exceed a speed of seven miles a second to escape into space. Escape velocities for other planetary orbs of different size and mass range from only 1.5 miles per second on the moon to 3.1 on Mars, 6.5 on Venus and 38 miles per second on giant Jupiter. The higher the escape velocities required, the lighter the gases which can be retained, for light molecules have higher average velocities than heavy ones. The average velocity for hydrogen in the Earth's atmosphere is 1¼ miles per second, while that for heavier nitrogen and oxygen averages only ¼ mile per second. The speed and direction of individual molecules are governed by the frequency of collision with other molecules, which in turn is determined by heat and density. Thus it becomes a statistical problem as to how often individual molecules in collision near the boundary of the atmosphere will achieve velocities sufficiently higher than average, in the right direction, to escape from the Earth.

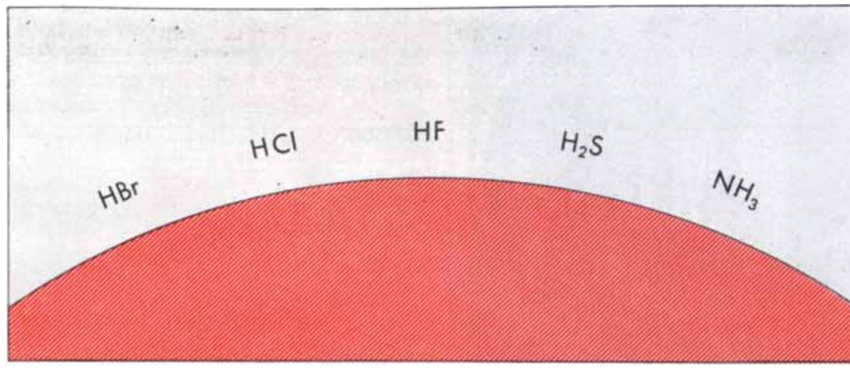
We can calculate for a given temperature in the highest regions the time it would take a given gas to escape. Most temperature estimates for the region above 185 miles center, with some uncertainty, around 2,370 degrees Fahrenheit. At this heat it would take only about 4,000 years for most of the hydrogen to escape. However, it would require 10^{45} and 10^{51} years respectively for nitrogen and oxygen to disappear. Since the Earth thus far is only an estimated three billion years old, these two gases are not likely to vanish very soon. One difficulty, however, is the problem posed by helium. This gas is continuously formed on Earth by radioactive processes, yet it has not accumulated in the atmosphere, hence it must be continuously escaping. But at 2,370 degrees F. it would take about 4×10^{13} years to escape, which is over 10,000 times the estimated age of the Earth. Lyman Spitzer, Jr., of Princeton University suggests that if temperatures at these heights reached 4,200 degrees for only 2 per cent of the time—and such sporadic increases could readily be caused by radiation from solar eruptions—then the escape of helium would be accounted for.

From these calculations we may see that the Earth can, indeed, hold an atmosphere of essentially its present composition for a long period. Nothing in this implies, however, that there will be no further changes in its composition, and we may now ask the question: Has the atmosphere's composition always been the same?

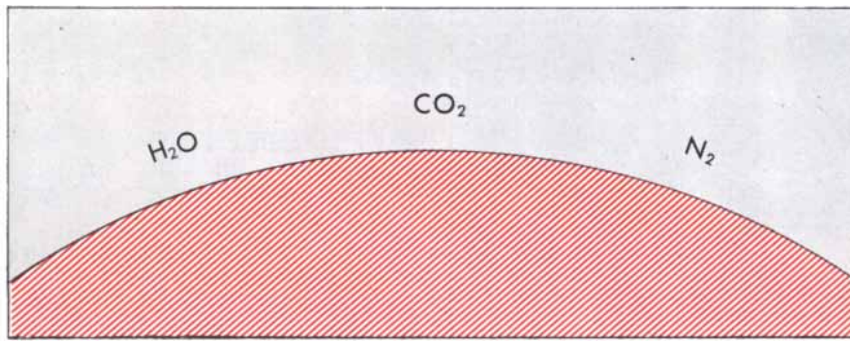
An answer can be arrived at by observing the present status of the rare gases. These are heavy enough to be permanent ingredients in the atmosphere and so inert that they must have been present in any original atmosphere the Earth might have had. The signal fact is that the rare gases are present here in only small amounts, much smaller than those known elsewhere in the universe. At the same time, oxygen, nitrogen, carbon dioxide and water vapor are present in much greater abundance than elsewhere. The relative distribution of the elements in the universe has been determined by spectroscopic analysis of solar and stellar matter and by chemical analysis of meteorites. These show that the rare gases are present here in only a few millionths to a billionth of their cosmic abundance. Now, since the solar system and probably the known universe are generally assumed to have been formed simultaneously, the Earth should have obtained a reasonably proportionate share of the various elements. Some of these could have escaped later. The minute fraction of rare gases left here leads to the conclusion that early circumstances were such that the Earth lost all its original atmosphere.

At this point we will have to indulge in some speculation about the early physical stages of the Earth. No matter how our imagination pictures them, we cannot get around the postulation that the surface temperature was very much higher than it is now. At higher temperatures, on the order of 14,500 degrees F., most gaseous substances would escape rapidly. Geochemical reasoning indicates that the earliest atmosphere contained some compounds of chlorine, fluorine, bromine, iodine and sulfur, as well as ammonia. At such heats, however, this rather unhealthy mixture could not have lasted for very long, and Atmosphere I must have vanished almost instantly as geological time goes.

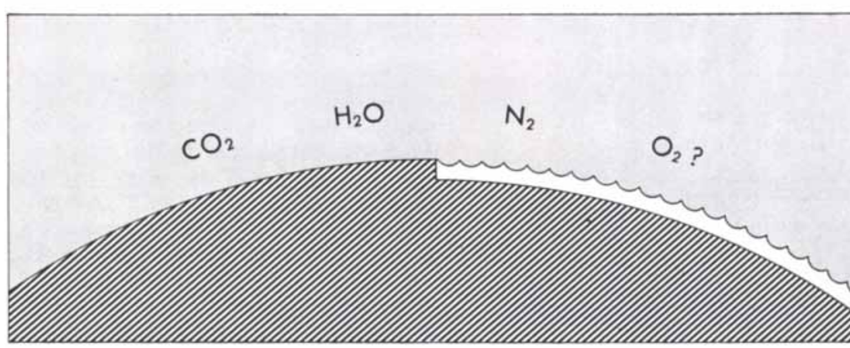
As the molten rocks cooled very rapidly in the second stage, they probably gave off gases which dissolved in the melt. Among these were water vapor, carbon dioxide and nitrogen, in about that order, and they probably comprised at least 90 per cent of Atmosphere II. Surface temperatures were then several hundred degrees. This stage may be compared with present-day exhalations and conditions around active volcanoes, and while it would be bold to assume that there is complete correspondence, this is likely to be as good an assumption as we can make. Volcanic exhalations vary considerably one from another, and even from one eruption to another. But suppose we take the mean composition of gases from Halemaumau in Hawaii. Here water vapor is 68 per cent of the gases by volume, carbon dioxide is 13



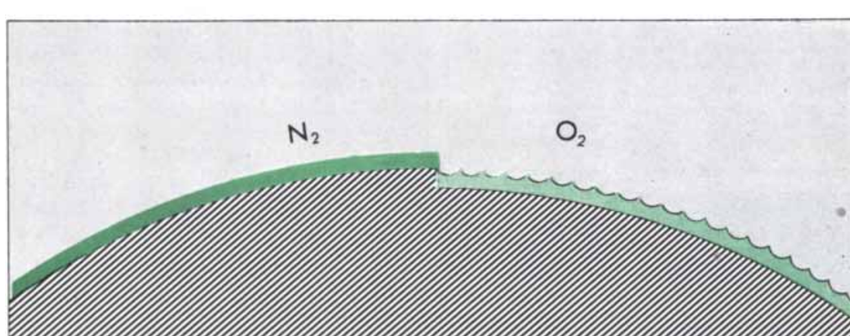
ATMOSPHERE I enveloped the Earth when it was very much hotter than it is today. It is thought that ammonia (NH_3) and compounds of such elements as bromine (Br), chlorine (Cl), fluorine (F) and sulfur (S) were present.



ATMOSPHERE II replaced Atmosphere I as the Earth cooled somewhat. Its principal constituents were probably carbon dioxide (CO_2), water (H_2O) and nitrogen (N_2). This mixture resembles a modern volcanic gas.



ATMOSPHERE III succeeded Atmosphere II when the Earth cooled sufficiently for water vapor to condense into oceans. This atmosphere may have contained some oxygen liberated by the photochemical breakdown of water.



ATMOSPHERE IV is the air of today. The carbon dioxide of Atmospheres II and III has been fixed in photosynthetic plants (*green*) and carbonate rocks. The plants are similarly responsible for replenishing the oxygen.

CONSTITUENT	SYMBOL	PER CENT (BY VOLUME)
NITROGEN	N_2	78.084
OXYGEN	O_2	20.946
ARGON	A	.934
CARBON DIOXIDE	CO_2	.033
NEON	Ne	.00001818
HELIUM	He	.00000524
METHANE	CH_4	.000002
KRYPTON	Kr	.00000114
HYDROGEN	H_2	.0000005
NITROUS OXIDE	N_2O	.0000005
XENON	Xe	.000000087

STABLE CONSTITUENTS of the air are given in this table. Nitrogen and oxygen comprise 99 per cent.

per cent and nitrogen 8 per cent, with the rest mainly sulfurous fumes. If Atmosphere II was of similar terrigenic origin, then it is important to note that there was no free oxygen.

This brings us to the question: where did atmospheric oxygen come from? It is now the second most abundant element on Earth and the one, of course, most important to life. There are three hypotheses. The first assumes that free oxygen was created in an early high-temperature stage of Atmosphere II by thermal dissociation of water vapor into hydrogen and oxygen, but this has many objections, the chief one being that the oxygen thus liberated would promptly recombine on contact with hot surface rocks. The second hypothesis proposes that oxygen was freed at a later, cooler stage by photochemical dissociation of water vapor in the upper atmosphere, but the difficulty here is to place enough water vapor at such altitudes to account for all the oxygen now in the air. Given a couple of billion years it might be possible, and at least some oxygen may well have been created by this means. The third hypothesis is the most attractive, for it explains the presence, accumulation and maintenance of oxygen by the photosynthesis reaction of carbon dioxide in plants giving off free oxygen.

The main drawback to the third hypothesis is that it requires plant life and hence a much later and cooler stage in the development of the Earth. But if we insert a few steps in the evolutionary process we may get to the point where it adequately describes what took place. As Atmosphere II cooled it would soon reach the critical temperature (705 degrees F.) at which liquid water can exist simultaneously with vapor. On further cooling, oceans could form. Once the temperature went below the boiling point of water (212 degrees F.) most of the water vapor would condense. Some of the carbon dioxide would then disappear, part of it dissolving in the water and part going into the formation of limestones and dolomites made up of calcium and magnesium carbonates.

This probably marked the end of Atmosphere II, of relatively short duration on a geological scale, and the beginning of Atmosphere III. From here on changes in the atmosphere become very slow indeed. There would be a slow feeding-in of gases from volcanic processes, along with slow interactions of weather processes on land and solution and sedimentation processes in the seas. At the beginning, Atmosphere III probably was not too radically different from II, except in lower temperatures and different proportions of gases. Initially these might have been about 74 per cent carbon dioxide, 15 per cent water vapor and 10 per cent nitrogen.

We now have to visualize a further slight but rapid cooling to about 160 degrees F., at which point life processes could begin. We cannot cover all the speculations on this point, but it is important to note that some living cells can live in an atmosphere without oxygen. The present purple sulfur bacteria are an instance of this, producing organic matter in a carbon dioxide atmosphere. Some such organisms may have been the first living things on Earth, preparing the way for the earliest green plants, which in turn would supply most of the free oxygen to support higher forms of life. Further evolution would bind about 40 per cent of the carbon dioxide in Atmosphere III, while the rest went into the deposition of carbonate rocks. Perhaps two billion years were re-

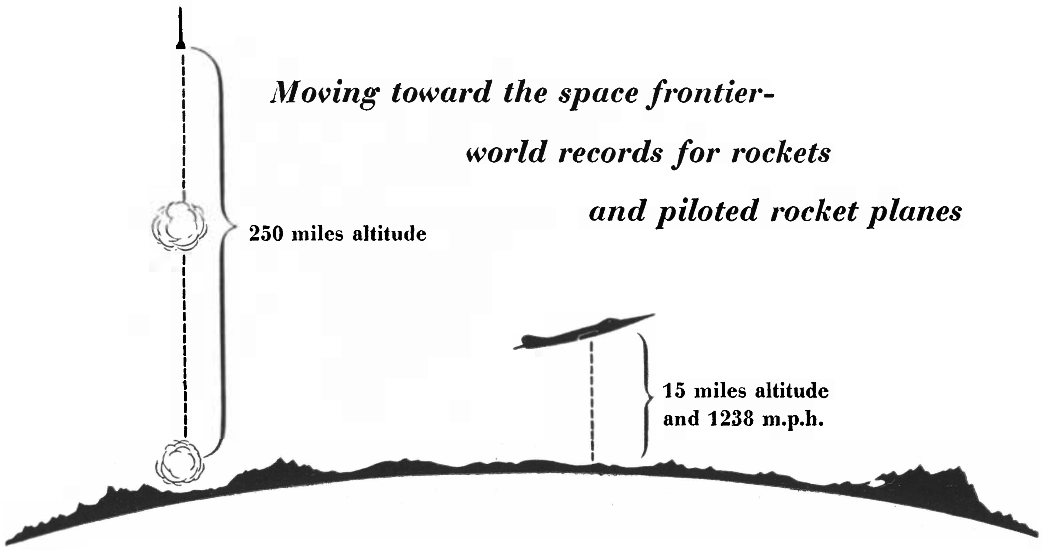
CONSTITUENT	SYMBOL
WATER VAPOR	H_2O
OZONE	O_3
HYDROGEN PEROXIDE	H_2O_2
AMMONIA	NH_3
HYDROGEN SULFIDE	H_2S
SULPHUR DIOXIDE	SO_2
SULPHUR TRIOXIDE	SO_3
CARBON MONOXIDE	CO
RADON	RaEm
DUST (SOOT, ROCKS AND SEA SALT)	

VARIABLE CONSTITUENTS are also given. There is even some variation of stable gases above 44 miles.

Moving toward the space frontier-

world records for rockets

and piloted rocket planes

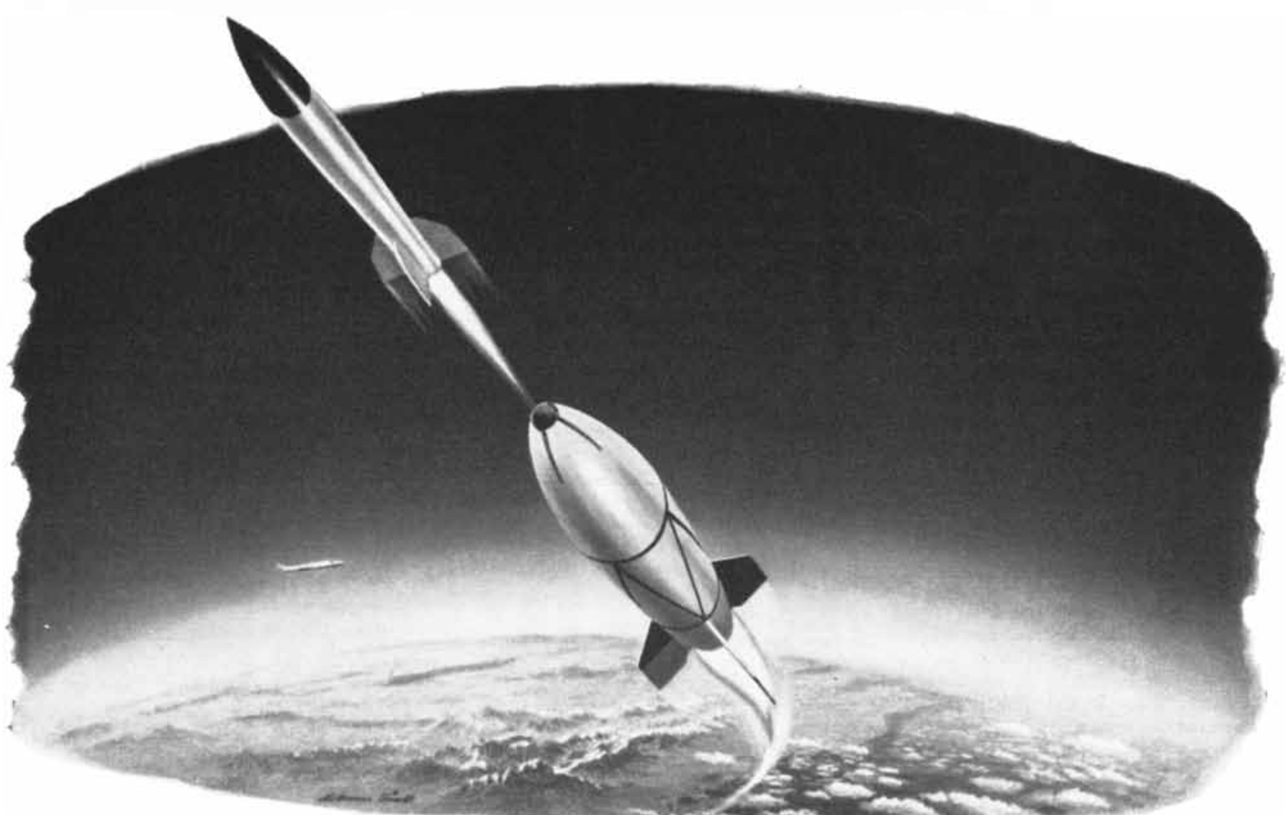


—the Douglas Skyrocket and Wac-Corporal

How soon will man cross the Space Frontier? Already, Douglas-built planes, rockets, and missiles—including the Wac-Corporal and D-558-2 Skyrocket—have probed at its fringes.

In a record climb, the Douglas D-558-2 reached an altitude where its pilot was *weightless*, as in a flight through space, while the Wac rocket, set in the nose of the V-2, travelled one-quarter of the way to the proposed orbit of a man-made satellite. Most important, both records came during *normal research*—planned to keep the United States and its Armed Forces out in front in the fields of guided missiles and supersonic aircraft.

Performance of Skyrocket and Wac-Corporal is proof of Douglas leadership in all phases of flight. *Farther and faster with a bigger payload* is the basic rule of Douglas design.



Army's Wac shown leaving V-2

Depend on *DOUGLAS* First in Aviation

quired to transform Atmosphere III into the present nitrogen-oxygen mixture of Atmosphere IV. During the past billion years this atmosphere has probably been essentially in a state of equilibrium. Production and consumption of the various gases balance. The major producer in the process is the volcanoes; the big flywheels are plants and the oceans.

One instance may be given to show how tidy is this balance. Argon constitutes nearly 1 per cent of our present atmosphere, being the third most frequent element in it. Where did it come from? Most atmospheric argon is in the isotopic form of argon 40, while a small fraction is argon 36. Argon 40 has apparently been formed by the radioactive decay of potassium 40, a rare, radioactive isotope of the more common potassium 39. At any rate, all the argon 40 now in the air can be accounted for by slow accumulation from this source.

Thus it may be shown that the Earth's atmosphere is in the fourth stage of a long evolution since the creation of the planet. Where do we go from here? Some scientists have looked at the other planets to find an answer, reasoning that one or another of them may have passed the present evolutionary stage of the Earth. Most of the planets on which we have any information, such as Venus, Jupiter and Saturn, seem to have atmospheres still in a much earlier phase than the Earth's. The only one that appears to fit a later stage is Mars, but there are major initial differences between Mars and the Earth. One is its lower density and hence much lower escape velocity. The present Martian atmosphere seems to be mainly nitrogen, argon, carbon dioxide and water vapor. No oxygen has been noted in the spectrograms. Whatever oxygen may have been present has either escaped or has been used up in the oxidation of rocks. But it is not probable that the Earth's oxygen will escape and it is a moot question whether it will be used up, so Mars provides only the cloudiest of answers.

The big question on Earth is the influence of human activity on the atmosphere. There is some evidence that industrial life has increased the amount of carbon dioxide in the air, while in certain areas such gases as nitrous oxide, carbon monoxide and sulfur dioxide are definitely on the increase. Solid suspensions and radioactive debris are also becoming more prominent. So far, however, nature holds the upper hand and cleanses many of the pollution products from the atmosphere with rainfall. Meanwhile photosynthesis still adds oxygen to the air in a mighty stream. It is only reasonable to conclude that further billions of years may elapse before Atmosphere V, with its possible composition of nitrogen, argon, carbon dioxide and water vapor, spells a grand-scale *finis* to most terrestrial life.

BOOKS

The modern view of evolution and how the paleontologist has contributed to it

by Julian S. Huxley

LIFE OF THE PAST, by George Gaylord Simpson. Yale University Press ($4.00).

I SUPPOSE that most people, if asked to name the outstanding recent achievement of science, would answer the discoveries of modern physics in the subatomic world. It is true that these discoveries are in the proper sense of the word fundamental, since they concern the ultimate bases of matter and energy, and that their applications in the sphere of atomic fission are uniquely spectacular and alarming. But to my mind they are not so essential as the achievement characterized by the one word evolution.

I use the term essential advisedly. The major upshot of the achievement of evolutionary science has been the realization that the universe in general and life in particular is not a machine but a process. All reality is in a perfectly proper sense evolution, and its essential features are to be sought not in the analysis of static structures or reversible changes but through the study of the irrevocable patterns of evolutionary transformation.

The magnitude of the evolutionary achievement has been obscured by the fact that it has been dispersed over a number of separate fields—geology, cosmology, biology, archaeology and history—and that even in the key field of evolutionary biology it has been spread over a long period of time. It is now 94 years since the revolution in biological thought was started by Charles Darwin with the publication of his *Origin of Species*. But before the revolution could be consummated, the separate sciences of comparative anatomy, embryology, ecology, animal behavior or ethology, paleontology, cytology and finally genetics had still to be independently developed, and then their partial contributions synthesized in a comprehensive whole.

This period of synthesis has occupied the past 25 years. We are now beginning to reap some of its fruits in the shape of a revivified taxonomy, a scientific natural history, a new approach to human genetics, a truly biological paleontology, and above all a clear general picture of the evolutionary process to whose framework we can relate all the partial disciplines and separate facts of both the biological and the human sciences.

As a result, evolutionary science has endowed man with a new extension of awareness. Just as the telescope provided an exosomatic sense organ which extended man's spatial range of vision and laid the basis for a new awareness of the cosmic universe, so evolutionary science, on the basis of the sensory extension provided by the microscope, has become a human organ which gives a new awareness of our planetary world.

George Gaylord Simpson has played a leading role in the synthesis of evolutionary thought. He could not have done this had he not been one of the world's outstanding paleontologists, with an immense output of first-class research, and had he not early realized that paleontology cannot be adequately pursued or properly understood without a knowledge of other branches of biology. Perhaps more than any other living man, Simpson has made paleontology come alive as a truly biological science. In this short but pregnant book he succeeds admirably in conveying to the educated layman (and, I may add, to his non-paleontological colleagues in other scientific fields) an understanding of this vital branch of biology.

Let me enumerate some of his most important points. In the first place, he makes it clear that the modern evolutionary biologist, whether working on taxonomy in the world's museums, on evolutionary genetics in the laboratory or the field, on ecology and ethology, or on the trends of evolution as disclosed by fossils, must always think in terms of populations. The old concept of an individual "type," which has underlain most of the work on zoological and botanical classification, must be repudiated. It was derived from theological ideas about creation or from metaphysical ideas about nature, and, though useful for a time as a means of introducing order into the bewildering range of organic forms, it is now a hindrance to scientific progress.

When we examine the actual course of evolution in a well-documented fossil series, we find that at any one moment of time, represented by a particular geological horizon, the fossils show a considerable range of variation in their adaptive characters. The example given by Simpson is the variation in size of molar teeth in Ectocion. This primitive hoofed mammal first appeared early in the Cenozoic period, which began some 60 million years ago and extends to the present. If we move on to the next fossil-bearing horizon, we find that evolution has taken place: the average length of the teeth has increased, thus providing a better adaptation for chewing vegetable food. The shortest teeth are now absent, and there are a few teeth that are longer than any of the earlier ones. But the bulk of the new population overlaps with the old, though the proportion of short teeth is lower and of long teeth higher. This trend continues into a third and later horizon.

The old method of classifying by types divided the fossils into species according to absolute length of teeth: the earliest population was thus assigned to three separate species, the next also to three species, excluding one from the earlier horizon and including a "new" one. This makes nonsense of the facts: it is biologically impossible for three almost identical species, obviously leading the same way of life, to coexist in a single area. What really happened was a gradual shift, in average and in extremes, of a various population. The modern biologist classifies all these fossils of Ectocion as a single species but allots subspecific rank to the populations from the three successive horizons.

It is worth recalling that, when Darwin wrote the *Origin*, no single long-continued evolutionary trend among fossils had yet been brought to light; this had to wait for 20 years until 1879, when the U. S. paleontologist O. C. Marsh demonstrated all the essential stages in horse evolution. In the three quarters of a century since then, large numbers of well-documented fossil series have come to light, both among vertebrates and invertebrates, so that paleontology today has largely become a science of evolutionary trends.

As a result we can now definitely exclude one of the main earlier theories of evolution, that of orthogenesis, of straight-line evolutionary trends in definite directions under the influence of some inner "force" or "urge." As Simpson makes abundantly clear, this simply does not square with the facts. Trends never continue in a straight line for the whole of their course. Indeed they are never single: they are composed of many separate trends, which affect different characteristics at different times, and operate at different rates in different lines of descent.

Meanwhile the progress of genetics had made it equally clear that the second of the three main theories of evolution, that of Lamarckism or inheritance of acquired characteristics, was also excluded by the facts. We are thus left with the neo-Darwinian or selectionist theory, which makes natural selection primarily responsible for evolutionary change. Simpson, in common with most modern biologists and virtually all modern geneticists, subscribes to this view (though he prefers to call it "the modern evolutionary synthesis," since it brings together facts and ideas from every branch of biological science).

He makes it clear that both the rate and the direction of evolutionary change are related primarily not to rate or directedness of mutation but to intensity and direction of selection. And this in turn, he might have added, depends on what is available in the way of evolutionary opportunity.

We may apply this last concept to one of the major facts about evolutionary trends which recent study has revealed—the frequency of parallel evolution, the way in which related but separate lines of some given group will show closely similar trends in time. This is well exemplified by the evolution of the horse family, which has now been worked out in great detail (and excellently summarized by Simpson himself in his recent book *Horses*). Over and over again we find the main adaptive themes of the group being repeated (though always with minor variation of extent and tempo) in several independent stocks or species. During the later evolution of the family, for instance, we observe the reduction of side-toes and specialization of the central hoof, and other adaptations conducive to swift running on open plains; the increase of the height of the molar teeth, the evolution of a special hard layer of enamel, and other adaptations conducive to better mastication of grasses.

Here the external evolutionary opportunity was provided by the evolution and spread of the grasses over the open plains produced by the drier climate of the later Cenozoic; the internal opportunity was provided by the as yet unrealized potentialities of the horse stock for specialized exploitation of these new conditions. For some 15 million years the opportunity was essentially the same for all the various kinds of horses; and accordingly they all evolved in a similar direction.

Another field in which the old static ideas have been rendered obsolete is that of biogeography, the geographical distribution of animals and plants. When I was an undergraduate, and indeed for some time after I had become a professor, it was still generally agreed that the world could be neatly divided into a small number of Zoogeographical Realms or Regions. There was some dispute as to the precise boundaries of some of the regions, especially between specialists who found that boundaries determined for the distribution of one group would not always fit that of another, but in general the idea of a static map of regions was accepted as the goal of biogeography and all that remained was to define its accuracy.

Today, however, this concept has been replaced by that of a few major blocks of land, corresponding to the main continental areas of today, which have undergone recurrent separation and reunion during geological time. Separation permits and indeed promotes independent differentiation, with the development of special and often unique characteristics in the local fauna and flora. Union, on the other hand, promotes migration between major blocks and reduces the degree of their special biological peculiarities.

For many cases, such as the North American and Eurasiatic blocks and the North and South American blocks, we have now abundant documentation on their past history from the late Cretaceous period, which preceded the Cenozoic. In the South American block we find three strata or historical layers of mammals. The first entered the area from the north by a land connection around the very beginning of the Cenozoic, and gave rise to an assemblage of creatures quite unlike that produced by the mammalian stock elsewhere, notably the armadillos, anteaters, tree sloths and various types now extinct.

The second stratum consisted of what Simpson calls the island-hoppers—less primitive placental mammals which later managed to enter South America by way of the chain of islands which then stretched along the region we now call Central America. These included an early primate stock which radiated into all the prehensile-tailed, flat-nosed monkeys of the modern New World, and a set of primitive rodents which were largely extinguished later in competition with the immigrants of the third stratum.

This third layer entered South America in force when the land connection with North America was reestablished, and included representatives of almost all the advanced groups of placental mammals, including carnivores, pigs, deer, horses and tapirs, camels and llamas, rats and mice. The present land fauna of South America is the resultant of these three distinct immigrations, of their subsequent differentiation in isolation over different periods of time, and of their competitive interaction.

Some of the most striking discoveries of modern paleontology concern a field in which Simpson has been preeminent—the rate of evolution. This can conveniently be measured, once enough fossil material has been collected, by the number of new genera produced by a group in each million years of evolution. In general it is found that advanced groups, whose high degree of organization has given them a dominant position in the world of life, have a faster rate of evolution than primitive groups. Thus even the successful invertebrate phylum of brachiopods (lampshells) produced only from one half to nearly four genera per million years, while true fish produced one and a quarter to over seven genera. (The highest figure for "pre-fish" or placoderms was three, while the still more primitive jawless pre-fish never reached two.)

Then there is a striking difference between aquatic and terrestrial forms, the greater variety of the land habitat acting as a stimulus to more rapid evolution. The still half-aquatic Amphibia barely reached two genera per million years, while the reptiles, for most of their history, varied between 5 and 12. The

The fossil of an extinct ganoid fish

mammals in their heyday of the Cenozoic reached nearly 30!

Finally, in no group does the rate stay constant. Bursts of relatively rapid change, resulting in much greater diversification of the group, alternate with periods of slower evolution. Thus the lampshells had one peak of rapid change in the middle Paleozoic (about 300 million years ago) and another still higher one in the middle Mesozoic (about 150 million years ago). The reptiles had two bursts, one around the end of the Paleozoic (more than 200 million years ago), the other during the Cretaceous around 100 million years ago.

Wherever we have adequate knowledge, we can relate bursts of change either to the opening of a new environment or habitat, or to the acquisition of new types of organization permitting better exploitation of an existing habitat. The former was the case with the first reptilian burst, which marked the real conquest of the land by vertebrates. The latter is illustrated by the explosive evolution of the placental mammals in the Cenozoic, which was the outcome of their higher organization with respect to temperature regulation, care of young and brain development.

This is one of the most interesting facts of evolution, and I wish that Simpson had amplified it in terms of the concept of evolutionary opportunity. Sometimes the opportunity is provided by an accident of dispersal, as when the ancestral ground-finches were blown out to the Galapagos Islands, where they found an area almost free of predators and competitors, and were therefore able to differentiate into the entire family of the Geospizidae (which more than anything else convinced Darwin of the fact of evolution). Sometimes it is provided by a geographical accident, as when Australia was cut off from access by land animals after the entry of the primitive marsupial mammals. These found an opportunity which elsewhere was denied them by the competition of the evolving placental mammals and blossomed out during the Cenozoic into the extraordinary assemblage of creatures in Australia today.

I have no room to go into the many curious and interesting details which Simpson manages to bring out in this small book: the explanation of the Devil's Corkscrews of Nebraska as the burrows of an extinct species of small beaver; the fact that for 400 million years carnivorous sea snails have been killing other shellfish by boring holes in their shells with the aid of a horny tooth ribbon; the perfectly sensible explanation of the strange development of the coiled oysters and some of the later ammonites, which had been used by mystically-minded paleontologists as proof of inner urges driving the stock to extinction; the meaning of the fantastic bony rigging borne by the Pelycosaurian reptiles on their backbones, now elucidated as primitive temperature-regulating devices serving to absorb or radiate heat as required; the amazing techniques by which fossils of various sorts are made to yield their secrets.

There are a few small points of criticism. In characterizing the main groups of plants and animals, which he does with admirable conciseness in an appendix, Simpson occasionally omits what seem to me important biological features. Thus he fails to mention the major characteristics of sponges, namely that they have evolved neither mouths nor the rudiments of nervous tissue. Similarly he neglects a central feature in the evolution of land plants—the gradual subordination of the gametophyte to the sporophyte generation—and their final liberation from the need of water for fertilization.

Again, in maintaining that the monotremes or egg-laying mammals of Australia do not represent "a stage of evolution ancestral to all other mammals," but "might be classified as therapsid reptiles," he seems to be adopting an illogical position. They secrete milk, they show incipient temperature regulation, they possess true hair, and their jaw-articulation is of mammalian type. This assemblage of diagnostic mammalian characters cannot well have been developed independently on two separate evolutionary occasions, and if it does not constitute them mammals, I do not see what meaning we can give to that term. They may not themselves be an ancestral group, but they must be derived with little change from forms at an ancestral stage of true mammalian organization.

These, however, are minor points. In general the evolutionary biologist can have nothing but praise and gratitude for this résumé, which so admirably illuminates the whole subject of paleontology and therefore the history of life. Many specialists seem afraid of committing themselves to broad generalizations about the course of evolution. Simpson, I am glad to say, is not among their number. He does not hide away among the trees of his special knowledge, but is willing to look at the forest of the whole vast subject and tell us about its form and its significance.

While reminding us that extinction is commoner than survival, and that most surviving lines eventually come to a dead end in their evolutionary development, he also traces a picture of the rarer, but in the long run, more significant trends of improvement. Among these he rightly singles out the increase of awareness and understanding as the most important. As he says in his final chapter, "of all the progressions seen in the history of life, this most merits the name of progress, that is, not merely cumulative change but also change for the better."

Nor does he hesitate to draw conclusions about man and his place in the evolutionary process. He points out that the modern view on species and on classification, which is replacing the old formalistic and non-evolutionary system of types and rigid taxonomic categories, is not merely of interest to professional biologists and museum specialists, but "profoundly affects our whole understanding of the world of life. . . . Ultimately it affects man's understanding of his own destiny and his place in the universe."

And he concludes the book with a splendid assertion of the evolutionist's view of man. Man, he writes, "stands alone in the universe, a unique product of a long, unconscious, impersonal, material process, with unique understanding and potentialities. These he owes to no one but himself and it is to himself that he is responsible. He is not the creature of uncontrollable and undeterminable forces, but his own master. He can and must decide and manage his own destiny."

We should be grateful to Simpson, not merely for his brilliant account of the facts and findings of his science of paleontology, but for this illuminating distillation of its broader significance and profounder values.

Short Reviews

Biological Hazards of Atomic Energy, edited by A. Haddow. Oxford University Press ($9.00). In October, 1950, a conference on the biological hazards of atomic energy was convened in London by the Institute of Biology and the Atomic Scientists' Association. The papers read at the meetings, reproduced in this book, are of unusual interest. They make it possible for the first time to gain a balanced picture of a danger both more and less serious, more and less terrifying than is commonly believed. Among the more noteworthy contributions are discussions of the cell and heredity under ionizing radiation by C. D. Darlington ("it is a long chain of events that connects the first damage to the cell with the ultimate good or evil done to the human race"); genetic effects of radiations by D. G. Catcheside; the "long-term" genetical hazard of atomic energy by K. Mather; the influence of radiation on the human race as a whole by E. B. Ford ("the genetic effect of atomic energy will be wholly bad because it will slightly increase the sum of misery and wastage against which the race must battle"); the fate of cells descended from individual cells of an irradiated tissue by G. Pontecorvo ("a fundamental field of radiation genetics in which the present knowledge is almost nil"); tumor induction by penetrating radiations by A. Glücksmann. In considering the moral issue C. A. Coulson insists, as Norbert Wiener, Sir Henry Dale and a few other scientists have done, that the scientist, far from being justified in claiming that he is merely a disinterested seeker of knowledge and therefore not responsible for the misuse of inventions and discoveries, has a special moral responsibility to see to it that his work contributes to human welfare rather than to universal destruction. The final essay by Kathleen Lonsdale brings to notice an appalling fact, namely that among uranium mine workers (and to a lesser extent among gold miners) there is an enormous frequency of cancer deaths. In the Czechoslovakian city of Joachimsthal, according to a paper published in 1939, the deaths from cancer among miners aged 35 to 44 were more than 30 times as great as in a similar age group of males in Vienna. Comparable statistics describe conditions at Schneeberg in Germany, and in areas surrounding the South African gold mines. Dr. Lonsdale points out that in rich uranium deposits (Canada and the Belgian Congo) the uranium oxide content of the ore is 50 per cent or more and every ton of ore contains about .1 gram of radium; yet the maximum permissible quantity of radium in the human skeleton is .0000001 gram, a quantity which will occur "in every gram of dust in the mines."

ENCYCLOPEDIA OF ABERRATIONS, edited by Edward Podolsky, M.D. Philosophical Library ($10.00). Abasia is a loss of the power to walk; abrosia is the refusal to eat; abulia is a severe impairment of the will; acathisia is the inability to sit down; aeschrolalia is a stream of filthy talk; anamastasia is the lack of energy to rise from a recumbent to a sitting position; basophobia is a fear of standing up; brontophobia is the extreme dread of thunder; chasmus hystericus is hysterical yawning; contrectation is the impulse to touch members of the opposite sex indiscriminately; gammacism is childish talk by an affected person; head-banging is plain head-banging; heterolalia is using words that are not intended by the speaker; hypobulia is haste in making decisions; hypophonia is inability to speak above a whisper; kakorrhaphiophobia is an exaggerated fear of failure; Munchausen's syndrome is a passion for gaining admittance to hospitals by giving out a Munchausen-like medical history; osphresiolagnia is the delusion that everything has an unpleasant odor; triakaidekaphobia is irrational fear of the number 13; uranomania is the delusion that one is of divine or heavenly origin. These samples are from a cooperative work to which numerous psychiatrists, psychoanalysts and psychologists have contributed. Many of the definitions are short and not always adequate; some, such as the discussions of folie à deux, dementia praecox, body image disturbances, narcolepsy, Nun's Melancholy, manic depressive psychosis, anxiety, amnesia are journal articles simply incorporated into the encyclopedia, apparently without any attempt to edit them. Despite the fact that some of the entries plainly display verbomania (torrent of words, spoken with compulsive force) this is an absorbing book, in which almost everyone will find all his friends and at least part of himself described with distressing fidelity.

THE FUTURE OF CITIES AND URBAN REDEVELOPMENT, edited by Coleman Woodbury. The University of Chicago Press ($9.00). URBAN REDEVELOPMENT PROBLEMS AND PRACTICES, edited by Coleman Woodbury. University of Chicago Press ($7.50). These symposia are the "chief products" of the Urban Redevelopment Study, financed by a grant in 1948 from the Spelman Fund of New York to a group of housing and planning organizations. The study was for the purpose of examining the problem of doing away with "the major forms of physical blight in cities and bringing about changes in urban structure and institutions contributing to a favorable environment for a healthy civic, economic and social life for all urban dwellers." This worthy objective is celebrated in two worthy and rather ponderous volumes. The essays in the first book treat topics such as the goals and methods of redesigning cities, the bearing of industrial location on city planning, the needs and desires of the city dweller, and the municipal government aspects of the problem. In the second volume among subjects considered by various experts are "measuring the quality of housing in planning for redevelopment," the economics of population densities and urban patterns, the relocation of families, and related legal and economic matters. These are careful, solid studies of a pressing subject; so solid, unfortunately, that only the specialist will have the stamina to tunnel through them.

WORLD RAILWAYS, edited by Henry Sampson. Rand McNally & Company ($25.00). For the second edition of this massive and engrossing handbook, which attempts to do for railways what the two famous Jane's manuals do for fighting ships and aircraft, the editor has mended certain shortcomings of the first and has added a considerable amount of fresh material bringing the work up to date. There is offered, for the sober use of railroad men and the delectation of enthusiasts, information on 1,447 railways, *e.g.*, Aberdeen and Rockfish (U. S.), Arcata and Mad River (U. S.), Ostsjaellandske Jernbane Selskab (Denmark), Coatzacoalcos and Campeche (Mexico), Ybbs-Kemmelbach (Austria), Zumarraga a Zumaya (Spain), Tallulah Falls (U. S.), Chemin de Fer de Sfax à Gafsa (Tunisia). The book has 125 maps of rail nets; 594 photographs of locomotives, wrecking cranes, switches, coaches, freight cars, sleeping and dining cars, tank cars and hoppers, lounge cars, refrigerator cars, control boards, refueling and watering platforms and cable cars; 256 drawings of structures and gradient profiles, and 550 pages of text and statistics.

THE TROPICAL RAIN FOREST, by P. W. Richards. Cambridge University Press ($12.50). An extensive study of all that is known of the great evergreen forests in the tropical lowlands of South America, Africa and Malaysia, which constitute about half of the entire world's forest area. Richards' ecological survey is addressed to zoologists and geographers as well as to botanists and foresters. A handsome and particularly well-illustrated volume.

SECOND ANNUAL REPORT ON STRESS, by Hans Selye and Alexander Horava. Acta, Inc. ($10.00). A guide to the literature with brief commentaries on recent developments in a field where Dr. Selye, director of the Institute of Medicine and Experimental Surgery of the University of Montreal, is the principal figure. The report, in the nature of a supplement to Selye's *Stress* (1950), lists pertinent articles in more than 4,000 publications.

THE EPIGENETICS OF BIRDS, by C. H. Waddington. Cambridge University Press ($7.00). A valuable review by a leading British geneticist of the literature since 1930 on the experimental embryology of birds. Epigenetics, in Waddington's usage, means "the science concerned with the causal analysis of development." He offers an orderly survey of a large, active and important branch of biological research, and adds his own illuminating comments. Illustrations.

ATLAS OF THE WORLD'S RESOURCES, VOL. II: THE MINERAL RESOURCES OF THE WORLD, by William Van Royen and Oliver Bowles in collaboration with Elmer W. Pehrson. Prentice-Hall, Inc. ($12.00). A cooperative work describing in text, maps, graphs and charts the location, practical availability, basic processing methods and output of the world's mineral reserves. The book covers the minerals of greatest commercial importance: coal, petroleum, iron ore, manganese, bauxite, copper, lead, zinc, tin, uranium, phosphate rock, graphite, mica, potash, salt, asbestos, sulfur and so on.

SEAWEEDS AND THEIR USES, by V. J. Chapman. Pitman Publishing Corp. ($6.00). An interesting general account of these abundant and valuable plants. Chapman explains why the algae, though an almost inexhaustible source of fertilizer, food, medicines and chemicals, have not supported a flourishing industry anywhere except in Japan. He also predicts that when certain problems are solved and a few prejudices overcome—and particularly when shortages grow more acute—seaweeds will come fully into their own as a source of food.

PERSONALITY: IN NATURE, SOCIETY AND CULTURE, edited by Clyde Kluckhohn and Henry A. Murray with the collaboration of David M. Schneider. Alfred A. Knopf ($7.50). A compendious, wide-angle anthology of papers by various specialists—biologists, psychoanalysts, sociologists, anthropologists, psychologists—on the relation of the individual to society. This second edition presents 13 new essays, including an interesting paper by Raymond A. Bauer on "The Psychology of the Soviet Middle Elite."

SPEECH AND HEARING IN COMMUNICATION, by Harvey Fletcher. D. Van Nostrand Company, Inc. ($9.75). A thoroughly revised and rewritten version of a book published in 1929 and dealing quantitatively with every aspect of an electrical communication system: the talker's method of speech and the sound waves he creates, the machine he talks into, the transmission line, the receiver, the hearing process and the relevant behavior of the listener. Several chapters summarize 30 years of work by Bell Telephone Laboratories on the perception of speech by listeners having normal hearing. For specialists.

EXPERIMENTAL NUCLEAR PHYSICS, VOL. I, edited by E. Segré. John Wiley & Sons, Inc. ($15.00). The first volume of what promises to be a most useful cooperative attempt to keep the experimentalist abreast of the techniques, findings and theoretical interpretations developing in nuclear research. The five main divisions are detection methods, passage of radiation through matter, nuclear moments and statistics, nuclear two-body problems and elements of nuclear structure, charged-particle dynamics and optics. A very well-produced volume.

MEDICINE AND PATHOLOGY, edited by V. Zachary Cope. Her Majesty's Stationery Office ($11.00). The first volume of the United Kingdom Official Medical History of the Second World War, an extensive project in which 17 additional volumes are in the making, dealing with the medical record of the fighting services, the national health at the beginning of the war, the expansion of the Health and Medical Services to meet war conditions on the civilian front, problems of wartime nutrition, medico-social changes, migrations of the civilian population to meet wartime requirements, industrial medicine, and related topics. An invaluable reference survey of the single major, undiluted benefit of the last war.

Encyclopedia of American History, edited by Richard B. Morris. Harper & Brothers ($6.00). A very handy little reference manual with three main divisions: the first is a basic chronology from 10,000 B.C. to the election of Eisenhower; the second is a topical chronology tracing certain basic topics such as territorial expansion, transportation and communication, the Constitution and the Supreme Court, the American economy, science and invention, thought and culture; the third is a collection of 300 biographies of notable Americans. There are numerous maps and charts, and a full index.

Notes

All About Ships & Shipping, edited by Edwin P. Harnack. Faber & Faber Limited ($5.50). Ninth, revised edition of a fat little illustrated handbook containing an immense amount of accurate information on the making and sailing of ships, navigational methods, the history of the British merchant navy, tides, weather, lighthouses, signals, emblems, buoys, docks, yachting and so on.

Bodily Changes in Pain, Hunger, Fear and Rage, by Walter B. Cannon. Charles T. Branford Company ($5.00). A reissue, which will be widely welcomed, of a famous pioneer study of the relations between emotional excitement and physiological change.

The Collected Works of Bernhard Riemann, edited by Heinrich Weber with a supplement by M. Noether and W. Wirtinger. Dover Publications, Inc. ($4.95). Reissue of the second edition, in the original German with a new English introduction by Hans Lewy, of the collected papers of a mathematician whose work not only foreshadowed but opened the gate to the modern revolution of the physical sciences. This is the most recent of an admirable series of reprints of out-of-print classics, an undertaking for which Dover Publications deserves the thanks of the scientific community.

Astrophysics, the Atmospheres of the Sun and Stars, by Lawrence H. Aller. The Ronald Press Company ($12.00). An advanced monograph covering methods and results of the study of stellar atmospheres and solar-terrestrial relationships. Topics include atomic and molecular spectra, the gas laws, the emission and absorption of radiation, the Fraunhofer spectrum and solar phenomena.

The History of English Law Before the Time of Edward I, by Sir Frederick Pollock and Frederic William Maitland. Cambridge University Press ($25.00). This masterpiece of English historical and legal scholarship is also a stately work of literature; a reissue of the second edition is more than welcome. The book, indispensable for students and specialists, can be recommended to any reader seriously interested in the growth of social and political institutions in medieval England.

The Outer Layers of a Star, by R. v. d. R. Woolley and D. W. N. Stibbs. Oxford University Press ($8.00). This book in the *International Series of Monographs on Physics* is concerned with "the relations between the total radiation from a star, its color, and the lines in the star's spectrum." Its point of departure is the work of A. S. Eddington, E. A. Milne and S. Chandrasekhar on radiative equilibrium.

Statistical Thermodynamics, by Sir Ralph Fowler and E. A. Guggenheim. Cambridge University Press ($10.50). Third impression, with minor corrections, of the standard student's version of the late Sir Ralph Fowler's notable study *Statistical Mechanics*.

Progress in Nuclear Physics, Vol. II, edited by O. R. Frisch. Academic Press, Inc. ($9.25). Eight papers, mostly by British scientists, reporting on various atomic energy investigations: nuclear paramagnetic resonance, neutron-proton interaction, fission, the shell model of nuclear structure, ionization by fast particles and other topics.

The Theory and Applications of Harmonic Integrals, by W. V. D. Hodge. Cambridge University Press ($5.50). The second edition of a standard monograph, with misprints and errors corrected, and one or two minor additions.

Conformal Mapping, by L. Bieberbach. Chelsea Publishing Company ($2.25). English translation by F. Steinhardt of the fourth edition of this excellent introduction to conformal geometry.

The Stars Are Yours, by James Sayre Pickering. The Macmillan Company ($3.95). This revised edition of a book by a Hayden Planetarium lecturer includes references to recent discoveries and a new section on star names and the location of planets. A pleasant all-around account for beginners.

Makers of Modern Science. Charles Scribner's Sons ($4.00). This book contains three biographies: one of Charles Darwin by Paul B. Sears, one of Sigmund Freud by Gregory Zilboorg and one of Albert Einstein by Leopold Infeld. An agreeable package for the general reader.

THE AMATEUR SCIENTIST

On the popular diversion of free diving, and a well-built Cassegrainian telescope

Conducted by Albert G. Ingalls

READERS of SCIENTIFIC AMERICAN need no introduction to Stanley Meltzoff. His cover paintings have adorned many issues of this publication in the past five years. But unless you happened to meet him emerging from the surf at Shark River, N. J., with flippered feet and swimming mask you would never recognize him as a frogman, skin diver and amateur ichthyologist. This sport and amateur science is becoming popular this summer, but Meltzoff took it up in 1948.

"For as long as I can remember," he says, "our family has summered on the beach. We all learned to swim early and our big sport was body-surfing. During late spring and early fall, when the breakers run high, you swim out 200 yards or so, catch a big one and skim back on your belly like a surfboard. We always dreaded July and August because then the Atlantic settled down like a millpond and that ended the thrills. At least that was the way it was until five years ago.

"Then one day in mid-July a gadget in a sporting goods store caught my eye. It was a swimming mask; an oval of rubber molded around a disk of shatterproof glass. I bought one on impulse. That week end, as usual for the season, my companions on the beach consisted of a dozen or so bass fishermen idly casting their lines into the surf and pulling them back empty, and a group of elderly ladies who enjoyed bobbing up and down close to the lifelines. The fishermen's persistence always puzzled me. Everyone knew the beach had been fished out for years.

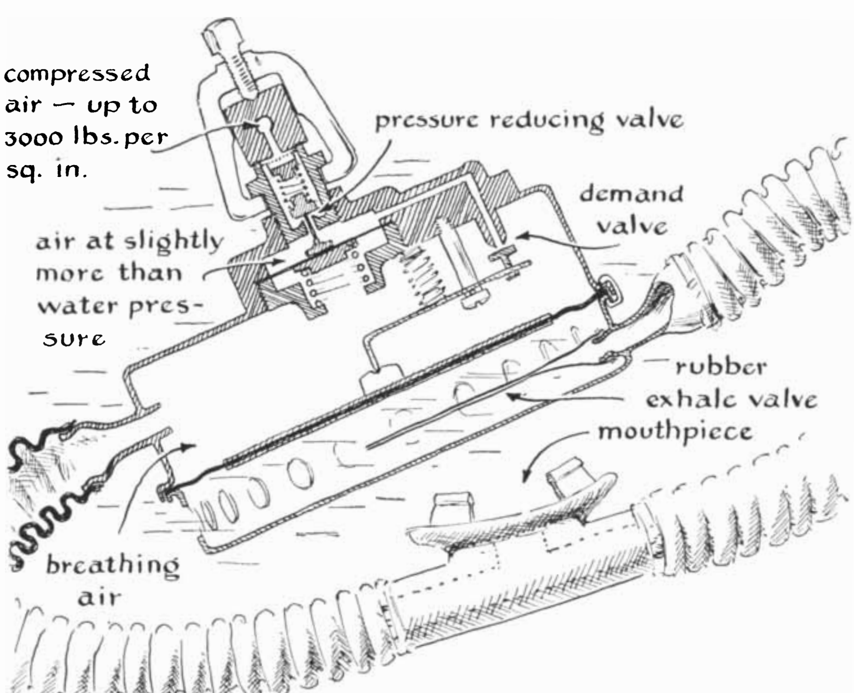
"I fitted the mask over my eyes and nose and waded out beyond the ladies. I kicked off and dipped below the surface. The spectacle left me stunned. It was like floating in air. The sandy bottom curved away steeply into a cold, eerie blue. But within 100 yards the water was alive with clouds of bass—big ones by the hundreds. Cautiously I drifted down among them. Instead of darting away, the bass seemed to accept me as one of their own, lazily staying just beyond reach. Some weighing up to 25 pounds were wandering in and out among the ladies.

"Something had to be done about those fish. I rushed to our cottage and came back with a bamboo pole sharpened to a point. As things turned out, the bass were quite safe. My excited thrusts simply threw me off balance and robbed the spear of its force. Finally I gave up. But why weren't the fishermen hooking anything? I dove toward their lines to find out. At that moment, I suppose, I became seriously interested in the ways of things that live in the sea. The next day I bought a pair of rubber swim fins and I have been skin diving ever since.

"A few hours under water disclosed the reason for the fishermen's plight. The bass simply recognized the tackle as a clumsy fraud and kept their distance. They quickly learned to steer clear of men-fish, too. With a spear gun powered by rubber bands, bought that first season, I took several hundred pounds of fish. A half-dozen other enthusiasts also learned spear fishing. But by the end of the summer, the bass had learned to circle casually just beyond our range. In contrast the small, unhunted species came as close as ever.

"That season I also learned of some important advances in the art of skin diving. The snorkel had appeared some years before. This is a short length of plastic tubing which enables you to breathe while doing a dead-man float. One end is fitted with a mouthpiece which is gripped between the teeth; the other has a float valve which rides on the surface and closes automatically when submerged. The swimmer breathes through his mouth under water and exhales through a rubber flap valve in the mouthpiece. A snorkel enables the most inexperienced swimmer to float for hours without lifting his face from the water. Whenever you see something interesting below, you simply hold your breath, do a jackknife flip and down you go. Ordinary swimmers can dive to 30 feet and experts go down beyond 100.

"I also learned with disappointment that our waters off New Jersey are rarely as clear, or as densely populated with striped bass, as on that first day. The sea has a climate of its own and often adverse conditions cut visibility to a foot or less, especially near harbors or the mouths of rivers heavy with silt. That is why the clear waters of California and the Mediterranean make those localities



Cutaway of the aqualung mechanism

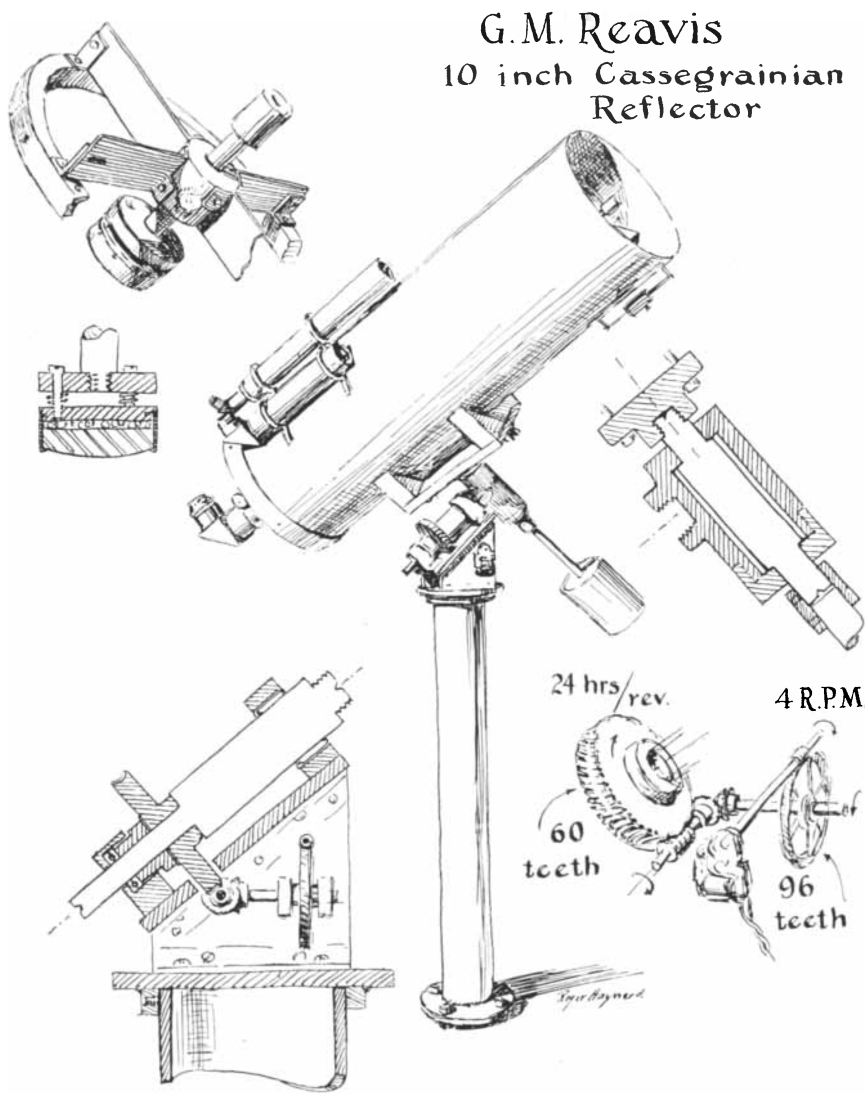
world centers of skin diving. As in many U. S. lakes, good visibility is characteristic there throughout the year."

Good underwater seeing means a lot to Meltzoff, who is first of all an artist. Although the sea anemones and their relatives which coat the floor of tropical seas in brilliant colors do not thrive off the Jersey coast, he finds an endless challenge in the more subdued and less familiar forms in northern waters. At first he was content to make short dives for a hurried examination of the bottom, but such glimpses were not very satisfying. Moreover, Meltzoff wanted to try painting under water. For this he needed a means of staying below for longer periods, but conventional diving gear was out of the question. A deep-sea diving suit with air pump, tender and accessories costs thousands of dollars and gives the diver little freedom of action. He is tethered to his pump by an air hose. His shoes weigh 40 pounds or more. To move, he must adjust his buoyancy by means of a manually operated valve controlling the pressure in his suit. A slight error may cripple him for life. Hence, except for a few daring enthusiasts such as Dr. Jerome Schweitzer, the dentist explorer and diver of New York City, not many amateurs were attracted to oceanography until a solution was found for the problem of entering the hydrosphere safely and inexpensively for extended periods. This happened in 1943, though the U. S. did not learn of it until after the war. Captain Jacques-Yves Cousteau tells the whole thrilling story in a current best-seller, *The Silent World.* A gunnery officer of the scuttled French Navy, Cousteau was waiting out the Italian occupation by skin diving off the Riviera. There he and two swimming companions, Frederic Dumas and Philippe Tailliez, got an idea for a self-contained compressed-air lung. He submitted it to Emile Gagnan, an expert on industrial gas equipment, and together they worked out the practical details. The result was the aqualung, a device that has revolutionized diving and enabled comparative laymen to penetrate a vast new frontier as primeval as the land surface of 20,000 years ago. When it is realized that this is the last virgin territory of the Earth, the importance of the aqualung becomes apparent.

The aqualung has three major parts: a bottle of air compressed to 150 atmospheres, which is strapped to the diver's back; a two-stage pressure-reduction mechanism or "demand regulator" which automatically supplies air on demand at pressure equal to that of the surrounding water; and a loop of flexible tubing leading out of and back into the regulator, through which tube the diver inhales and exhales by means of a special mouthpiece in its center. This differs from earlier compressed-air devices, relying on manually controlled valves and a continuous, wasteful flow of air, chiefly in its ingenious two-stage air-pressure regulator. In the first stage the air is expanded to a constant pressure of about six atmospheres, controlled by a flexible diaphragm and compressed spring arrangement. In the second stage this air is admitted on demand to a larger chamber where a larger diaphragm in contact with the water equalizes the pressure to match that of the surrounding medium, no matter what the depth. Anyone who has tried to breathe through a garden hose while submerged will appreciate the necessity of having air supplied at pressure corresponding with the depth. It is impossible to expand the lungs against the weight of water at a depth of six feet, J. Fenimore Cooper and his Indians to the contrary notwithstanding.

As Cousteau explains it, when a diver inhales from the aqualung he slightly reduces the pressure on the inside of the second-stage diaphragm. This actuates a demand valve which permits air to flow from the first stage until the pressure returns to equilibrium with the water on the outside of the diaphragm. When the diver exhales, his breath passes up the second section of the tube to a rubber flap valve situated near this diaphragm, which means that it is expelled at the pressure of the intake. Since all internal and external pressures are thus in equilibrium, the diver receives little subjective indication of depth. Although the total weight of the apparatus is 50 pounds, it is so designed that it is buoyantly balanced under water. The air supply is sufficient to permit a diver to work for half an hour at a depth of 100 feet, and he can breathe effortlessly down to about 300 feet. An automatic warning device operates as the air supply nears exhaustion, giving the diver about five minutes in which to surface.

A third type of diving apparatus, invented in time for World War II, also enables the swimmer to make free dives. This is the so-called "re-breather" device in which a trickle of oxygen flows continuously into a closed system of tubes and filters that re-circulate the initial supply of air and remove the waste products of respiration. No telltale bubbles emerge from this system and hence it was extensively used for underwater demolition by the fighting frogmen. Meltzoff and his diving companion, James McCloskey of Port-au-peck, N. J., believe that with further development the re-breather system may displace the aqualung. Pound for pound, oxygen should permit longer dives than air. But under water, they admit, it is tricky stuff. Pure oxygen at a depth pressure of 50 feet becomes a poison giving rise to convulsions and other violent reactions. Present re-breather apparatus is subject to malfunction, and the very existence of a variety of designs indicates the need for more development. McCloskey always tells beginners intent on purchasing war-surplus re-breather equipment



An amateur's third telescope

at bargain prices to remember that frogmen were classed as expendable.

In contrast, Meltzoff and McCloskey point out, not a single fatality has been traced to the malfunctioning of an aqualung despite tens of thousands of dives. "Perhaps the greatest hazard of the aqualung to inexperienced swimmers," says Meltzoff, "is the perfection with which it works. You tend to forget that it is there. You are carried away with the environment and ignore the fact that you are a fragile trespasser out of your accustomed medium. Properly ballasted, you can sit in a chair while observing life on the bottom with all the feeling of comfort and security you enjoy in your living room. Breathe deeply and your lungs lift you on an effortless glide toward the surface. Exhale, and you plane down. You fly without flapping! It is easy to forget that you are a land animal. At great depths nitrogen concentrates in your blood with all the effects of heady wine. As Cousteau has observed, in this state of transport it sometimes requires a supreme act of will to avoid pulling out your mouthpiece and offering it to a passing fish. It is well for the aqualung beginner to avoid dives below 60 feet, even though he has a lot of snorkel experience."

McCloskey, like Meltzoff, also learned to dive as a boy. His first equipment consisted of an inverted bucket fitted with a window and supplied with air via a garden hose and automobile tire pump. "The helmet still has its place in amateur diving," he says, "but compressed air is a lot safer. Moreover, you can swim wherever you want to go. While stationed in Florida during the war, for example, I became interested in barracuda. They are supposed to be man-eaters. Knowing something about the habits of fish, I didn't believe it. I have a theory that the experienced skin diver is in no more danger than any big game hunter. Wild animals tend to avoid conflict unless provoked or cornered. Florida is filled with tales of swimmers who supposedly lost their lives to barracuda. I could not discover a single individual who ever witnessed such an attack. All the tales shared one feature in common: 'A distant relative once knew a man who had heard a shrimp fisherman say . . .' Finally I went down for a free-swimming look, something you cannot do in a helmet. Within the first five minutes I spotted three barracuda idling peacefully among the bathers in Miami Beach. One warning shout of 'barracuda' would have sent them all scrambling for shore.

"This is not to say that barracuda will not attack. Once, while studying the habits of parrot fish off the Coca River I happened to glance behind me and there, not more than 15 feet away, was a huge silvery shape at just about my level. He was at least eight feet long and must have weighed 500 pounds. To my dismay, I discovered that he was taking an interest in me. He wore a nasty expression and bared his teeth. Then I realized that he was between me and the beach. Perhaps he thought he was cornered. Animals can get some strange ideas. I promptly exhaled and cautiously planed toward the bottom, 100 feet below. After a few seconds the barracuda gave his tail an uneasy flip and then tore out of there like a racing dirigible, obviously as relieved as I was.

"The worst encounters I have experienced during dives have been with those creatures which every bather in tropical waters knows about: crabs, Portuguese men-of-war, sea nettles, and other animals that pinch or sting when you ignore their rights. I must confess that I always feel uncomfortable when sharks are around. I do not know why this should be so. None has ever made a pass at me. The professionals say that sharks are unpredictable beasts, so I've decided to leave them for some graduate student on the lookout for a pregnant subject for his doctor's thesis."

Meltzoff and McCloskey make a good diving team: one is interested in recording the sights of the sea, and the other its sounds. McCloskey has a background in electrical engineering and is an executive in a thriving young firm making electronic computers. Friends have suggested that he should write a book someday entitled *The Noisy World* as a companion to Cousteau's volume. McCloskey is interested in developing a hydrophone to be worn like a hearing aid. His tentative design incorporates a local oscillator for beating against supersonic vibrations. This would enable him to hear sounds well beyond the normal range of human hearing. He also hopes to build a magnetic tape recorder for underwater use. Fish have a mysterious way of acting in unison when exposed to a variety of stimuli. If they talk, McCloskey's proposed apparatus should enable the amateur to eavesdrop. The development of sensitive ship hydrophones during the war established the fact that fish vibrate over a broad range of frequencies, but the operator could not link the sounds with the species because he could not see under water. A hydrophone-equipped skin diver would not be hampered by this limitation. Whales have been known to emit certain supersonic vibrations in a group of radar-like pulses, possibly as an aid to navigation. Some fish sounds can be heard without electronic aid. Groupers, says McCloskey, occasionally make a harsh, grating noise, and Cousteau has observed that any thrashing near the surface seems to attract the attention of sharks. Perhaps they are sensitive to sub-audible vibrations. Some work is already under way on this subject at various oceanographic institutions, but any significant findings must await further cataloguing of fish sounds.

"Equipped with an underwater lung," says McCloskey, "the skin diver finds himself in a territory as virgin as that of Linnaeus—a vast expanse of the unknown, by no means limited to ichthyology. Fish naturally hold the greatest interest for our club because most of us started as spear fishermen. But show me the hunter who is not also an amateur naturalist. This year our club is cooperating with Rutgers University on a census of New Jersey's coastal fish—a project suggested by Meltzoff. Eventually, we hope to map the 'swimways' of the various species just as the bird-banders have helped to chart the flyways of game fowl and other birds. In addition we hope to learn much more about our shore life. Until the advent of the compressed-air lung, these studies were largely confined to the zone that extends between the tides. Now we can observe what happens to the sea-mats, squirts, shrimp and other small crustacea at high tide.

"And what possibilities the lung opens to the fellow who lives near a fresh-water lake! There the water stratifies far more sharply than in the sea, and aquatic life zones itself accordingly. I have done very little fresh-water diving, but that little revealed no great difference in technique. In salt water I must weigh off with about seven pounds of lead attached to my belt. Fresh water diving requires only three or four pounds."

The other day we asked Meltzoff a question that had been on our mind for several weeks; what about the "bends"? "First of all," he said, "it should be understood that the compressed-air lung is not a toy. You can hurt yourself with it. Below 50 feet excess nitrogen in the blood forces you to decompress on the way up for various periods at various levels, depending on the duration of your dive. If you stay at 100 feet for an hour you must decompress at 20 feet for 16 minutes and at 10 feet for another 16 minutes. But if you are at 100 feet for only 25 minutes you can surface without decompression. Experienced skin divers do not worry about the bends. However, beginners have been known to hurt themselves seriously in water only 20 feet deep by an effect which has nothing to do with the bends. As the diver begins his ascent his lungs are filled with air under pressure proportionate to the depth. During ascent the pressure of the surrounding water drops. Unless the diver continues to breathe as he rises the difference in pressure between a depth of 20 feet and the surface can rupture his lungs. On the other hand, if he remembers to exhale while ascending he can surface from a depth of 100 feet without a lung. The first requirement for compressed-air diving is experience and this is best acquired by training with a snorkel. The aqualung is no substitute for skill in underwater swimming."

TELESCOPE-BUILDING has not been treated in this department for months, but it continues, easily at the rate of several new amateur telescopes a day. Each is individually designed by its builder around basic principles described in *Amateur Telescope Making*. Each therefore embodies interesting original features. A 10-inch Cassegrainian reflector built by G. M. Reavis, a linotype operator of Fresno, Calif., is no exception. His is not, however, a first telescope. Like nearly all novices, Reavis began by building a simple six-inch Newtonian which he used for several years to gain experience.

In a Cassegrainian the light rays are received by a concave mirror at the lower end of the tube, then reflected to a small convex mirror near the top, from which they are reflected again through a central hole in the primary mirror into the eyepiece. To permit a more comfortable angle of observation, Reavis added a third reflection near the eyepiece by means of a flat diagonal mirror. While the Cassegrainian, being folded into short compass by its secondary mirror, may be thought of as the equivalent in magnification of a Newtonian telescope four times as long, it is much more difficult to make and is not recommended for the beginner. Nor is the 10-inch Cassegrainian the easiest size to encompass, its volume, weight and cost being 4.6 times that of a six-inch. Reavis spent $200 and more than two years on and off, with time out to make a 3½-inch refractor, in building his Cassegrainian. Its primary mirror is $f/5$ and its spherically convex mirror amplifies the image four times. Equipped with a giant eyepiece of 1½-inch focal length, the telescope magnifies 133 times. Reavis says that "even with this much power the wide field lens takes in the full image of the moon, showing a wealth of detail, and it is truly a marvelous sight.

"Each of the two finding telescopes riding on the main telescope," he continues, "has a three-inch objective lens. I usually pick up the object on the short one, a richest-field (wide-field) refractor of 12 power, then switch to the long one which has a 23½-inch focal length and magnifies 50 times, though with a narrower field. All this is unnecessarily elaborate, as such finders aren't really necessary. However, they are often used as separate telescopes served by the main mounting and they do greatly impress guests."

Reavis made his own patterns for the mounting and did most of the machine work on his lathe. He finds that the telescope is rigid enough except when a Southern Pacific freight locomotive pounds along within 1,000 feet, converting it temporarily into a seismoscope. Four one-inch bolts embedded in concrete adjustably hold a 1⅛-inch steel plate to which the heavy-wall, six-inch steel-pipe pedestal is welded. A rugged ring welded to a rigid plate is attached to the top of this pipe with four Allen setscrews, permitting easy removal and adjustment. "Here, however, the welding stopped," Reavis writes, "and I used bolted angle iron to attach the side plates and the latitude plate, because welding would have warped everything.

"The bearings are housed in cast-iron pillow blocks. The heavy T for the polar and declination axes was cast from a pattern I made. The polar axis is a two-inch shaft with a ball thrust bearing at its lower end and a Torrington needle bearing at its upper." Roger Hayward, the illustrator, who is also an architect and amateur mechanic, commented after making the drawings for this article: "Torrington bearings are of particular interest because they take so little room. Amateurs should take more advantage of them. These are the only kind of roller bearings in which the outside of the shaft runs directly on the rollers, and thus the amateur can turn this surface for himself. The rollers are small, hardened steel rods, ⅛-inch in diameter or thereabouts."

Reavis continues: "The drive consists of a 12-watt Telechron motor giving four revolutions per minute and working through the gear train shown in the drawing. This gives sun time rather than sidereal time, but it holds the telescope on an object as long as I want to look. I had to use mitre gears because I didn't allow enough room between the two vertical side plates for the motor and gears. The motor was larger than I had expected, and I had to put it on the outside of one plate and, in order to get clearance for the 96-tooth gear, I had to cut a slot in the other side plate. There is a friction clutch on the 60-tooth gear. You set the telescope on some object and it starts tracking wherever you point it." Since perfect telescopes are as uncommon as perfect people, this department often urges builders to confess their mistakes, which may thus help others to avoid them. Many have willingly pointed out imperfections, at least in the telescopes.

At first Reavis felt so kindly toward the compound telescope that he writes: "How gratified I am that I made one instead of a Newtonian of equal diameter and equivalent focal length, for I like better being at the bottom end of a short tube than standing on a ladder to look into the side of a tube which in this case would be 16 feet long. Best of all is the ability to get high powers with nothing stronger than a ½-inch eyepiece." After some months of use he was only a little less enthusiastic, finding that the secondary mirror gave better definition with its outer quarter-inch zone masked, which, of course, gave less illumination. He plans to refine the secondary. He adds: "The compound type suffers in comparison with other types in that the field of view doesn't have as much contrast as with a Newtonian or a refractor." Theoretically the quality of optical workmanship needs to be increased in proportion to the square root of the number of surfaces in the optical train, and thus a two-mirror telescope should have optics 1.4 times more precise than the one-mirror variety, while a three-mirror telescope should have optics 1.7 times more precise.

By counterweighting the secondary mirror, Reavis brought "outboard" stresses inboard where they are neutralized and cannot distort the supports. It is the same principle as that explained by Russell Porter in *Amateur Telescope Making*, page 131, and in *Amateur Telescope Making—Advanced*, page 375. The sliding rod permits adjusting the secondary mirror lengthwise in the telescope to place the image approximately in the focal plane of the eyepiece. This is a convenience when design calculations have erred a little.

Reavis contributes a new method for cutting clean channels in pitch laps without having chips flying all over a room. "Pour the lap, then pencil on it the outline for the channels, cover each with Scotch tape, cut them out with a razor blade, peel off the tape and your channels are almost as neat as Porter drew them." He polished his mirror until a 150-power microscope was required to show very tiny pits near its edge. For the same purpose Fred Ferson of Biloxi, Miss., with much experience in making pitless optical surfaces of a kind that few amateurs make, uses a 10-power jeweler's loupe magnifier with the light from an unfrosted lamp bulb shining obliquely on the surface. Undiffused light from the narrow filament creates stronger shadows of the pits than light from a frosted bulb.

Walter J. Kastner, Jr., of Union, N. J., has described his method of searching for pits and studying them while grinding a mirror. "After roughing out the mirror with the coarsest size of abrasive, dry it and hold it between the eye and a lamp bulb about four feet distant, with the ground surface facing you. Observe closely the manner in which the pits disperse the light. Each pit larger than average is seen to stand out clearly. After one 'wet' with the next size of abrasive, inspect the mirror in the same manner. The light will be seen to be more evenly diffused, except where the largest pits were and are; hence they will now look worse than ever. After four or more 'wets' with the same size abrasive the surface will diffuse the light more or less evenly, but you will still see extra-large pits. You may then decide that a little more grinding will remove them but even if you try this for 5, 10 or 15 'wets' you will still see extra-large pits. The probable reason is that new pits are made each time you begin a new 'wet,' because extra-large grains dig out new pits which are not fully ground out when that 'wet' is finished. Therefore forget about them and start the third size of abrasive and repeat the observing. Keep doing this for each remaining size of grains. You will observe that even with the finest size of abrasive, there are small pits that you can never seem to remove. They can at least be reduced in size by avoiding pressure on the disk, even to lifting up on it and grinding very slowly until the sound caused by these larger grains is replaced by the smooth grinding of equal-sized grains.

"Please don't tell me," Kastner adds, "that my abrasives have been contaminated. Even after stirring the grains in water, letting them settle, and using only the top part, pits appear." Unfortunately nothing as simple as elutriation or washing will remove the "cobblestones and brickbats" with which the graded sizes *are* contaminated when the manufacturer produces them, and which his methods of grading do not exclude. In *Amateur Telescope Making: Book Three*, to be published later this year, a method will be described by which the optical worker can extract this "road ballast" from his abrasive grains and be done with the scratches and outsized pits caused by them.

Speaking of new books, F. Twyman's *Prism and Lens Making*, first published during the war and now issued in a second edition with its text almost quadrupled, may be considered in that category. It is accurately subtitled "A textbook for optical glassworkers" and, while it is poorly suited to the beginner, being aimed at the professional, it should appeal to the advanced amateur. Though it deals with quantity production as well as single operations, its chief value to the amateur is its omnibus nature. The author, for 40 years managing director of the British optical firm of Adam Hilger, Ltd., has obviously been guided by the same motive as the editor of *Amateur Telescope Making* in bringing together within the covers of a single book a wide variety of scattered data on practical optics. Thus the reader may open it anywhere and browse to advantage in its 622 pages. It also contains a chapter on microscope lens making. The book may be had through the Jarrell-Ash Company, Boston, Mass.

INDEX OF ADVERTISERS

AUGUST, 1953

ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION ... 20
Agency: Ketchum, MacLeod & Grove, Inc.
ALUMINUM COMPANY OF AMERICA, DEVELOPMENT DIVISION ... 50, 51
Agency: Fuller & Smith & Ross, Inc.
AMERICAN CHEMICAL PAINT COMPANY ... 8
Agency: May Advertising Company
AMERICAN CYANAMID COMPANY ... BACK COVER
Agency: Hazard Advertising Company
AMERICAN FELT COMPANY ... 69
Agency: St. Georges & Keyes, Inc.
AMPEX ELECTRIC CORPORATION ... 92
Agency: Walther-Boland Associates
ART TREASURES OF THE WORLD (GREYSTONE CORP.) ... 5
Agency: Maxwell Sackheim & Co., Inc.

BAUSCH & LOMB OPTICAL COMPANY ... 81
Agency: Ed Wolff & Associates
BECKMAN INSTRUMENTS, INC. ... 63
Agency: Dozier, Eastman and Company
BELL TELEPHONE LABORATORIES ... 7
Agency: N. W. Ayer & Son, Incorporated
BENDIX AVIATION CORPORATION, FRIEZ INSTRUMENT DIVISION ... 46, 69
Agency: MacManus, John & Adams, Inc.
BERKELEY, EDMUND C., AND ASSOCIATES ... 93
Agency: Battistone, Bruce and Doniger, Inc.
BERSWORTH CHEMICAL CO. ... 12
Agency: Meissner & Culver, Inc.
BRUSH ELECTRONICS COMPANY ... 4
Agency: The Griswold-Eshleman Co.
BURLINGTON INSTRUMENT COMPANY ... 80
Agency: Weston-Barnett, Inc.

CAMBRIDGE UNIVERSITY PRESS ... 91
Agency: Sussman & Sugar, Inc.
CLEVELAND PNEUMATIC TOOL COMPANY ... 11
Agency: Meldrum & Fewsmith, Inc.
CORNING GLASS WORKS ... 45
Agency: Charles L. Rumrill & Co., Inc.
CRUCIBLE STEEL COMPANY OF AMERICA ... 22
Agency: G. M. Basford Company

DOUGLAS AIRCRAFT COMPANY, INC. ... 85
Agency: J. Walter Thompson Company
DOW CORNING CORPORATION ... 41
Agency: Don Wagnitz, Advertising
DU PONT, E. I., DE NEMOURS & CO., INC. ... 73
Agency: Batten, Barton, Durstine & Osborn, Inc.
DUREZ PLASTICS & CHEMICALS, INC. ... 40
Agency: Comstock & Company

EASTMAN KODAK COMPANY ... 39
Agency: Charles L. Rumrill & Co., Inc.
EDMUND SCIENTIFIC CORP. ... 95
Agency: Walter S. Chittick Company
ENGINEERING RESEARCH ASSOCIATES, A DIVISION OF REMINGTON RAND INC. ... 48
Agency: F. H. Faber, Advertising
EXAKTA CAMERA COMPANY ... 95

FAIRCHILD ENGINE & AIRPLANE CORPORATION ... 79
Agency: Buchanan & Company, Inc.

GENERAL ELECTRIC COMPANY, X-RAY DEPARTMENT ... 47
Agency: Klau-Van Pietersom-Dunlap Associates, Inc.
GILSON SLIDE RULE CO. ... 80
GLYCERINE PRODUCERS' ASSOCIATION ... 100
Agency: G. M. Basford Company
GOODRICH, B. F., CHEMICAL COMPANY ... INSIDE FRONT COVER
Agency: The Griswold-Eshleman Co.
GOODYEAR AIRCRAFT CORPORATION ... 1
Agency: Kudner Agency, Inc.

HAYDON MFG. CO., INC. ... 84
Agency: Hugh H. Graham & Associates, Inc.
HEWLETT-PACKARD COMPANY ... 19
Agency: L. C. Cole Company
HILLYER INSTRUMENT COMPANY, INC. ... 2
Agency: Renner Advertisers

INDIANA STEEL PRODUCTS CO., THE ... 68
Agency: The Fensholt Advertising Agency

JACK & HEINTZ, INC. ... 17
Agency: Fuller & Smith & Ross, Inc.
JAEGERS, A. ... 97
Agency: Carol Advertising Agency

KOPPERS COMPANY, INC., CHEMICAL DIVISION (CHEMICALS) ... 61
Agency: Batten, Barton, Durstine & Osborn, Inc.
KOPPERS COMPANY, INC., CHEMICAL DIVISION (PLASTICS) ... 71
Agency: Batten, Barton, Durstine & Osborn, Inc.

LEITZ, E., INC. ... 14
Agency: N. W. Ayer & Son, Incorporated
LIBBEY-OWENS-FORD GLASS CO., LIBERTY MIRROR DIVISION ... 42
Agency: Fuller & Smith & Ross, Inc.
LIBRASCOPE, INCORPORATED ... 44
Agency: Western Advertising Agency, Inc.
LINGUAPHONE INSTITUTE ... 93
Agency: Kaplan & Bruck Advertising
LOCKHEED AIRCRAFT CORPORATION ... 75
Agency: Hal Stebbins, Inc.
LUDWIG, F. G., ASSOCIATES ... 98
Agency: E. J. Lush, Inc.

MACANDREWS & FORBES COMPANY ... 3
Agency: Gray & Rogers, Advertising
MALLORY, P. R., & CO., INC. ... 49
Agency: The Aitkin-Kynett Co.
MELPAR, INC. ... 16
Agency: Equity Advertising Agency
MINIATURE PRECISION BEARINGS, INCORPORATED ... 9
Agency: Ad-Service Incorporated
MINNEAPOLIS-HONEYWELL REGULATOR CO., INDUSTRIAL DIVISION ... 15
Agency: The Aitkin-Kynett Co.

NUCLEAR DEVELOPMENT ASSOCIATES, INC. ... 42
Agency: Ruder & Finn Associates

PITTSBURGH COKE & CHEMICAL CO. ... INSIDE BACK COVER
Agency: Walker & Downing
PITTSBURGH LECTRODRYER CORPORATION ... 18
Agency: Fuller & Smith & Ross, Inc.

RADIO CORPORATION OF AMERICA ... 13
Agency: J. Walter Thompson Company
RADIO CORPORATION OF AMERICA, SPECIALIZED EMPLOYMENT DIVISION ... 87
Agency: Al Paul Lefton Company, Inc.
RADIO CORPORATION OF AMERICA, RCA LABORATORIES DIVISION ... 98
RADIO CRAFTSMEN, INC., THE ... 86
Agency: Campbell-Mithun, Inc.
RAYTHEON MANUFACTURNG COMPANY ... 16
Agency: Walter B. Snow & Staff, Inc.
REPUBLIC STEEL CORP. ... 52
Agency: Meldrum & Fewsmith, Inc.
ROGERS CORPORATION ... 6
Agency: The Charles Brunelle Company

SIGMA INSTRUMENTS, INC. ... 10
Agency: Meissner & Culver, Inc.
SPERRY PRODUCTS, INC. ... 72
Agency: Hugh H. Graham & Associates, Inc.
STATHAM LABORATORIES ... 74
Agency: Western Advertising Agency, Inc.

THOMPSON PRODUCTS, INC., JET DIVISION ... 43
Agency: Meldrum & Fewsmith, Inc.

UNITED BINOCULAR CO. ... 97
Agency: E. H. Brown Advertising Agency

BIBLIOGRAPHY

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

THE NUCLEAR REACTOR AS A RESEARCH INSTRUMENT

PILE NEUTRON RESEARCH TECHNIQUES—I. D. J. Hughes in *Nucleonics*, Vol. 6, No. 2, pages 5-17; February, 1950.

PILE NEUTRON RESEARCH TECHNIQUES—II. D. J. Hughes in *Nucleonics*, Vol. 6, No. 5, pages 38-53; May, 1950.

PILE NEUTRON RESEARCH TECHNIQUES—III. D. J. Hughes, Vol. 6, No. 6, pages 50-55; June, 1950.

ARCHAEOLOGY AND THE EARLIEST ART

THE ART AND RELIGION OF FOSSIL MAN. English translation by J. Townsend Russell, Jr. Yale University Press, 1930.

FOUR HUNDRED CENTURIES OF CAVE ART. Abbé H. Breuil. English translation by Miss Mary E. Boyle. Realized by Fernand Windels. Montignac, Dordogne. Centre d'Etudes et de Documentation Préhistoriques, 1952.

THE LASCAUX CAVE PAINTINGS. Fernand Windels. Faber and Faber, 1949.

SOIL CONDITIONERS

SOIL SCIENCE, Vol. 73, No. 6; June, 1952.

STATUS REPORT ON SOIL CONDITIONING CHEMICALS, No. 1. W. P. Martin in *Soil Science Society of America Proceedings*, Vol. 17, No. 1, pages 1-9; January, 1953.

STATUS REPORT ON SOIL CONDITIONING CHEMICALS, No. 2. L. V. Sherwood and J. C. Engibous in *Soil Science Society of America Proceedings*, Vol. 17, No. 1, pages 9-16; January, 1953.

CELL DIVISION

THE CELL IN DEVELOPMENT AND HEREDITY. Edmund B. Wilson. The Macmillan Company, 1925.

THE ISOLATION AND BIOCHEMICAL CHARACTERIZATION OF THE MITOTIC APPARATUS OF DIVIDING CELLS. Daniel Mazia and Katsuma Dan in *Proceedings of the National Academy of Science*, Vol. 38, No. 9, pages 826-838; September, 1952.

MITOSIS. Franz Schrader. Columbia University Press, 1944.

THE MITOTIC CYCLE. Arthur Hughes. Academic Press, 1952.

STRUCTURAL AGENTS IN MITOSIS. M. M. Swann in *International Review of Cytology*, Vol. 1, pages 195-210; 1952.

FRANCIS HAUKSBEE

PHYSICO-MECHANICAL EXPERIMENTS ON VARIOUS SUBJECTS. Francis Hauksbee. Printed for J. Senex at the *Globe* in Salisbury Court, and W. Taylor at the *Ship* in Pater Noster Row; 1719.

ESSENTIAL OILS

THE ESSENTIAL OILS. E. Guenther. D. Van Nostrand Co., Inc., 1948.

METHODS OF EXTRACTING VOLATILE OILS FROM PLANT MATERIAL AND THE PRODUCTION OF SUCH OILS IN THE UNITED STATES. Arthur F. Sievers in *U.S. Department of Agriculture Technical Bulletin No. 16*, United States Government Printing Office; January, 1928.

THE GENETICS OF THE DUNKERS

GENETIC DRIFT IN A RELIGIOUS ISOLATE: AN ANALYSIS OF THE CAUSES OF VARIATION IN BLOOD GROUP AND OTHER GENE FREQUENCIES IN A SMALL POPULATION. Bentley Glass, Milton S. Sacks, Elsa F. Jahn and Charles Hess in *The American Naturalist*, Vol. 86, No. 828, pages 145-159; May-June, 1952.

RACES: A STUDY OF THE PROBLEMS OF RACE FORMATION IN MAN. Carleton S. Coon, Stanley M. Garn and Joseph B. Birdsell. Charles C. Thomas, 1950.

THE ORIGIN OF THE ATMOSPHERE

THE ATMOSPHERE OF THE EARTH AND PLANETS. Edited by Gerard P. Kuiper. The University of Chicago Press, 1952.

THE EVOLUTION OF THE EARTH'S ATMOSPHERE. Sir Harold Spencer Jones in *Science Progress*, Vol. 38, No. 151, pages 417-429; July, 1950.

GEOCHEMISTRY OF THE ATMOSPHERE. Kalervo Rankama and Th. G. Sahama in Chapter 7, *Geochemistry*, pages 300-318. The University of Chicago Press, 1950.

PLANETARY ATMOSPHERES. R. O. Redman in *Nature*, Vol. 165, No. 4208, page 987; June 24, 1950.

THE AMATEUR SCIENTIST

BETWEEN THE TIDES. Philip Street. Philosophical Library, 1953.

THE SILENT WORLD. Captain J.-Y. Cousteau and Frédéric Dumas. Harper & Brothers, 1953.

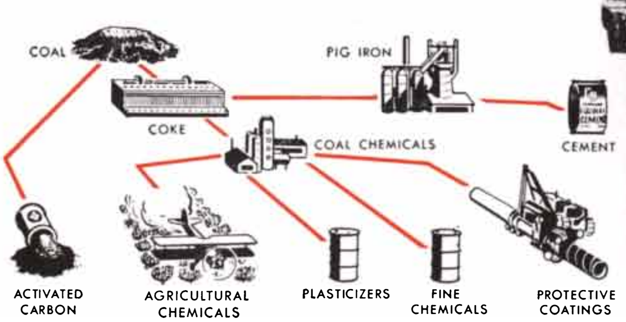
AMATEUR TELESCOPE MAKING. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

AMATEUR TELESCOPE MAKING—ADVANCED. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

EVERY TIME this big unloading bucket bites into a bargeload of coal, we're starting another chemical miracle on its way to you. Your new synthetic fiber suit, the drug that "knocked" your flu so fast and the bright enamel on your new car could all have been born in the coal chemical recovery mains of our coke ovens.

But *this* may be the real miracle: From our coking operations we produce not only coke and coal chemicals, but we follow through with basic products like pig iron and cement on one hand and finished chemical products like Pittsburgh Insecticides and Dyestuffs on the other—all in *one continuous, interlocking operation.* This highly developed integration—and it now embraces ten operating divisions—requires considerable engineering skill and years to perfect. But the payoff is the unusual production efficiency and product quality control that have become synonymous with Pittsburgh Coke & Chemical.

W&D 4541



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

Photograph by Bob and Ira Spring, FPG

Tomorrow's paper takes to water!

Spectacular indeed are the great log drives that bring pulp wood to the paper mills of America. But equally spectacular, and of more practical significance to users of paper, are the new and interesting qualities the paper industry is giving to its products.

One of the most remarkable of these qualities is wet strength—the ability of paper to remain strong even when completely water-soaked. Paper manufacturers impart this quality through the use of American Cyanamid Company's MELOSTRENGTH* Resin—and you reap the benefits in stronger paper towels, wiping tissues, bags, laundry tags, meat wrappers, food containers, maps, blueprints and many other paper products.

Here is an example of how the paper industry, working closely with the chemical industry, is giving you constantly increasing value in the products it makes for you.

AMERICAN *Cyanamid* COMPANY

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

*Trade-mark

Materials for the Paper Industry—One of the Many Industries Served by Cyanamid