SCIENTIFIC AMERICAN

DRUGGED SPIDER AND WEBS

FIFTY CENTS

December 1954

Beauty bath for metals

Two important elements of a nickel plating process are the canvas-bagged anodes and plating solution above. A third is Amberlite® ion exchange resins.

Rinse water from a single plating plant may total 200,000 gallons daily. Amberlite resins permit recovery of metals and water from rinse solutions. Costs are cut because valuable metals are salvaged and the water made suitable for reuse—even as boiler feed. Stream pollution is virtually eliminated. Metals recovered include nickel, copper, chromium, gold, and silver.

Other metal-treating industries benefit from ion exchange, too. Amberlite ion exchange resins, for example, remove metallic contaminants from alodizing, anodizing, and chromic acid stripping baths. Because the baths can be used again and again, savings are large.

Why not write us about your problem? Find out why ion exchange is the right way to metal recovery, why the resin that's *right* is *Amberlite*.

Ask for this complete review of ion exchange in the metals treating industry.

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA

LETTERS

Sirs:

Although as a physicist I am hardly qualified to speak on economic psychology, I cannot resist making some comments on the interesting article by George Katona on that subject which appeared in the October *Scientific American*. It seems to me that many factors which enter into the determination of economic behavior are properly classed by the author as psychological; but one aspect, which stands out in bold relief in most of the examples he gives, differs from the others in that it appears capable of mathematical analysis. I refer to the fact that most people choose a course of action in a given situation which they believe will yield them the greatest value. Value is often, though not always, measured in economic terms —ethical and moral values count too, but to a degree which is a function of both the individual and of the situation in which he finds himself. Psychological, social, cultural, etc., factors enter into the values and goals of the individual, and also into constraints on the behavior of the individual in the given situation (law, custom, courses of possible action, etc.). The ensemble of these factors and constraints, together with what the individual can do, are the "rules" and possible "moves" of a "game." The individual is a player seeking to maximize the value to himself of the particular play he is engaged in. His behavior should therefore be viewed as the unfolding of a strategy designed to "win" as much as possible. The theory of games, as developed by John von Neumann and Oskar Morgenstern and others, permits of detailed mathematical analysis of many such situations. The actions of consumers, businessmen, etc., in the examples given seem to be largely explainable as strategies adopted to maximize what one can get for one's money, to get as much money as possible and the like, where present behavior is planned with expectation of future conditions entering into the calculation. Apparently classical economics errs in its neglect of this game aspect, with its large emphasis on future expectations, the feedback of new information, and the effects thereof on the future course of action.

It seems to me that the game aspect of economic (indeed, perhaps of all human) behavior may well account for many of its gross observable features. Transfer of information (and its distortion) must also be studied, for decisions are based on available information, which is seldom complete. One would expect situations in which the values are explicit, and the rules of the game sharply formulated, to be described by the new discipline far better than by the relatively static classical one. . . .

JEROME ROTHSTEIN

Red Bank, N. J.

Sirs:

It would appear that the basic development of the backward wave oscillator tunable over a wide frequency range is ascribed on page 52 of your October issue to a company other than Compagnie Générale de Télégraphie Sans Fils (C.S.F.), the French company whom we represent in the U. S.

Long prior to the date of your article on microwaves [Scientific American, August, 1952], which described the traveling wave tube, *i.e.*, on April 13, 1951, C.S.F. had filed a French patent application on the backward wave oscillator tube which eventuated August 15, 1953, in Patent No. 1,035,379.

At the 1953 National Electronics Conference in Chicago, Ill., September 28 to 30, Edward C. Dench of the Raytheon Manufacturing Company, Waltham, Mass., presented a paper in which the history of the backward wave oscillator tube was set forth with full credit there given to C.S.F., whose backward wave

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A plight before Christmas

(...and how Nickel *put the plight to flight*)

Not so long ago, the average man who wanted to give his wife gold jewelry for Christmas found himself in a sad predicament.

He couldn't afford it. Only a comparatively few people *could* in those days.

So jewelry manufacturers decided to try to lower the cost of gold jewelry... while keeping its quality high . . . by fusing an overlay of gold to a less expensive base metal.

But *which* base metal?

Experiments were started . . . but one after another, each base metal tried proved to be unsatisfactory in one way or another.

One metal corroded — left disagreeable green stains on skin.

Another suffered from a lack of strength.

Still another was too hard to work.

Then they tried nickel. There was the answer! Corrosion-resistance, strength, rigidity and ease of working, all in one metal. Today nickel is accepted by manufacturers as the best all-around foundation metal for quality jewelry.

In fact, bonding gold and other precious metals to a nickel base is so successful that it has opened up new possibilities for all sorts of industrial uses where the ageless qualities of a precious metal are wanted at a practical price.

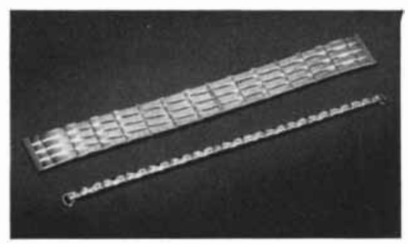
If *you* have a problem in which corrosion, high or low temperatures, stresses or fatigue resistance are troublesome factors, let's talk it over.

Two minds are always better than one, and we may be able to help you find out how well nickel or a nickel alloy may solve a troublesome problem for you.

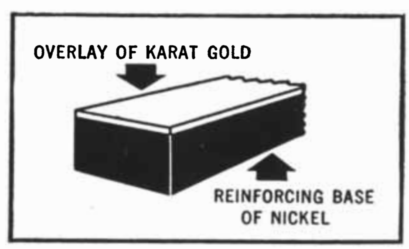
Because nickel is extremely malleable, it enables manufacturers to use their delicate dies and tools to best advantage . . . permitting them to develop even the most intricate designs.

Eyeglass frames used to be a problem for manufacturers and users. They used to snap and break too easily.

With nickel as a base for Karat Gold, the frames received the extra strength they required to successfully withstand the constant handling.



Jewelry parts, such as watch bands, for example, keep their original beauty and prevent skin discoloration . . . thanks to the strength and corrosion resistance that nickel supplies.



Today's gifts of quality gold-filled jewelry become tomorrow's heirlooms. And nickel plays an important part. As the base metal, nickel is bonded with an actual overlay of strictly controlled Karat Gold and rolled under pressure to make the Gold Filled used in today's quality jewelry.

INCO
TRADE MARK

NICKEL ALLOYS PERFORM BETTER LONGER

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street New York 5, N. Y.

oscillator tube is known by the trademark "Carcinotron."

There is now pending in the U. S. Patent Office an interference or priority contest in which one of the parties is the individual to whom your article ascribes the invention of the backward wave oscillator and another party is the French inventor of the tube, who is employed by C.S.F. This French inventor is the *senior* party in this interference, with an effective priority of filing more than one year prior to any of the other parties involved, and by reason of his earlier effective filing date, the legal presumption is in favor of C.S.F. But the ultimate decision of priority rests with the Patent Office.

A. HAASE-DUBOSC

American Radio Company
New York, N. Y.

Sirs:

In August of this year the Western Amateur Astronomers Association held its sixth annual convention in San Francisco. At that time it made its first annual award, the G. Bruce Blair medal for achievement in and contribution to the advancement of amateur astronomy. This has been awarded to Albert G. Ingalls of the staff of your magazine.

To the amateurs throughout the world, he and the late Russell W. Porter have been revered as the patron saints of the art of telescope making and of amateur research in the science of astronomy. His guiding hand in the columns of your magazine for over 25 years, and in his books on amateur telescope making, comprised of contributions by many amateurs as well as professionals, has been the source of much satisfaction and achievement by many thousands of people in all walks of life. Furthermore his advice and encouragement, in a most extensive personal correspondence, have been invaluable to the fraternity. During the last war he spent many long and arduous hours, not without great personal sacrifice, to organize amateurs into effective producers of optical work for the government.

All of these services have had a direct bearing on the advancement of science in variable star observation, comet study, planetary research, celestial photography, spectroscopy, optics and related fields. Many advanced optical companies, operating with thousands of workers, owe their start to Mr. Ingalls.

For these reasons the Western Amateur Astronomers are especially pleased to present their first award to this man

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Ketay also manufactures a wide selection of aircraft, missile, marine, and ordnance instruments; and control systems.

Ketay has pioneered in the design of rotating precision instruments. For example, as design agent for Frankford Arsenal and the Bureau of Ordnance, Ketay designed the military Size 15, 16, 18, 19, 23, 31, and 37 synchros. The services of the Research and Development Division are available to you!

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who they feel deserves it most. Appropriately enough, the medal has been made and etched entirely by the hands of amateur astronomers.

C. P. CUSTER, M. D.

Stockton, Calif.

Sirs:

I was interested in the letter by Frederick K. Vreeland in your September issue. In this letter Mr. Vreeland mentioned his early patents of a regenerative electrical oscillator. I thought your readers would be interested in the following quotation.

"Skipping over several sections of my story, I will say now that twenty years after my invention of electrical tuning a pupil of mine, Major Armstrong, discovered the electrical vacuum-tube oscillator, which promises to revolutionize wireless telegraphy and telephony. A similar invention, but a little earlier, was made by another pupil of mine, Mr. Vreeland. Both these inventions in their mode of operation remind me much of the operation of Serbian bagpipes. Perhaps some of those thrills which the Serbian bagpipes stirred up in me in my early youth were transferred to my pupils, Armstrong and Vreeland."

The quotation is taken from page 19 of Michael Pupin's book *From Immigrant to Inventor*, published in 1923.

IVAN BERNAL

Charlottesville, Va.

Sirs:

May I correct the legend to one of the figures which accompanied my article on "The Biology of the Negro" in your October number? The black circles in the three diagrams on pages 82 and 83 represent the frequencies of the A blood *genes* in Caucasians, Africans and American Negroes. This is correctly stated for the Negroes only, while the reference to the frequencies of the black circles among Caucasians and Africans as representing the frequencies of A-type *blood* is erroneous. With 25 per cent of A *genes* among Caucasians the frequency of A *types* is 40 per cent, and the 15 per cent A *genes* among Africans account for 20 per cent of A types.

CURT STERN

University of California
Berkeley, Calif.


REVERE
Today . . . competition-minded manufacturers on all sides are finding logical new reasons to use more and more aluminum sheet products. Aluminum's ready workability, corrosion resistance, strength, ease of welding and joining, and the way it lends itself to surface finishes of distinction—all very often combine to make it first choice in metals.
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Why not add the Revere A-B-C's to your own alphabet of manufacturing knowledge and experience? Call Revere NOW. Revere Copper and Brass Incorporated, *Founded by Paul Revere in 1801*, Executive Offices: 230 Park Avenue, New York 17, N. Y.
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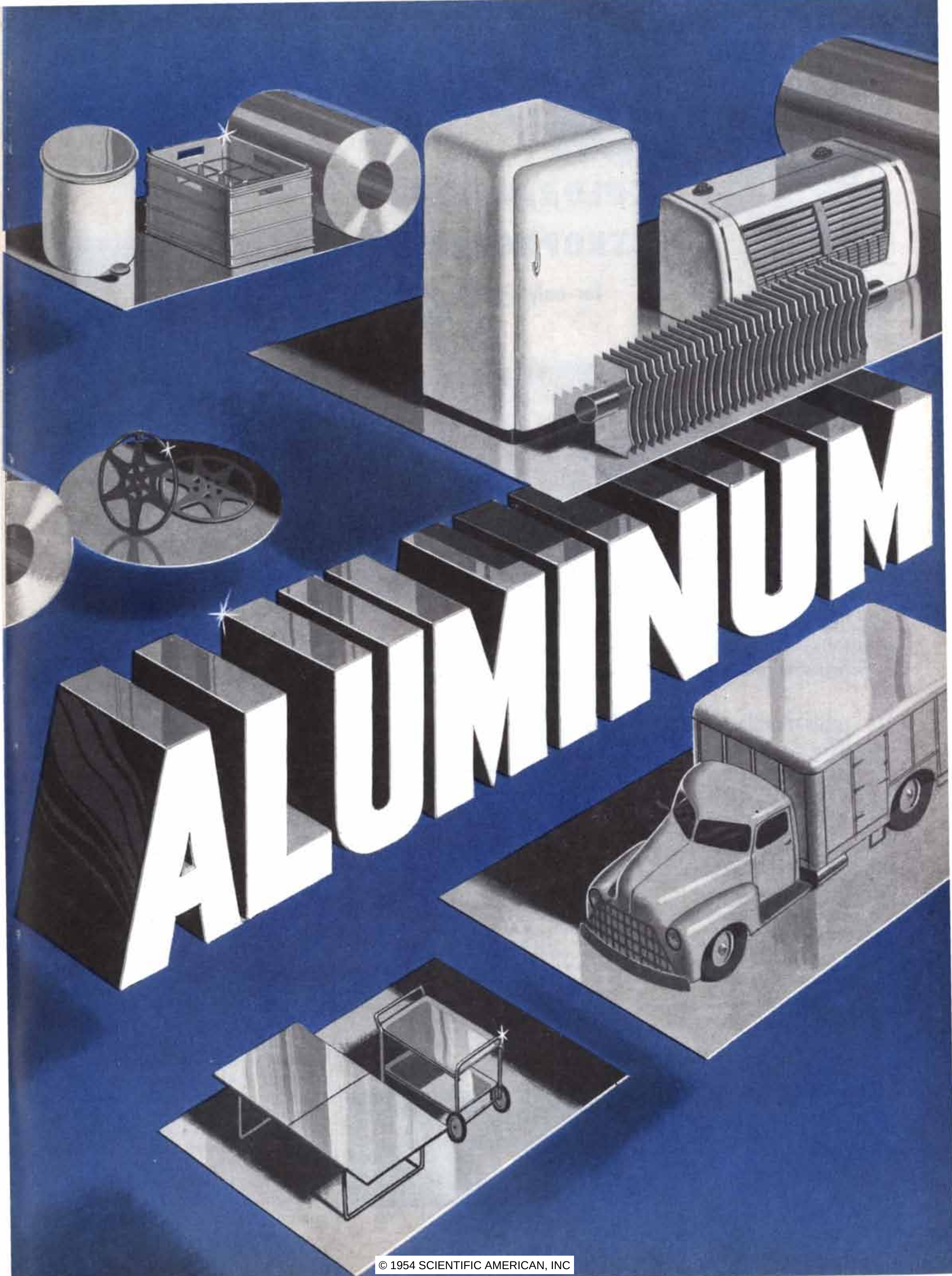

ALUMINUM

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

DECEMBER, 1904: "A Dutch naturalist, Hugo de Vries, has just given the finishing stroke to the theory of natural selection, and has proposed in place of it another hypothesis which he calls "the theory of mutation." His main idea is the abrupt mutation of living forms, of which he has sought direct proof. The best one would be to find a plant that was actually in its period of mutation and that might beget a number of daughter plants in which there should shortly appear the characters of a new species. There would be more chance of finding a wild species undergoing a crisis of mutation among the species that present a great many subspecies; de Vries, therefore, experimented with 100 plants that satisfied this condition. He chose seeds from those which were distinguished by some peculiarity or deviation, like fissuration of the leaves, ramification of the spines, etc. Only one attempt fully succeeded, that which related to the Onagra, *Oenothera lamarckiana*. De Vries cultivated it in his experimental beds from 1886 to 1900. In 1887 a new type made its appearance. In 1900, after eight generations, he had obtained, from 50,000 plants produced from his several sowings, 800 new individuals belonging to seven undescribed species. The new species appeared suddenly, without preliminary or intermediate forms. The result of these experiments furnishes a new and powerful argument in favor of the theory of mutation."

"The prospects for the early development of the gas turbine were discussed recently in a paper read before the British Institute of Mechanical Engineers, and, according to the author, those prospects are not very bright. Of course one of the chief difficulties is the high temperature of the gas, which necessitates, if the temperature is to be reduced to a degree that is not injurious to the cylinder, the carrying away of a large amount of heat by the cooling water. If it were attempted to dispense with cooling water, or to use only as much as

He's using the telephone that lends an extra hand

"Sure . . . I'm looking up the figures right now!" From busy executives to clerks, people in business can work more easily and efficiently with Bell's new Distant Talking Telephone. Small white rectangle is the loudspeaker.

For people who want to keep *both* hands free when they telephone, Bell Telephone Laboratories engineers have devised a new telephone with a sensitive microphone in its base.

To use it, simply press a button. The microphone picks up your voice and sends it on its way. Your party's voice comes to you through a small loudspeaker. Both hands are left free.

The volume can be adjusted to suit yourself. If privacy is needed, you simply lift the handset; this shuts off the microphone and loudspeaker and you talk just as you would on a regular telephone.

This new development of Bell Laboratories increases the number of ways your local Bell telephone company can serve in businesses and homes.

Pencil points to microphone in base of new telephone. Left-hand button controls volume, center one turns set "on" and lights up while in use. The third is an "off" button.

Bell Telephone Laboratories

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

would cause a moderate reduction of the temperature, the rotating parts of the turbine would have to run red hot, and there is no material known to the engineering art today that would hold together at such high temperature, if subjected to the great centrifugal forces that would be developed."

"The Imperial Commission of consumption experts appointed by the German government to investigate the relations between bovine and human tuberculosis bacilli held an important meeting in Berlin last month. Dr. Weber, one of the most eminent members of the Commission, reported that the result of the investigations so far is to show that bovine and human bacilli are absolutely distinct biologically from one another."

"Ahnigito, the giant meteorite discovered by Lieut. R. E. Peary in Greenland in 1894, has been removed from the Brooklyn Navy Yard, and more strikingly exhibited on a mounted pedestal under the entrance arch of the American Museum of Natural History. Ahnigito measures eleven and a half feet in length, is seven feet six inches wide, six feet thick, and tips the scales at thirty-seven and one half tons."

"An important communication on the properties and transformation of the radium emanation is published by Sir William Ramsay. In collaboration with Frederick Soddy, he has succeeded in determining the amount of emanation given out by radium bromide in a given time, and in determining the position of its brightest spectrum lines. The emanation resembles the gases of the argon family; the amount of radium transformed into emanation is about one thousandth part of its weight."

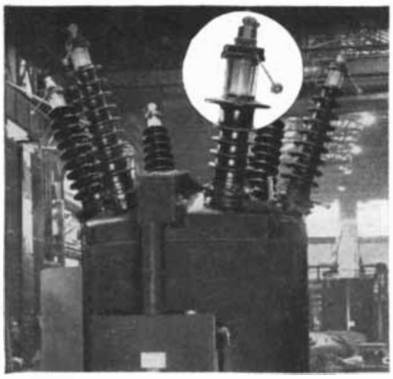
"The Bureau of the Census has just published, in the form of a bulletin, an interesting study and analysis of age statistics. The ages of the population were ascertained more accurately during the Census of 1900 than during any previous census of the United States. This improvement was largely due to the addition of an inquiry as to date of birth to the former direct question as to year of age. The analysis of the census returns affords convincing evidence of the tendency to understate ages. This tendency manifests itself in an unduly large proportion of the population reporting their age as 25, 30, 35, 40, etc. A skillful analysis of the returns shows that except among persons of advanced years, this concentration on multiples of five repre-

CORNING GLASS BULLETIN

FOR PEOPLE WHO MAKE THINGS

Sunglasses for circuit breakers. If you were responsible for the health of a battery of big outdoor circuit breakers, you'd be pretty careful about maintaining the dielectric strength of the oil which is used in them.

Exposure to too much sunlight tends to cause this oil to deteriorate and undermine its dielectric strength. So Canadian Westinghouse Co., Ltd. fits circuit breakers for outdoor use with "sunglasses" on the only part where the sun can get at the oil—out near the tips of the bushings that project like horns from the breaker tank.



Actually these "sunglasses" are oil gauges, but they're made of low actinic glass and it's the "low actinic" that keeps harmful rays from sapping the strength of the oil. Here's how this glass tames wayward angstroms:

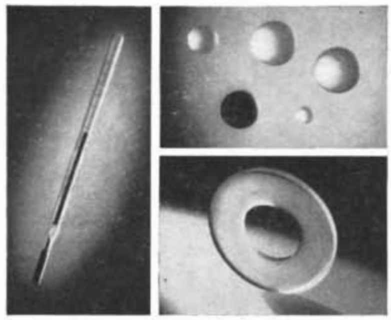
Wave length (Angstrom Units)	Percent Transmission
3000	0
4000	1
5000	4

Low actinic is just one of many special glasses Corning has developed for handling problems of radiant energy. Not only the sun's rays but rays of all kinds—from cosmic to infrared, from X- to radio—find a formidable opponent in glass.

▶ If you're interested in details, we have them for you. Just write us for our *color filter catalog*. It's full of information on how to stop some wave lengths and let others go by. Or we'll be glad to have a look at your own special ray-control problem, if you like. Our researchers are better than fair-to-middling at turning problem rays into rays of hope.

On non-human tolerance. Tolerance has a sort of chameleon-like aspect: in humans we want it broad and generous (Ralph Waldo Emerson has worked that one over pretty thoroughly); in engineering materials we often want it the opposite—narrow and close. (We'd like to work *this* one over briefly, because it's one of the things glass has that may interest you.)

Take the bore in thermometer tubing, for instance—the hole the



mercury works in. It's often so small you couldn't force even a split human hair into it. But, even when we extrude it in mile-long lengths, we hold it to that dimension within a tolerance of ±.0003″.

And the glass jewel bearings which delicate instruments like potentiometers use—they're made from rods accurate to a tolerance of .0235″. We make the rods. The instrument manufacturer buys them and makes the bearings—and gets a bonus, too, because he doesn't have to final polish them with abrasives. This saves time and money.

The glass rotary sealing rings shown above are part of an almost all-glass chemical pump. They keep liquids from leaking out when the pump's in action, which means they must fit tighter than tight. We make them to ±.0005″ tolerance. And we make them of VYCOR brand 96% silica glass which maintains its dimensional stability, resists acid corrosion like no other commercial material we know of, and stands the thermal shock that develops if the pump runs dry.

▶ If you'd like more on the tolerances you can hold glass to, on its ease of processing and its thermal and physical strength, the next paragraphs tell you about two books that are good reading.

Good reading, if . . . If you know an engineer who's hungering for some really technical information about this complex material called glass, you might recommend adding a couple of brass-tack bulletins to his bill of fare.

One of them condenses into fourteen pages a whale of a lot of useful information on mechanical and electrical properties, thermal stresses, heat transmission, corrosion resistance, viscosity, and other measurable attributes of PYREX, CORNING, and VYCOR brand glasses. We file it as Bulletin B-83; its more imposing title is "Properties of Selected Glasses."

The other one is Bulletin B-84—"Manufacture and Design of Commercial Glassware." It talks about glass melting. It describes the problems and limitations of designing blown glassware and pressed glassware. It gives forth on annealing and tempering, hole drilling, sealing components together, metallizing, assembling glass and metal, and other useful subjects.

▶ Neither of these booklets is the kind your engineer friend will curl up in bed with, but both can contribute to his understanding and profitable use of glass as the versatile and often surprisingly talented design and engineering material it is. We'll be glad to send you, or him, or both of you, copies.

We offer *carte blanche* service. If sun, nor reading, nor tolerances aren't currently weighing you down, let's put our heads together over whatever materials or processing problem may be specific with you right now. Could be glass has something to offer. If it has, we'll be delighted to expound at pertinent length. If it hasn't, downhearted as we'll be, we'll tell you so. May we hear from you?

Corning means research in Glass

CORNING GLASS WORKS 30-12 Crystal St., Corning, N.Y.

sents in the majority of cases an understatement of age."

"Some of the European governments, which have at hand the means of making alcohol in large quantities at small cost, have undertaken to encourage the manufacture of spirits. The Emperor of Germany, for instance, has given the matter some considerable personal attention, and has offered prizes for efficient designs of engines and lighting apparatus making use of alcohol. The same thing has been done to a minor degree by the Russians, but it has been discovered to be a lamentable fact that, as the manufacture of alcohol increased, the amount consumed as a beverage also grew lamentably larger and larger. The alcohol habit has taken such a hold on the Russians that recently the Imperial Minister of Finance offered a prize of 50,000 rubles, which is equal to $25,750, for the discovery of some means by which the alcohol would be rendered so distasteful that it could not be consumed in this manner."

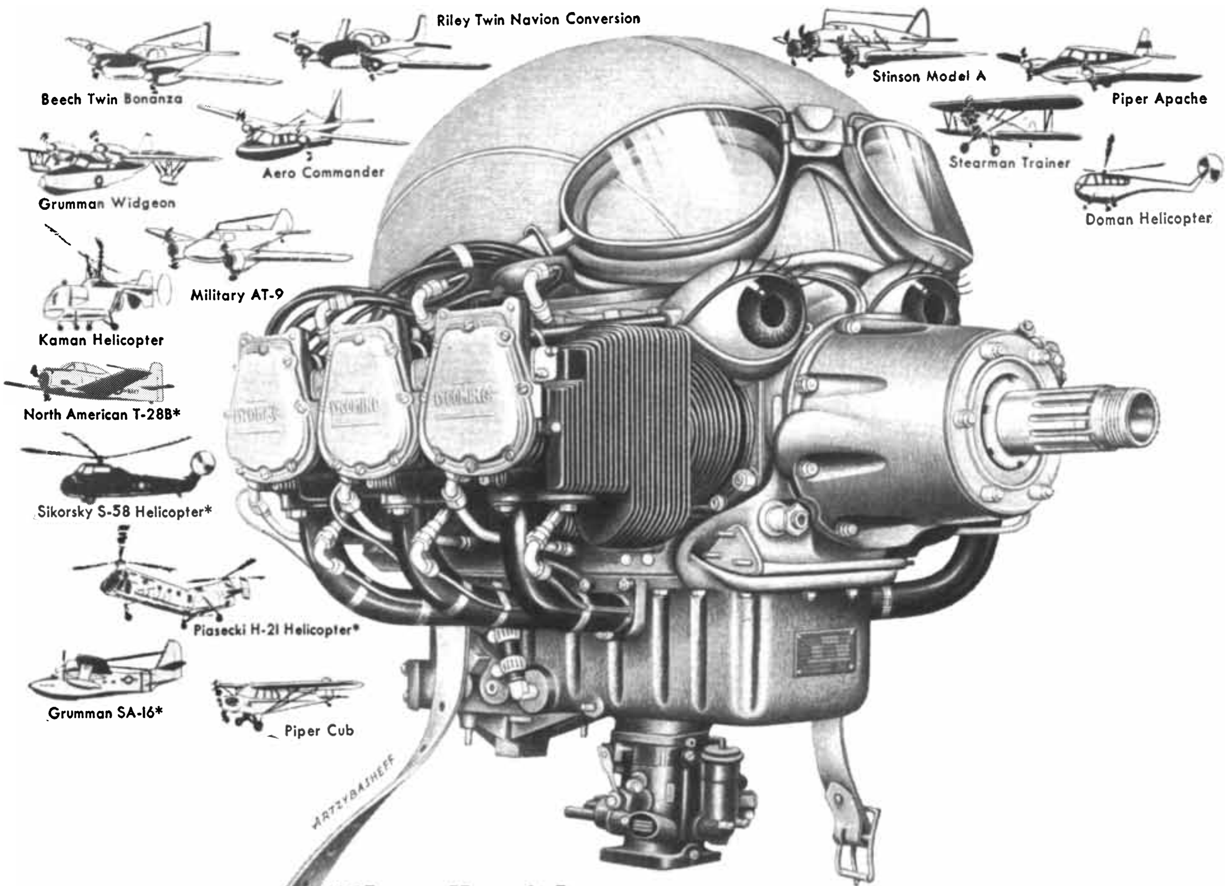
SCIENTIFIC AMERICAN

DECEMBER, 1854: "In the list of patent claims published this week, we notice the grant to J. A. Roebling of Trenton, N. J., for a machine to manufacture wire rope."

"Great quantities of potatoes have recently been imported into New York from Scotland and Ireland. Has this esculent become so difficult to cultivate in our own country?"

"The Sault Ste. Marie canal will be ready for navigation at the opening of the spring. A vessel may then clear from the head of Lake Superior for any part of the world, and pass through the River St. Lawrence without breaking bulk."

"We perceive by some of our English contemporaries that Peter Spence, chemist at Manchester, has pointed out the evils of the new anti-smoke law, which requires all the smoke of factories, breweries, &c., to be consumed. He asserts that the smoke purified the air in a peculiar manner, by the absorption of the sulfuric acid generated by the combustion of the coal, which generally contains some sulfur, and that for want of smoke, this sulfuric acid was destroying the shrubbery of gentlemen's gardens around Manchester."



meet a "flyer" with over 250,000,000 hours behind him!

"He's" a new Lycoming air-cooled engine. He's backed by Lycoming's experience in creating and producing 50,000 aircraft power plants . . . each with a flight-proved life expectancy of at least 5,000 hours.

You learn a lot about flying in 25 years . . . and 50,000 engines!

Our first Lycoming aircraft engines gained us invaluable experience flying for one of America's first scheduled air lines. Their successors have flown military missions in aircraft from liaison planes, to trainers, to helicopters. As "civilians," they now fly small single-engine utility planes, and leading twin-engine "flying offices" for businessmen.

Do *you* need this kind of dependable air-cooled power . . . or any of the diversified services listed above our signature? Lycoming's wealth of creative engineering ability . . . its 2½ million square feet of floor space . . . and 6,000-plus machine tools stand ready to serve you. *Whatever* your problem . . . *look to Lycoming!*

Aircraft Engines
Industrial and Tank Engines
Engine Overhaul
Generating Units

Turbine Engineering and Research
Engineering Design and Development
Hardened and Ground Precision Parts
Gears and Machine Parts

Complete Assemblies
Heat-Treating and Plating
Steel Fabrication
Castings
Boilers

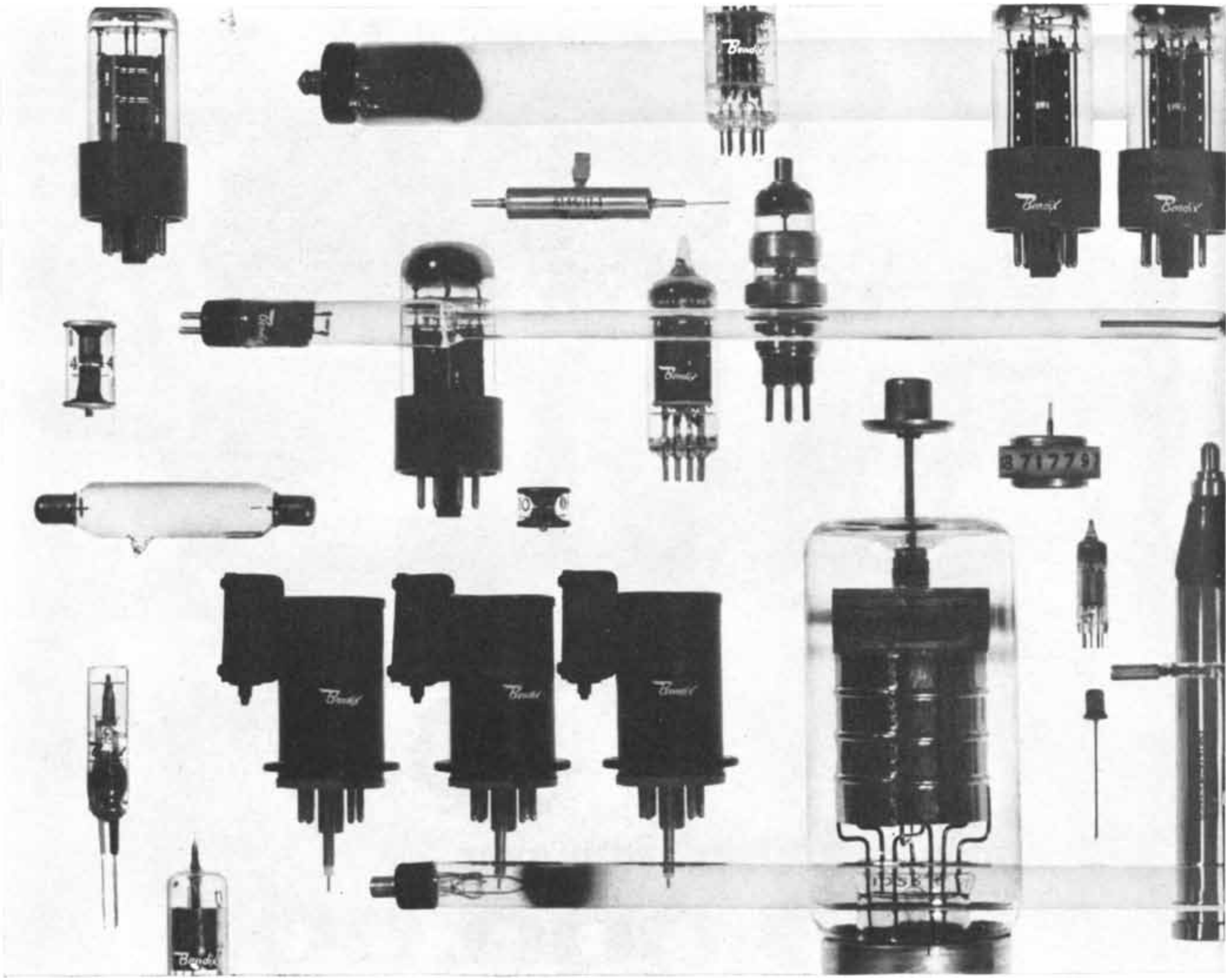
FOR RESEARCH · FOR PRECISION PRODUCTION

LOOK TO **Lycoming**

DIVISION OF AVCO MANUFACTURING CORPORATION

STRATFORD, CONN.
Manufacturing plants in Stratford, Conn., and Williamsport, Pa.

*Wright-Cyclone engine, built by Lycoming under license from Curtiss-Wright Corporation, Wright Aeronautical Division.



Bendix ... a fine source for special purpose

THIS is another business Bendix got into because we couldn't buy what we needed. Our own stiff requirements from electronic tubes for aviation, radar and guided missile use couldn't be met by ordinary tubes designed for home radio, public address systems, etc. As an example, we needed a certain tube for a guided missile that could momentarily withstand the shock of striking the target and penetrating it before firing the charge. It was no job for any ordinary tube.

What We Did About It

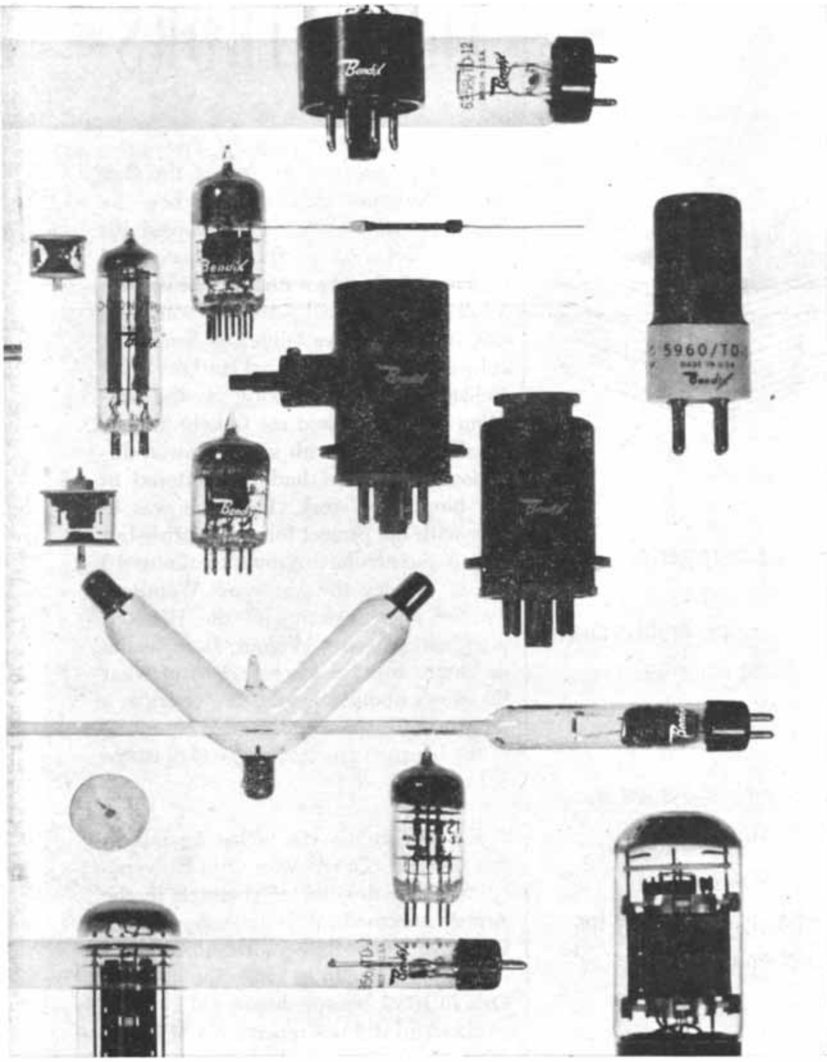
We developed a "ruggedizing" process which gives a bulldog physique to a normally fragile instrument. Today Bendix' ruggedized and special-purpose tubes are favored in all kinds of industrial and military applications because they outperform ordinary tubes and last many times longer.

How Ruggedizing Saves You Money

Satisfied customers have furnished us with many case histories proving the value of Bendix special-purpose ruggedized electronic tubes. A major aircraft manufacturer recently test-compared a certain type of Bendix tube with a radio-type tube it has been using. It not only saved money from the Bendix tube lasting 18 times longer but from the time saved not having to make 18 replacements.

Receiving . . . Microwave . . . Gas

Right now we make about 150 different types of special-purpose tubes which fall into three main categories: (1) Receiving and other special vacuum tubes, (2) Microwave tubes such as klystrons and noise sources, and (3) Gas tubes such as thyratrons, voltage regulators and spark gaps.



THE NAME MILLIONS TRUST

Bendix

AVIATION CORPORATION

PRINCIPAL DIVISIONS AND BASIC PRODUCTS

RED BANK, EATONTOWN, N. J.
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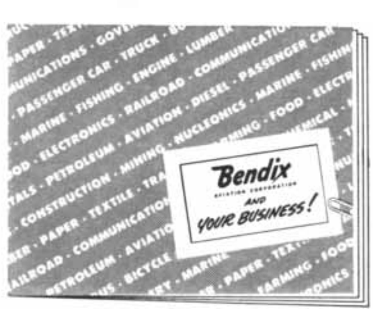


THE AUTHORS

ALVIN M. WEINBERG ("Power Reactors") is research director of the Oak Ridge National Laboratory, where he has been since 1946. He received his higher education at the University of Chicago, including a Ph.D. in physics in 1939. His original interest was biophysics, but he was diverted from that subject the day after Pearl Harbor. "Carl Eckart, who was working on the uranium problem, asked me to help him on a half-time basis with some neutron-diffusion problems I had encountered in my biophysics work. The plan was to stay with the project for six months—but the six months have grown to almost 13 years." During the war years Weinberg worked on the design of the Hanford piles with Eugene Wigner, from whom he claims to have learned most of what he knows about reactors. Weinberg is a pianist in his spare time and is chairman of the board of trustees of the Oak Ridge School of Music.

KAARE RODAHL ("Ice Islands in the Arctic") is a fellow of Oslo University and also director of research in the Arctic Aeromedical Laboratory at the Ladd Air Force Base in Alaska. Born in Norway, he began to study medicine at Oslo in 1935, became immersed in arctic studies and did not receive his M.D. till 1948. By that time he had done research in arctic nutrition, gone on two expeditions to Greenland, spent a time in England looking into the excess of vitamin A in the liver of polar bears, examined the biology of seals off Labrador and participated in a Danish expedition to Peary Land. In 1950 he joined the Arctic Aeromedical Laboratory as chief of its department of physiology. When Lieutenant Colonel Joseph O. Fletcher asked him whether he would like to help set up a base on an ice island, Rodahl was enraptured by the opportunity, but his wife was expecting their first baby. She insisted that he go, pointing out that at births "men are not only superfluous but often a nuisance."

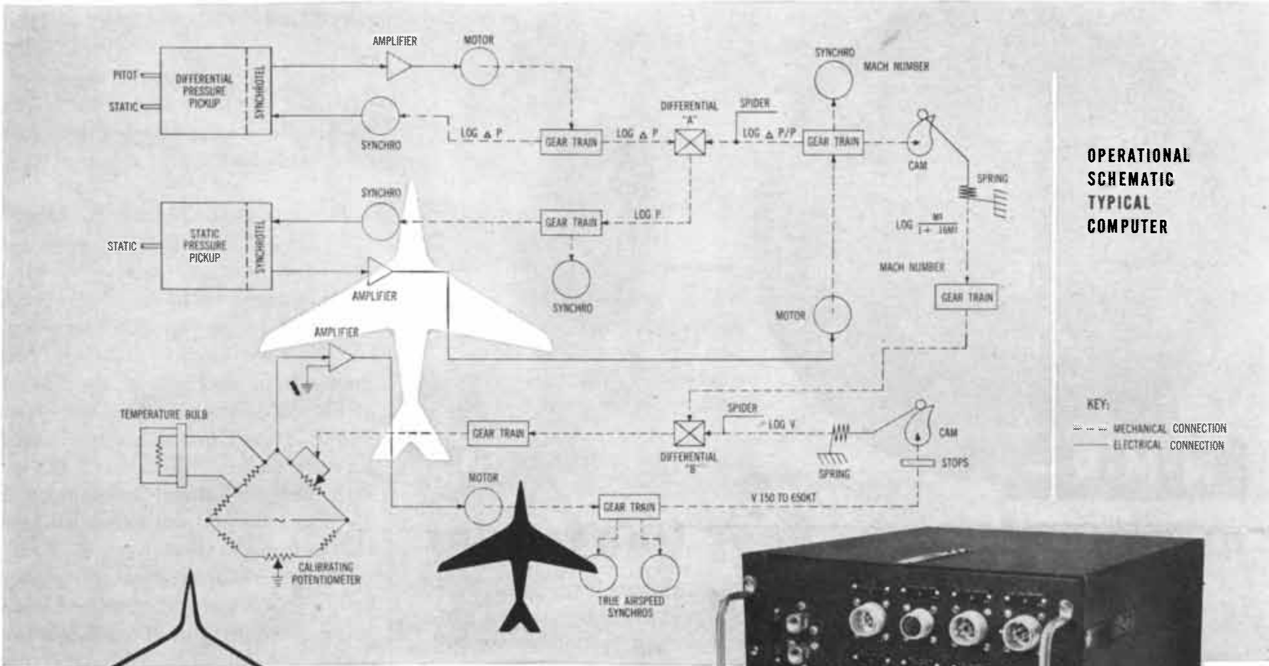
HUGH C. TROWELL ("Kwashiorkor") is senior Uganda Government medical specialist. He has spent 25 years working for the British Colonial Medical Service in Africa. As doctor in charge of the children's ward in the old hospital in Nairobi, Kenya, he found many children suffering from an unknown, fatal disease, and he doggedly continued to search for

its cause after he was transferred to the Makerere College Medical School in Uganda, where he teaches and treats patients besides doing research. His long years of work on the disease were summed up in a book this year. Trowell is a Fellow of the Royal College of Physicians in London and was decorated with an Order of the British Empire by Queen Elizabeth during her recent visit to Uganda. His wife is head of the department of fine arts at Makerere College.

ERNEST C. POLLARD ("The Physics of Viruses") is professor of biophysics at Yale University. He adopted viruses as his field of research after a career as a nuclear physicist and wartime worker in radar. He is chairman of the Scientists' Committee on Loyalty and Security and was co-author of an article on Fort Monmouth in the June issue of this magazine.

GEORGE E. MYLONAS ("Mycenae, City of Agamemnon") is chairman of the department of art and archaeology at Washington University in St. Louis. He was born in Smyrna, Turkey, one of the cities that claims Homer as a native son. As a child Mylonas lived about a block from the River Meles, by whose banks Homer may or may not have been born. He writes: "When I was 12, a gardener accidentally discovered an ancient grave in the courtyard of our church. I happened to be there, and when among the bones some vases were found and I took one in my hands, I knew then that my life work would be archaeology." His studies at the University of Athens were interrupted by service in the Greek Army during World War I and months spent as a prisoner of war in Turkey. After his release he first worked at the American School of Classical Studies in Athens and in 1928 came to the U. S. and took a Ph.D. at The Johns Hopkins University. He has been at Washington University since 1933 and has participated in several archaeological expeditions to Greece.

PETER N. WITT ("Spider Webs and Drugs") is a pharmacologist at the University of Bern in Switzerland. His parentage is Swiss-German, and he received his early education in Germany. As a boy he kept some 200 pets, including an antelope, pigeons, squirrels, turtles and fish. He was also the proud owner of a share in the local zoo, where he spent Saturday afternoons in and out of cages watching the animals. He studied medicine in Germany and Austria during World War II, working in field hos-



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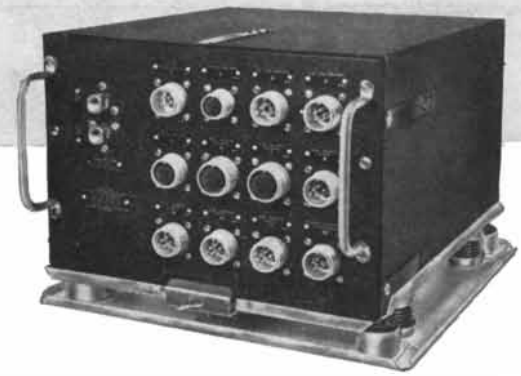

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pitals in Europe. Later he went into experimental pharmacology, making a specialty of comparative studies of the effects of drugs on various species of animals. He spent last year in the U. S. on a Rockefeller fellowship at the Harvard Medical School.

H. C. CORBEN and S. DEBENEDETTI ("The Ultimate Atom") are physicists who have worked together at the Carnegie Institute of Technology. DeBenedetti, an experimental physicist, was born in Florence, Italy, and holds a doctorate in physics from the University of Florence. After working as a research fellow at the Curie Laboratory in Paris, he came to the U. S. in 1940. He was at Oak Ridge National Laboratory from 1946 to 1948 and since then has been at Carnegie Tech. He is now a U. S. citizen. Corben, a mathematical physicist, recently took a leave of absence from Carnegie Tech to join the guided missile division of The Ramo-Wooldridge Corporation in Los Angeles. He was born in England and educated there (Cambridge University) and in Australia, where he taught for five years and got married. He joined the faculty at Carnegie Tech in 1946. He is currently helping his wife with her final draft of a humorous book on Australia.

E. N. da C. ANDRADE ("Robert Hooke") was for many years professor of physics at London University and has more recently been known for his studies in the history of science. He was born in London in 1887 of a family of Portuguese descent. He went to University College in London, began to study the structure of metals and discovered what is now known as Andrade's law for the creep of metals. He then obtained a Ph.D. *summa cum laude* at the University of Heidelberg and joined Ernest Rutherford's laboratory at Manchester. In 1913 he obtained the first measurement of the wavelengths of gamma rays. He saw active service in France in World War I and afterwards taught physics at the Artillery College until 1928, when he was appointed to the London University faculty. Andrade has received many honors and has been a Fellow of the Royal Society since 1935. Among his many accomplishments are the writing of poetry, a fluency in French and German which has served him well on the lecture platform, and a cultivated palate which is peculiarly receptive to *rouget flambé au fenouil.* He has a notable collection of 17th-century scientific books, though much of it was destroyed in German bombings.

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"Electro-Sheet" was developed and is made only by Anaconda*. Down at the Raritan Copper Works of the International Smelting and Refining Company (an Anaconda subsidiary) at Perth Amboy, N. J., production engineers turn it out in a wide range of thicknesses, as thin as one-thousandth of an inch (½ as thick as this page) and in five-foot-wide rolls thousands of feet in length.

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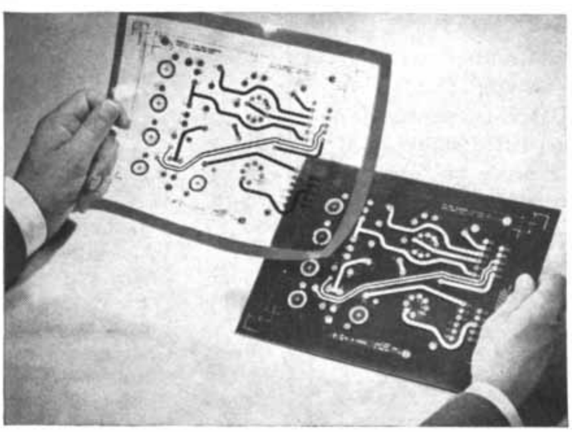

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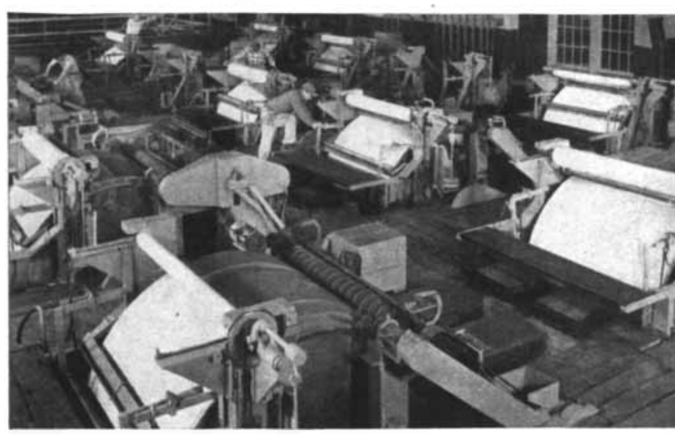
COPPER MAGIC makes a new kind of wiring. At left is wiring circuit on film before "printing". This pattern is then transferred to copper sheet bonded to plastic. At right, unwanted copper has been etched away, leaving the finished wiring board.



ON HUGE LEAD DRUMS Anaconda turns out "Electro-Sheet" copper weighing from ½ to 7 oz. per square foot. Drums rotate in a copper sulphate solution. Electricity deposits copper on the drums in smooth, clean, continuous sheets.

THE COVER

The painting on the cover shows a spider of the species *Zilla x-notata* spinning its web. The web is crazily disorganized because the spider has been fed a fly containing a drug. Because the effects of many drugs on web-spinning are characteristic, this phenomenon can be used to study the basic mechanism of drug action (*see page 80*). The tracery behind the misshapen web is the regular web normally spun by Zilla. At the upper left-hand corner of the normal web is an open sector, in the middle of which is a single "signal" thread.

THE ILLUSTRATIONS

Cover painting by Walter Linsenmaier

Page	Source
33-38	Irving Geis
39	Oak Ridge National Laboratory
40	U. S. Air Force
42-43	Emil Lowenstein
45	Marion F. Brinegar (*top*), A. P. Crary (*middle*), W. A. Wood (*bottom*)
46-50	Eric Mose
62	Robley C. Williams, University of California (*top and lower left*); Robley C. Williams and Dean Fraser, University of California (*lower right*)
64-68	Bunji Tagawa
70	Councilman Morgan, Columbia University College of Physicians and Surgeons
72	V. & N. Tombazi
73-74	Bunji Tagawa
75-78	V. & N. Tombazi
80	John Langley Howard
81	Peter Witt
82-83	John Langley Howard
84-86	Peter Witt
89	Bunji Tagawa
90-92	Carnegie Institute of Technology
94-98	Burndy Library
101-106	Marian Parry
108-114	Roger Hayward

DESIGNING WITH ALUMINUM

This is one of a series of infomation sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

NO. 9

CHOOSING AN ALUMINUM CASTING ALLOY & HEAT-TREATMENT

CHOOSING the proper aluminum casting alloy and heat-treatment requires a complete knowledge of the service conditions of the part under consideration, as well as of the alloys, heat treatments, and various casting methods in common use.

There are over thirty recognized casting alloys, with as many as five different heat-treatment possibilities for some, which results in quite a formidable number of choices. From these available alloy and heat-treatment combinations the possible range of typical mechanical properties varies widely as can be seen in the following table:

TABLE 1 Range of Mechanical Properties of Cast Aluminum Alloys

Ult. Tensile Strength	19,000 to 46,000 PSI
Yield Strength	8,000 to 43,000 PSI
Elongation	Zero to 14% in 2″
Fatigue	5,500 to 23,000 PSI
Brinell Hardness	40 to 140

The physical properties likewise, vary over a broad range as shown below:

TABLE 2 Range of Some Physical Properties of Cast Aluminum Alloys

General foundry characteristics	Fair to Excellent
Susceptibility to hot-shortness	Appreciable to Very Little
Ability to be cast in thin sections	Fair to Excellent
Leak tightness	Fair to Excellent
Internal shrinkage	Considerable to Very Little
Machinability	Fair to Excellent
Weldability	Not Recomended to Excellent
Resistance to certain chemicals and compounds	Can't use to Recommended
Strength at elevated temperatures	Low to Moderate
Resistance to corrosion	Fair to Excellent
Impact, or shock-load resistance	Poor to Excellent
Thermal conductivity	.21 to .45 CGS units @ 25°C
Electrical conductivity	21 to 50% of copper (equal volume basis)
Stability to low temperature aging	Low stability to stable

Because of this wide range of properties from which to select, it is recommended that the alloy and heat-treatment be determined by the designer, rather than by the foundryman, because usually the designer has all the data which affect the choice. The foundry should be consulted, but should not be the sole judge. Other factors, each equally as important as foundry characteristics, enter into the alloy and heat-treatment selection.

The designer usually knows which property is required to the fullest extent for the part in question. This should, theoretically, make it fairly easy to select the correct combination from the tables, by merely choosing the one that has the desired property to the maximum degree. But unfortunately, castings having the desired ultimate strength for instance, may not have the required elongation or shock resistance, nor the desirable foundry characteristics. Another having the desired foundry characteristics may not have the required strength and machining properties.

Still another combination may have the required mechanical properties, foundry characteristics and corrosion resistance, but because of size and shape of casting, cannot be given the theoretically ideal heat-treatment. Compromises will have to be made in almost all cases and this can best be done by the designer. In fact, it will sometimes be necessary to actually change the design of part in order to make it adaptable for production in a given alloy and heat-treatment or to cast it by a certain process.

Factors to Consider

To enable the designer to make best alloy and heat-treat recommendations, he should be familiar with production and service requirements. He should also have a fair working knowledge of the aluminum alloys, heat treatments, and of the possibilities and limitations of the various casting processes.

The production and service requirements have a large bearing on the casting method, as do size and shape of part. For example, castings required in fairly large numbers, should be made either by permanent mold or die casting process, provided the size and design features of casting and available alloys are suitable.

Sand casting process is usually confined to producing parts required in small quantities, those having hollow cavities and complex arrangement of ribs, pockets, etc., and to those whose size makes them unsuited for casting in metal molds. In many cases it will be advantageous to redesign a part to make it adaptable for production by either permanent mold or die casting method.

Once the casting method is determined, the alloy choice is narrowed down appreciably.

Next to be considered are the service requirements. If high strength is necessary, that ordinarily eliminates the unheat-treatable alloys unless sufficient metal can be added to compensate for the lower mechanical properties. This can be further and rapidly narrowed down when the remaining requirements such as leak tightness, corrosion resistance, machinability and others are considered.

In some instances, one certain property may be required to the maximum degree—for example, highest possible yield. This immediately narrows down the alloy and heat treatment choice as well as casting method to a possible one or two, and bigger compromises will have to be made for the other requirements.

In other cases the large size and shape of casting may not permit the safe use of a "solution heat-treatment," but will limit it to use of a "straight aging treatment" taking place in approximate temperature range of 300° F to 500° F, or to no treatment at all, thereby sacrificing, to a degree, some of the mechanical properties and slightly decreasing machinability.

The reason for this limitation is the fact that the first half of a solution heat-treatment takes place at a temperature ranging between 930° F to 1,000° F, followed by rapid quench in water. At those temperatures, the mechanical strength of aluminum is practically zero and therefore certain large unsupported areas of the casting, or the whole casting at times, may sag or distort from its own weight. Sometimes the size and shape of part are such that it can withstand the effects of the high temperatures but cannot be quenched without danger of warping or cracking.

Die castings are always used in the as-cast condition, which limits the choice to one of alloy selection only.

To assist the designer in becoming familiar with the various casting processes, mechanical properties, and physical properties we refer him to these tables on the following pages:

Table #3—Typical Mechanical Properties of Aluminum Sand Castings

Table #4—Typical Mechanical Properties of Aluminum Permanent Mold Castings

Table #5—Typical Mechanical Properties of Aluminum Die Castings

Table #6—Alloy selection Guide

PLEASE TURN TO NEXT PAGE ➡

SAND CASTING ALLOYS—TABLE 3

Alloy	H. T.[3]	Typical Mechanical Properties[1]					Casting and Service Characteristics[2]						
		Tensile Strength psi	Yield Strength psi	Elongation Per Cent in 2"	Hardness Brinnell 10/500	Fatigue psi	Feeding Ability	Pressure Tightness	Hot-Shortness	General Cast-ability	Machin-ability	Corrosion Resist-ance	Weld-ability[5]
43	AC	19,000	8,000	8.0	40	6,500	E	E	VL	E	F	E	VG
108	AC	21,000	14,000	2.5	55	8,000	E	E	MIN	VG	G	G	G
112	AC	24,000	15,000	1.5	70	9,000	F	F	MOD	G	G	G	F
113	AC	24,000	15,000	1.5	70	9,000	G	G	MOD	G	G	G	G
122	T2	27,000	20,000	1.0	80	9,500	G	VG	MOD	G	E	F	F
122	T61	41,000	40,000	(6)	115	8,500	G	VG	MOD	G	E	F	F
142	T21	27,000	18,000	1.0	70	6,500	G	F	AP	F	G	G	F
142	T571	32,000	28,000	.5	85	8,000	G	F	AP	F	G	G	F
142	T77	28,000	25,000	2.0	75	9,500	G	F	AP	F	G	G	F
195	T4[4]	32,000	16,000	8.5	60	6,000	G	G	AP	F	G	G	F
195	T6	36,000	24,000	5.0	75	6,500	G	G	AP	F	VG	G	F
195	T62	40,000	30,000	2.0	90	7,000	G	G	AP	F	E	G	F
212	AC	23,000	14,000	2.0	65	8,000	G	G	MOD	G	E	G	G
214	AC	25,000	12,000	9.0	50	5,500	F	F	MOD	F	E	E	G
B214	AC	20,000	13,000	2.0	50	....	G	F	MOD	F	E	E	G
F214	AC	21,000	12,000	3.0	50	....	G	F	MOD	F	E	E	G
220	T4	46,000	25,000	14.0	75	7,000	F	F	MOD	F	E	E	G
319	AC	27,000	18,000	2.0	70	10,000	G	E	VL	VG	G	G	G
319	T6	36,000	24,000	2.0	80	10,000	G	E	VL	VG	G	G	G
355	T51	28,000	23,000	1.5	65	7,000	E	E	VL	E	E	VG	VG
355	T6	35,000	25,000	2.5	80	8,500	E	E	VL	E	E	VG	VG
355	T61	39,000	35,000	1.0	90	....	E	E	VL	E	E	VG	VG
355	T7	38,000	36,000	0.5	85	8,500	E	E	VL	E	E	VG	VG
355	T71	35,000	29,000	1.5	75	10,000	E	E	VL	E	G	VG	VG
356	T51	25,000	20,000	2.0	60	7,500	E	E	VL	E	G	E	VG
356	T6	33,000	24,000	4.0	70	8,000	E	E	VL	E	G	E	VG
356	T7	34,000	30,000	2.0	75	....	E	E	VL	E	E	E	VG
356	T71	28,000	21,000	4.5	60	....	E	E	VL	E	G	E	VG

NOTES:

1. Properties determined on standard tensile test bars cast under favorable conditions and properly heat-treated, when applicable.
2. Ratings: E, excellent; VG, very good; G, good; F, fair—apply to all castings and service characteristics except Hot-Shortness; MOD, moderate; VL, very little; AP, appreciable; MIN, minor—applies to Hot-Shortness only.
3. AC, as cast.
4. On standing at room temperature for several weeks, properties approach those of T6 condition.
5. Weld before heat-treating, using appropriate filler rod.
6. Less than 0.5% elongation.

PERMANENT MOLD CASTING ALLOYS—TABLE 4

Alloy	H. T.[3]	Typical Mechanical Properties[1]					Casting and Service Characteristics[2]						
		Tensile Strength psi	Yield Strength psi	Elongation Percent in 2"	Hardness Brinnell 10/500	Fatigue psi	Feeding Ability	Pressure Tightness	Hot-Shortness	General Cast-ability	Machin-ability	Corrosion Resist-ance	Weld-ability[5]
43	AC	23,000	9,000	10.0	45	....	E	E	VL	E	F	E	VG
A108	AC	28,000	16,000	2.0	70	....	E	G	MIN	VG	G	G	G
113	AC	28,000	19,000	2.0	70	....	F	G	MOD	F	G	F	F
C113	AC	30,000	24,000	1.0	80	9,500	G	VG	VL	G	G	G	G
122	T52	35,000	31,000	1.0	100	....	G	G	MOD	G	E	F	F
122	T551	37,000	35,000	......	115	8,500	G	G	MOD	G	E	F	F
122	T65	48,000	36,000	......	140	9,000	G	G	MOD	G	E	F	F
A132	T551	36,000	28,000	.5	105	13,500	F	VG	VL	F	F	G	G
A132	T65	47,000	43,000	.5	125	....	F	VG	VL	F	F	G	G
D132	T5	36,000	28,000	1.0	105	13,500	G	VG	MIN	G	F	G	G
138	AC	30,000	24,000	1.5	100	....	....	VG	....	....	G	....	....
142	T571	40,000	34,000	1.0	105	10,500	F	F	AP	F	VG	G	F
142	T61	47,000	42,000	.5	110	9,500	F	F	AP	F	VG	G	F
B195	T4[4]	37,000	19,000	9.0	75	9,500	F	F	MOD	F	G	G	G
B195	T6	40,000	26,000	5.0	90	10,000	F	F	MOD	F	G	G	G
B195	T7	39,000	20,000	4.5	80	9,000	F	F	MOD	F	G	G	G
A214	AC	27,000	16,000	7.0	60	....	F	F	AP	F	E	E	G
319	AC	34,000	19,000	2.5	85	....	G	G	VL	G	G	G	G
319	T6	40,000	27,000	3.0	95	....	G	G	VL	G	G	G	G
333	AC	34,000	19,000	2.0	90	14,500	G	G	VL	G	F	G	G
333	T5	34,000	25,000	1.0	100	12,000	G	G	VL	G	F	G	G
333	T6	42,000	30,000	1.5	105	15,000	G	G	VL	G	F	G	G
333	T7	37,000	28,000	2.0	90	12,000	G	G	VL	G	F	G	G
355	T51	30,000	24,000	2.0	75	....	E	E	VL	E	VG	VG	VG
355	T6	43,000	27,000	4.0	90	10,000	E	E	VL	E	VG	VG	VG
355	T62	45,000	40,000	1.5	105	10,000	E	E	VL	E	E	VG	VG
355	T7	40,000	30,000	2.0	85	10,000	E	E	VL	E	VG	VG	VG
355	T71	36,000	31,000	3.0	85	10,000	E	E	VL	E	VG	VG	VG
356	T6	40,000	27,000	5.0	90	13,000	E	E	VL	E	G	E	VG
356	T7	33,000	24,000	5.0	70	11,000	E	E	VL	E	G	E	VG
363	AC	35,000	23,000	2.7	85	....	E	VG	VL	E	E	G	E
363	T6	48,000	28,000	6.5	90	....	E	VG	VL	E	E	VG	E

NOTES:

1. Properties determined on standard tensile test bars cast under favorable conditions and properly heat-treated, when applicable.
2. Ratings: E, excellent; VG, very good; G, good; F, fair—apply to all castings and service characteristics except Hot-Shortness; MOD, moderate; VL, very little; AP, appreciable; MIN, minor—applies to Hot-Shortness only.
3. AC, as cast.
4. On standing at room temperature for several weeks, properties approach those of T6 condition.
5. Weld before heat-treating, using appropriate filler rod.

DIE CASTING ALLOYS—TABLE 5

Alloy	Condition[3]	Typical Mechanical Properties[1]					Casting and Service Characteristics[2]					
		Tensile Strength psi	Yield Strength psi	Elongation Per Cent in 2"	Hardness Brinnell 10/500	Fatigue psi	Mold Filling Capacity	Hot-Shortness	General Castability	Machin-ability	Corrosion Resistance	Weld-ability
13	AC	39,000	21,000	2.0	---	19,000	VG	VL	VG	F	VG	not
A 13	AC	35,000	16,000	3.5	---	....	VG	VL	VG	F	VG	recom-
43	AC	30,000	16,000	9.0	---	17,000	G	MIN	G	F	VG	mended
85	AC	40,000	24,000	5.0	---	22,000	G	MOD	G	F	VG	"
218	AC	45,000	27,000	8.0	---	23,000	F	AP	F	E	E	"
360	AC	44,000	27,000	3.0	---	19,000	E	VL	E	F	G	"
A360[4]	AC	41,000	23,000	5.0	---	18,000	E	VL	G	F	E	"
380	AC	45,000	26,000	2.0	---	20,000	VG	MOD	G	G	G	"
A380[4]	AC	46,000	25,000	3.0	---	19,000	VG	MOD	G	G	G	"
384	AC	46,000	27,000	1.0	---	21,000	VG	MOD	G	F	G	"

NOTES:

1. Properties determined from standard test bars cast under favorable conditions.
2. Ratings: E, excellent; VG, very good; F, fair—apply to all castings and service characteristics except "hot-shortness"; MOD, moderate; VL, very little; AP, appreciable; MIN, minor—apply to "hot-shortness" only.
3. As cast.
4. In A360 and A380, the iron content is controlled more closely than in 360 and 380 alloys.

SELECTION GUIDE—TABLE 6

Major Property Wanted	Sand Cast	Perm. Mold	Die Cast
General purpose— Low strength arranged in order of decreasing castability	43 108 112 113 212 214	43 A108 113 C113 A214	43 A 13 13
General purpose— Heat-treated[1] good balance of all properties for most applications	355-T6 356-T6 319-T6 19-ST6	355-T6 356-T6 319-T6 B19-ST6	380 A380 85 360 A360
Best castability for complex castings with thin sections—arranged in order of decreasing castability	43 108 356 355	43 A108 356 355	A360; 360 A 13; 13 43
High ductility and **shock resistance** arranged in order of decreasing properties	220-T4 195-T4 356-T6 214[2] 43	363-T6 B195-T4 356-T6 A214 43	218 A360 85 43
Pressure tight—Low stressed	43 108 319	43 A108 319	A360 A 13 43
Pressure tight—High stressed	356 355 319	356 355 319 363	A360

Major Property Wanted	Sand Cast	Perm. Mold	Die Cast
Corrosion Resistance	43 214 220 356 355	43 A214 356 355 363	218 A360
Ornamental and Architectural Applications—also food handling, dairy equipment, cooking utensils and marine fittings	43 214[2] B214[2] F214[2]	43 A214[2]	43 218[2]
Piston Alloys—good properties at operating temperatures	122 142	122 A132 D132 142	384 85
Other alloys having good properties at moderate temperatures	214	138 A214	13 360
Good machinability—Heat-treated castings machine better than those in as-cast condition, and generally those having highest hardness machine better than the softer ones in any one alloy	112 122 212 214 B214 F214 220-T4 195	122 355 363 A214 A108	218 380 A380

NOTES:

1. Except die castings.
2. These alloys take anodized finish without appreciable discoloration.

More detailed assistance with design, alloy selection, fabrication, and heat-treatment procedure is obtainable through any Kaiser Aluminum sales office located in principal cities, or write to Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

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CONTENTS FOR DECEMBER, 1954 VOL. 191, NO. 6

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

DECEMBER, 1954 VOL. 191, NO. 6

Power Reactors

The goal of economic atomic power is still in the distance. To discover the best approach to it, the U.S. is building five separate types of experimental nuclear power stations

by Alvin M. Weinberg

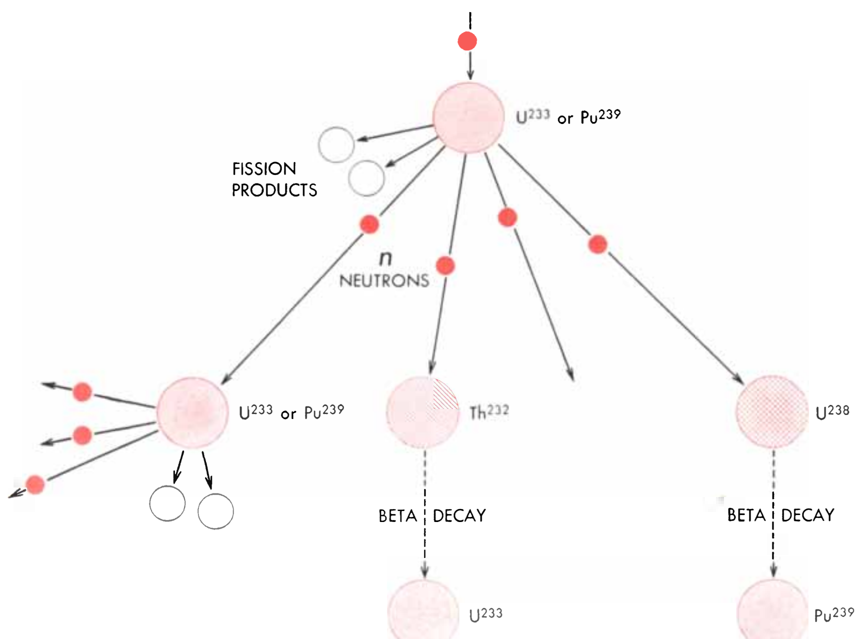
Within the next five years the Atomic Energy Commission will invest $200 million in a program to develop economical nuclear power plants. The Commission is hedging this bet, so to speak, by backing five different reactor plans—a technological sweepstakes quite without precedent. If any one of the five approaches reaches the goal, the reward of course will be considerable. But in any case the investment should at least bring us within sight of the objective of harnessing nuclear power on a basis competitive with coal and oil. (Military nuclear engines are a different story.)

Why five separate approaches? Why not one—or 20? It is no secret that no one line of reactor development has yet given convincing evidence of superior promise. In addition, the various reactor types are in a sense not really competitive because their objectives are not entirely comparable. On the other hand, not even the U. S. is rich enough to investigate every likely possibility. It has often been said that there are as many ideas for reactors as there are reactor designers. The various designers naturally have an emotional attachment to their own designs, or at least an attachment colored by their individual experience, but some selection must be made from the vast number of possible approaches. When the Joint Congressional Committee on Atomic Energy requested the AEC to project a five-year program of reactor development, the Commission listed five types which had been explored extensively for several years and had been selected as most promising.

Before describing these types, I should outline what the program seeks to achieve and what materials it has to work with.

There are two potential fuels: thorium and uranium. It therefore makes sense to try both, and the program includes thorium as well as uranium reactors. As the AEC has announced, a thorium reactor can breed more fuel than it burns through conversion of the thorium to fissionable uranium 233 by neutrons of thermal speed; this was probably the most important scientific announcement the Commission made in connection with the five-year program.

Closely related to the matter of fuel



FUEL-BREEDING CYCLE depends on neutron economy. Of *n* neutrons released when a fissionable atom splits (*top*), one must maintain the chain reaction (*left*), some will be absorbed by nonbreeding materials or escape (*second from right*), and at least one (*two are shown here*) must hit "fertile" Th-232 or U-238 atoms, which decay into U-233 or Pu-239.

PLANT	DEVELOPER	HEAT (KILOWATTS)	ELECTRICITY (KILOWATTS)	COST (MILLIONS OF DOLLARS)
PRESSURIZED WATER REACTOR	WESTINGHOUSE	264,000	60,000	85
EXPERIMENTAL BOILING-WATER REACTOR	ARGONNE	20,000	5,000	17
SODIUM REACTOR EXPERIMENT	NORTH AMERICAN	20,000	NONE	10
EXPERIMENTAL BREEDER REACTOR—II	ARGONNE	62,500	15,000	40
HOMOGENEOUS REACTOR EXPERIMENT—II	OAK RIDGE	3,000	NOT SPECIFIED	47
HOMOGENEOUS THORIUM REACTOR	OAK RIDGE	65,000	16,000	

EXPERIMENTAL REACTORS to be built under the five-year development program are tabulated above. Only the pressurized water reactor will be a commercial-scale power plant.

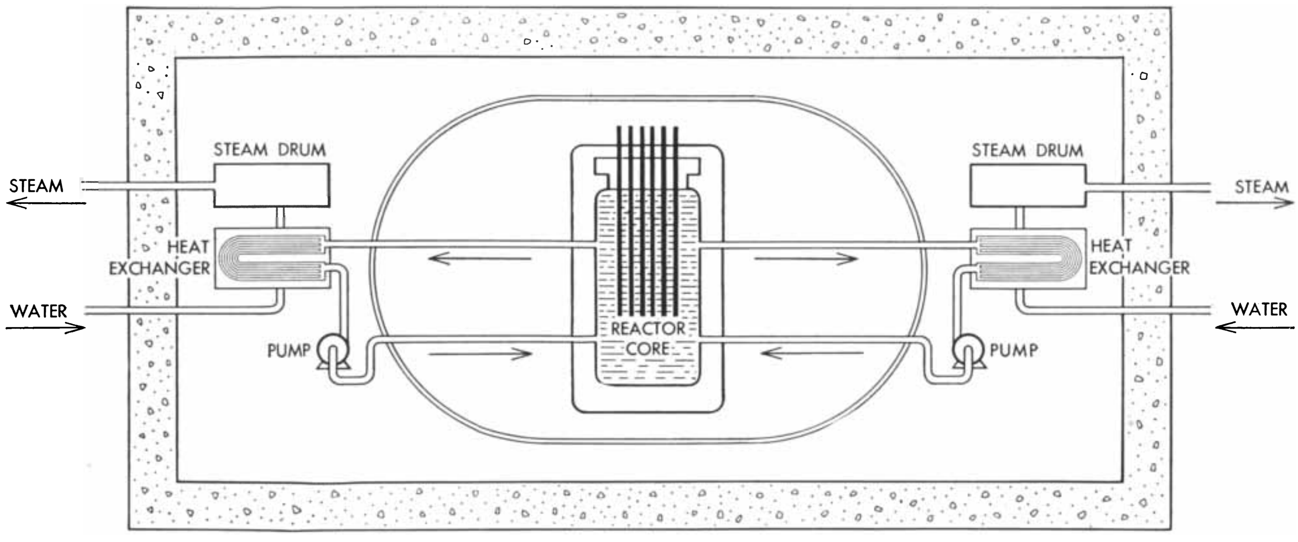
is neutron economy. In a chain reaction one neutron from each fission is always used up to cause a new fission and sustain the reaction; any extra neutrons can be used to manufacture atoms of new fuel, by converting uranium 238 into fissionable uranium 235 or thorium into U-233. To "breed" more fuel than is burned, the number of neutrons produced by each fission must exceed two by a fair margin, since some neutrons will always be wasted, say by absorption in structural materials. This consideration affects the choice of fuel.

According to information released by the AEC, the number of fast neutrons liberated by the fission of any fissionable atom (plutonium, U-233 or U-235) is "considerably greater than two." Thus either a uranium or a thorium reactor using fast neutrons could breed more fuel than it burned. But a fast-neutron reactor is so concentrated and small that it is difficult to cool and control. From the engineering standpoint there is strong incentive to prefer thermal-neutron reactors, for they are much larger and more dilute and therefore much easier to cool. The problem, however, is that the yield of available neutrons is reduced when they are slowed from fast to thermal speed. In the case of plutonium, generated in a uranium reactor, the yield of thermal neutrons per fission is only two. This seems to rule out uranium as the raw material for a thermal breeder. The thermal-neutron yield from U-233, generated in a thorium reactor, is "greater than two." Consequently thorium is an attractive possibility as the basis of a thermal breeder.

Even a uranium thermal reactor may produce some new fuel during operation, though not at as fast a rate as it burns its fuel. Such a reactor is said to be "regenerative." There is a continuous spectrum of possible regenerative reactors. As long as natural uranium is fairly cheap, and provided the reactor can burn as much as 1 per cent of all its original uranium atoms without reprocessing, the fuel cost of a nuclear power plant can be low—1.35 mills per kilowatt hour. Such a reactor of course is slightly regenerative, for only .7 per cent of the original atoms are fissionable U-235; the remaining .3 per cent of the fuel burned is plutonium which has been produced by conversion of U-238 through absorption of neutrons.

Another big issue in the reactor competition is the efficiency of the conversion of heat into electricity. This problem centers on the coolant. The most interesting fact here is that three of the five reactor schemes to be explored will use water (ordinary water or heavy water) as the coolant, in spite of the relatively low thermal efficiency inherent in water. The two main reasons are: first, that water is plentiful, and second, and more important, that it is the only common coolant which is also a moderator. An essential simplicity is achieved by combining the two functions of slowing neutrons and cooling in one material. One of the reactor types will take this combining of functions still further by using heavy water as moderator, coolant and carrier of the fuel in solution.

Heavy water, which is the best of all moderators because it absorbs almost no



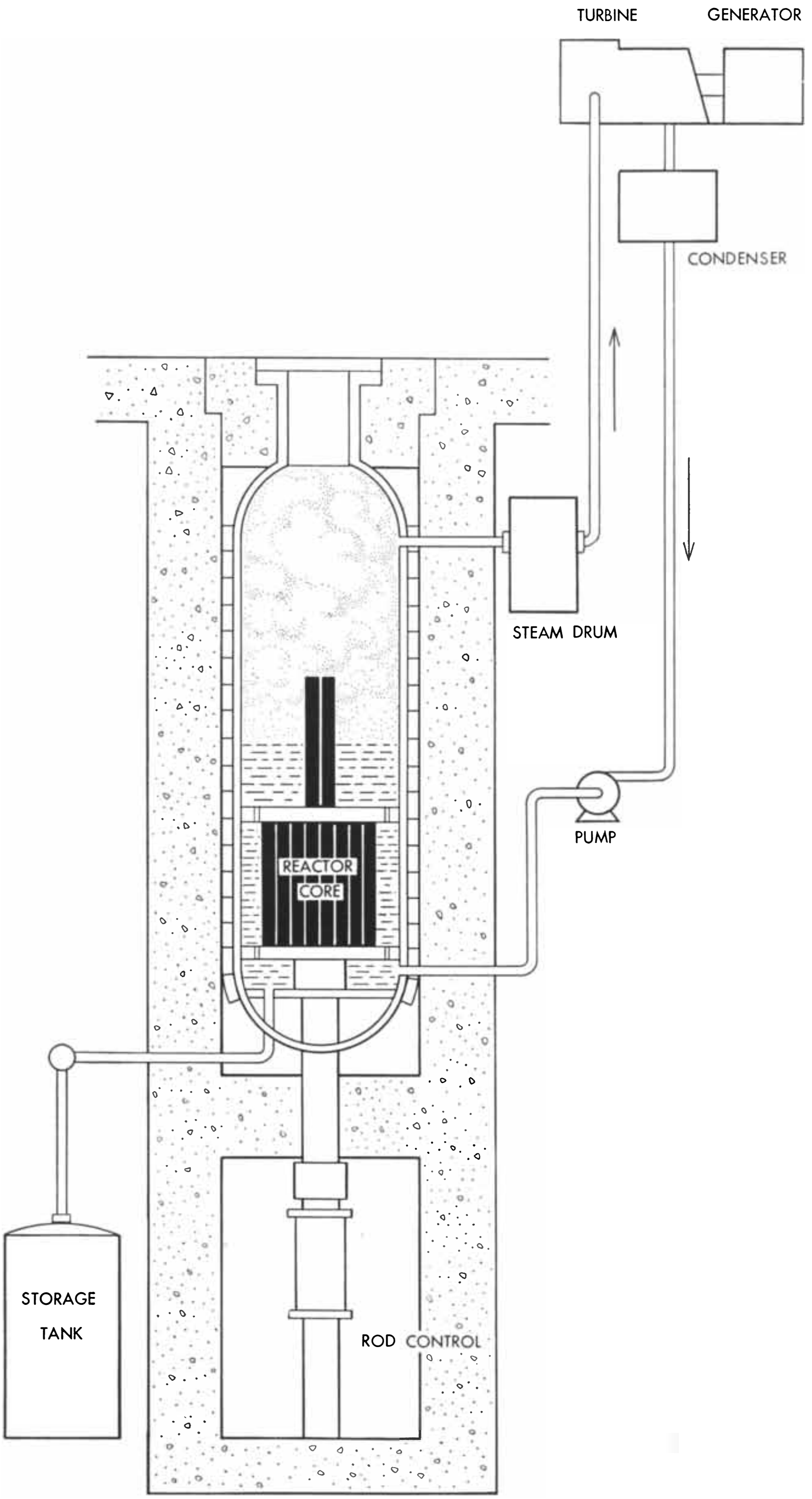
PRESSURIZED WATER REACTOR will have four loops to conduct coolant from the reactor core. One loop will serve as a spare. Only two of the four loops are shown here. The fuel elements of slightly enriched uranium rods will be coated with a corrosion-resistant metal. More than 10 tons of uranium will be used. A large gas-tight pressurized shell will surround the core assembly and the heat exchanger assemblies. The light-water coolant heated by uranium fission generates steam in the heat exchangers.

neutrons, offers another advantage: it has a high "material" efficiency which offsets its low thermal efficiency. It can spread out the dissolved uranium atoms in a very dilute solution without capturing many of the neutrons they produce. And as a result of this intimate contact with the fuel, the heavy water should extract the heat from the fissioning fuel very efficiently. Since the fuel is expensive, this highly efficient use of it has much the same effect as high thermal efficiency in lowering the cost of producing electricity.

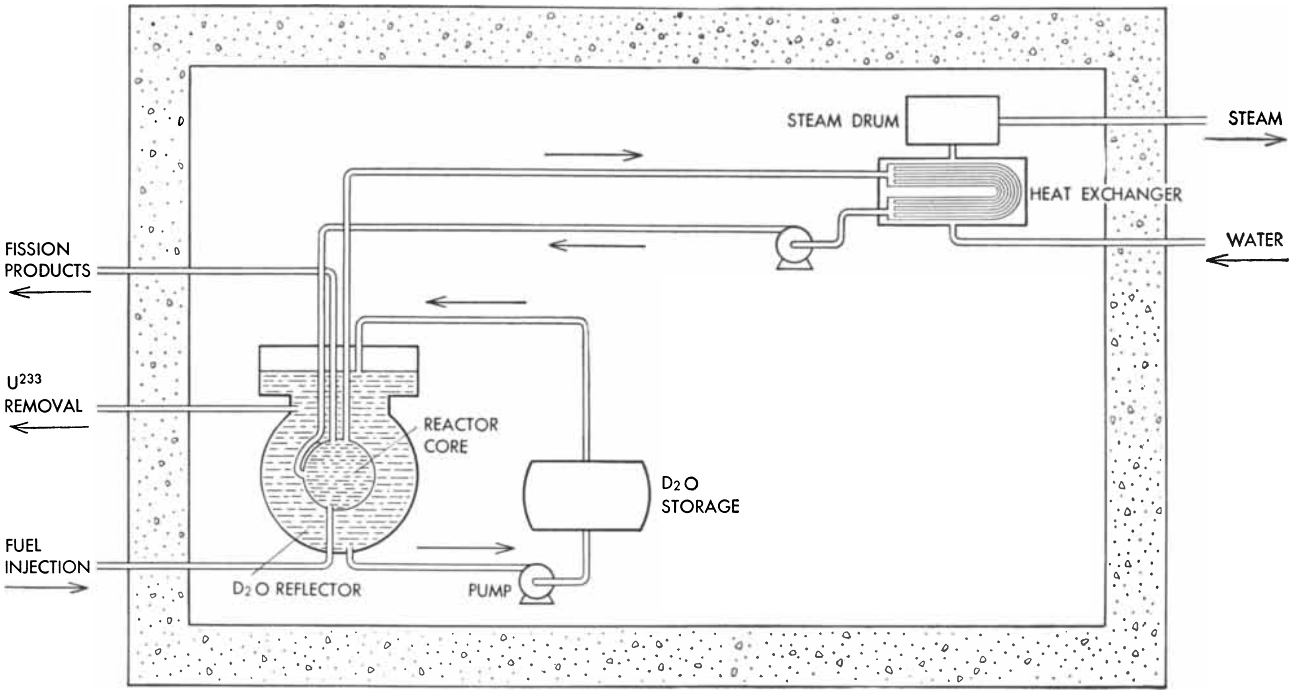
The sacrifice of thermal efficiency in favor of other efficiencies will apply to many other aspects of the design of nuclear power plants. In fact, it has been estimated that the most economical operating temperature for a nuclear-fueled steam plant will be between 600 and 800 degrees Fahrenheit—considerably lower than the standard in conventional steam plants. The lower-temperature steam system of course will be cheaper to build. It will be feasible if, as seems likely, the relative cost of the nuclear fuel can be reduced to the point where the fuel itself is practically free.

Still another test that nuclear power reactors will have to pass is economy in the processing of their fuel: that is, in dissolving, extracting, recovering and fabricating the metal. Here the most promising approach is the homogeneous reactor, where a continuous recycling of the dissolved fuel, as opposed to expensive batch methods, seems possible. It has already been disclosed that fused salts dissolved in liquid bismuth look promising as extractants of fission products from the fuel.

The entire problem of nuclear power is finally summed up in a single criterion: How many mills per kilowatt hour of electricity? As has been said so often, the costs comprise capital costs, fuel costs and operating costs. If there is any appreciable fuel regeneration, the fuel cost in nuclear plants will be negligible. However, the operating costs, including chemical reprocessing, may be several mills per kilowatt hour. To meet the competition of the best coal-fired steam plants in the U. S., nuclear plants will have to generate power at a cost between 4 and 7 mills, depending on the price of coal in the locality of the plant. Assuming that nuclear fuel is cheap, it will be possible to invest about $100 to $200 per kilowatt more in building the plant and still compete in power cost with a coal plant. The five-year-program reactors, being initial steps, are not themselves ex-



EXPERIMENTAL BOILING-WATER REACTOR has the advantage of a system in which water is heated to steam by the fission process in the reactor core and passes directly into the turbine. Some of the disadvantages are the unevenness of the boiling operation in the core and the radioactivity of steam in the turbine. The fuel element will be enriched uranium.



HOMOGENEOUS REACTOR EXPERIMENT—II, with the homogeneous thorium reactor modification of it also planned, is diagrammed here. Its fuel will be uranium dissolved in water, which undergoes fission and heats up. This heat, given up in the heat exchanger, generates steam for the turbine. A heavy-water reflector surrounds the core. Fission products are removable and additional fuel can be injected. In the thorium reactor a thorium blanket in which U-233 would breed would replace the reflector.

pected to achieve this, but it is hoped that they lie on paths of development which will lead to cheap nuclear power.

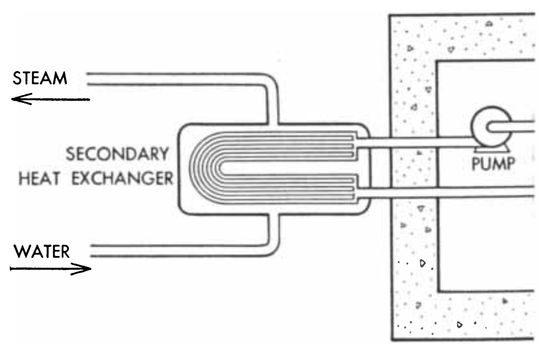
Now let us consider each of the five types of reactors to be investigated. It is convenient to group them according to their engineering genealogy—*i.e.*, the engineering tradition or development path along which they lie. From this point of view they fall into two groups: those using water as the coolant and those using a liquid metal coolant, such as sodium. Within each category, of course, there are many possible variations: for example, a given type of reactor may use uranium or thorium as the fuel, it may breed or regenerate fuel or operate only on its original charge, and so on. The unknowns being investigated are mainly engineering questions: How practical is sodium as a coolant? How long can a high-pressure radioactive water system be kept leakproof? Will the slightly radioactive turbine or the steam boiler be an important maintenance problem? As the following descriptions show, the reactors are intended primarily to answer such subtle questions of engineering feasibility and economics.

We begin with the pressurized water reactor (PWR) designed by the Westinghouse Electric Corporation for the Duquesne Light Company in Pittsburgh, which will operate the plant. Its principle is essentially that of the reactors Westinghouse has built for the Navy to power submarines. However, it will use as fuel slightly enriched natural uranium, instead of highly enriched U-235. The core of PWR will generate approximately 300,000 kilowatts of heat, which will be transferred to a heat exchanger by circulating water at a pressure of 2,000 pounds per square inch and a temperature of 525 degrees F. The heat exchanger will produce saturated steam at a pressure of 600 pounds per square inch. This steam in turn will go to a conventional turbine which is expected to generate a net electrical output of more than 60,000 kilowatts.

The high-pressure core will be contained in a carbon-steel vessel nine feet in diameter, coated with stainless steel. The uranium is to be disposed in a tight cluster of metallic fuel elements.

Because the expansion of the water as the temperature goes up allows neutrons to leak out more easily, such a system is inherently self-stabilizing; there is a possibility that PWR will need rather few control rods. The extremely remote possibility of a nuclear runaway is guarded against by enclosing each of the high-pressure components in a stout, gas-tight pressure vessel. The whole reactor system will be underground.

The submarine reactor has demonstrated the practicality of the high-pressure water system and pioneered some of the necessary equipment, such as the famous canned rotor pumps. Thus the PWR is less experimental than the other reactors to be built; in fact, the choice of water cooling and moderation for PWR was dictated by the requirement that the reactor demonstrate reliable nuclear power rather than cheap nuclear power.



SODIUM REACTOR EXPERIMENT will consist of a comparatively "old-fashioned" core (like those in the Hanford piles) immersed in a cooling bath of liquid sodium.

None of the estimates of cost suggest that PWR will be an economical power producer. However, as one tangible step along the road to a completely rationalized high-pressure water system PWR makes good sense.

Several paths lead from the PWR toward more economical power. For example, the great expense of fabricating the core will fall as automatic techniques for the manufacture of fuel elements are learned. Again, neutron economy can be greatly improved either by using heavy water instead of ordinary water or by replacing the uranium fuel with thorium and U-233. Furthermore, higher thermal efficiency and lower power cost might be realized by raising the pressure.

An obvious way to improve the performance of a water-cooled reactor is to generate turbine steam directly in the core instead of in a separate housing. One circulation loop would be eliminated, and the pressure of the system would be lowered, for the highest pressure in the reactor would be only that in the turbine. This rationalization of pressurized-water philosophy is so attractive that the AEC decided to include a direct-boiling reactor in the five-year program, and it is embodied in the second type: the experimental boiling-water reactor (EBWR) to be built by Argonne National Laboratory. Like PWR it will use slightly enriched uranium. There appears to be no reason, however, why thorium could not be used in the direct-boiler design. In that case this reactor might come close to breeding, especially if the moderator-coolant were heavy water. Ordinary water was chosen for EBWR because of the present difficulty of making the turbine sufficiently watertight to avoid losing any of the valuable heavy water.

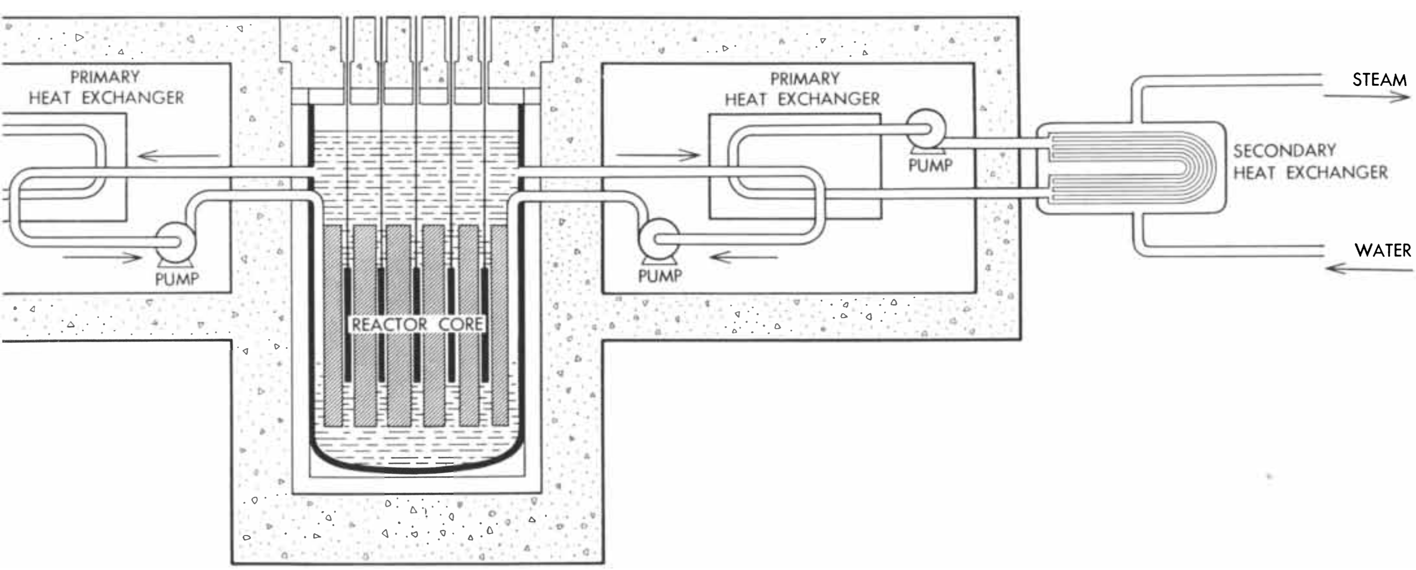
The main uncertainty about EBWR is connected with the roughness of operation caused by the boiling. As the moderator boils, its density fluctuates, and any density change will affect leakage of neutrons. In consequence the power level of the reactor will fluctuate; the higher the level, the greater the fluctuation. Thus the direct boiler will probably not be able to operate at as high a level of power per unit volume as a circulator like PWR. Its upper limit seems to be high enough, however, and the mechanical simplicity of the system is so attractive that the General Electric Company has stated its preference for the direct boiler as a long-term possibility.

Information on the roughness of operation of a direct-boiling reactor was obtained during the past two summers in experiments conducted by W. H. Zinn at the National Reactor Testing Station in Idaho, and also in some experiments on boiling in the low-intensity test reactor at the Oak Ridge National Laboratory. In all cases the experiments confirmed the view that reactors can be operated continuously in a stable fashion under boiling conditions.

The direct boiler and the circulating-water system share the essential limitations of all heterogeneous reactors—reactors in which the fuel, moderator and coolant are separate. At best they have a heat-transfer problem; they are susceptible to radiation damage; they accumulate neutron-absorbing fission products, and the reprocessing of their fuel is awkward. It is to circumvent these difficulties that the homogeneous system was introduced. The five-year program contemplates the construction of two homogeneous reactors, which constitute the third line of approach; actually it is a culmination of the two water systems described above.

In a homogeneous reactor the fuel (uranium or thorium) is dissolved in water. The uranium is in the form of a salt, uranyl sulfate. A solution of the salt will be circulated through pumps and heat exchangers to extract the heat produced by the fissioning atoms. The exchangers will generate fairly high-pressure, nonradioactive steam. It is possible to think of a direct-boiling homogeneous reactor—one in which the steam is generated in the reactor itself by boiling the water containing the fuel. However, the steam would be extremely radioactive, and the turbine that received it would be very awkward to service, to say nothing of the difficulty of making it leaktight so that the radioactive steam would not escape.

The first of the two homogeneous reactors will be a fairly modest version generating only 5,000 kilowatts of heat. Its main purpose will be to explore the engineering problems. It will be called



Slightly enriched uranium rods (*solid black bars*) run through channels in a graphite moderator (*hatched bars*). The liquid sodium surrounding the core circulates through a pair of cooling systems to make steam for twin generators. To avoid the danger of placing highly radioactive sodium near water, the coolant is made to give its heat to a second sodium loop in the primary heat exchanger. The nonradioactive fluid then boils water in the secondary heat exchanger. Concrete shields the primary units.

HRE-2, because it follows the plan of HRE-1 at Oak Ridge, the first high-temperature homogeneous reactor built. It will consist of a more or less spherical vessel, in which the fuel solution will circulate through a core so shaped that the fluid will become critical and heat up; after it leaves the core the fluid will travel through piping shaped to quench any chain reaction.

The most remarkable aspect of the homogeneous reactor is its seeming simplicity. For example, there are no mechanical control rods. The system is completely self-regulating. An experiment performed on the HRE-1 dramatically demonstrated this. At a core temperature of 338 degrees F. the reactor was barely critical. The main circulating pump was stopped and the fluid in the heat exchanger was cooled to 212 degrees F. Then the pump was started. As the cooler, and therefore more reactive, fluid poured into the core of the reactor, the reactor shot up in power by a factor of almost one million in a few tenths of a second. However, as soon as the water was heated the reactor leveled off to a steady output of 1,000 kilowatts. The initial flow of cooler water into the core caused a rise of reactivity at the rate of .8 per cent per second. Such a rise in any heterogeneous reactor would almost certainly lead to fairly violent, and possibly dangerous, pressure surges.

The nuclear stability of the aqueous homogeneous system is bought at the price of having to deal with billions of curies of radioactivity in solution under high pressure; that is, one buys almost complete nuclear safety, but one pays for it with a requirement of absolute leak-tightness and material control. It is to establish the engineering feasibility and long-term reliability of such a leaktight high-pressure system that HRE-2 is being built.

HRE-2 will be followed by a larger reactor with a heat output of at least 65,000 kilowatts. It is hoped that this will be the first thorium thermal breeder. This reactor (HTR) will contain thorium in heavy water, and it will manufacture U-233 in a thorium blanket.

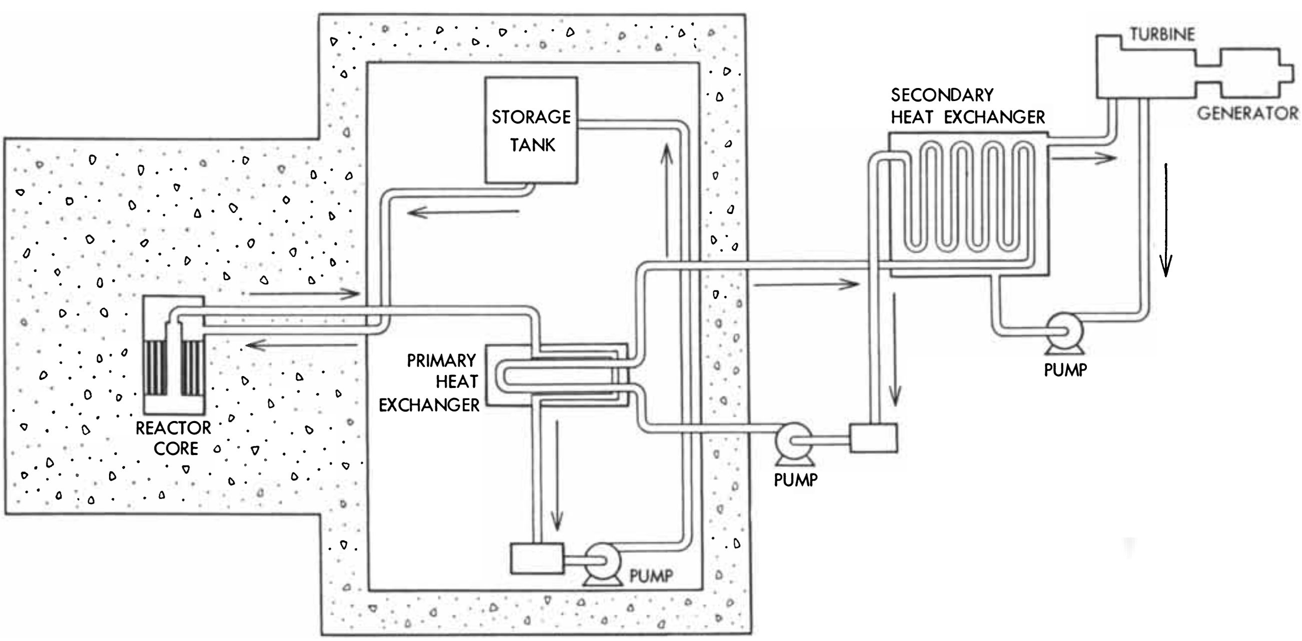
The inherent difficulties of a homogeneous reactor, almost entirely connected with handling colossally radioactive and corrosive fluids under high pressure, are so great that the probability of success is not as high as for the more conservative types. Yet the incentive is so great that a major effort has been launched to solve the admittedly formidable engineering problems.

The remaining two reactor approaches are put together because they both will use sodium as the coolant and their external equipment will be much the same. In both reactors hot sodium from the reactors will give its heat to steam which will operate turbogenerators. In order to avoid the possibility of contact between the steam and the radioactive sodium coming from the reactor, it has usually been considered desirable to incorporate an intermediate fluid to carry the heat from the reactor sodium to the steam generator.

One of these systems is the sodium reactor experiment (SRE) designed by North American Aviation, Inc. It resembles the Hanford reactors, except that sodium replaces the water that flows past and cools the fuel elements. Its moderator will be graphite, and the fuel will be disposed in tubes running through the graphite.

North American has already started construction of this 20,000-kilowatt reactor in California. From the nuclear standpoint the reactor is conservative, and so there should be no question of its ultimate success. However, there are difficult questions as to its economic outlook. Present estimates put its power cost in the range of 8 to 10 mills per kilowatt hour, which is a little high to be competitive in the U. S. Yet there are several developmental possibilities which, if successful, may ultimately lower the cost to four or five mills. These are: (1) simplification of the expensive sodium plumbing; (2) operation as a breeder or near-breeder with thorium; (3) improvement in the fuel elements to allow a higher burn-up than the 1 per cent suggested as the economic minimum.

A sodium-cooled reactor, which can be operated at very high temperatures, has greater thermal efficiency than a



EXPERIMENTAL BREEDER REACTOR—II is the fast breeder in the experimental program. Its design calls for a plutonium core, with no moderator, surrounded by a "blanket" of natural or depleted uranium (*vertical black lines*). Heat is removed from the compact core by circulating liquid sodium. As in the sodium reactor experiment, a secondary sodium loop serves to isolate the radioactive primary coolant from the boiler water. A concrete shield surrounds the reactor and radioactive sodium system.

water-cooled system. Whether this advantage will overbalance the greater simplicity of the best water system is the main question to be decided.

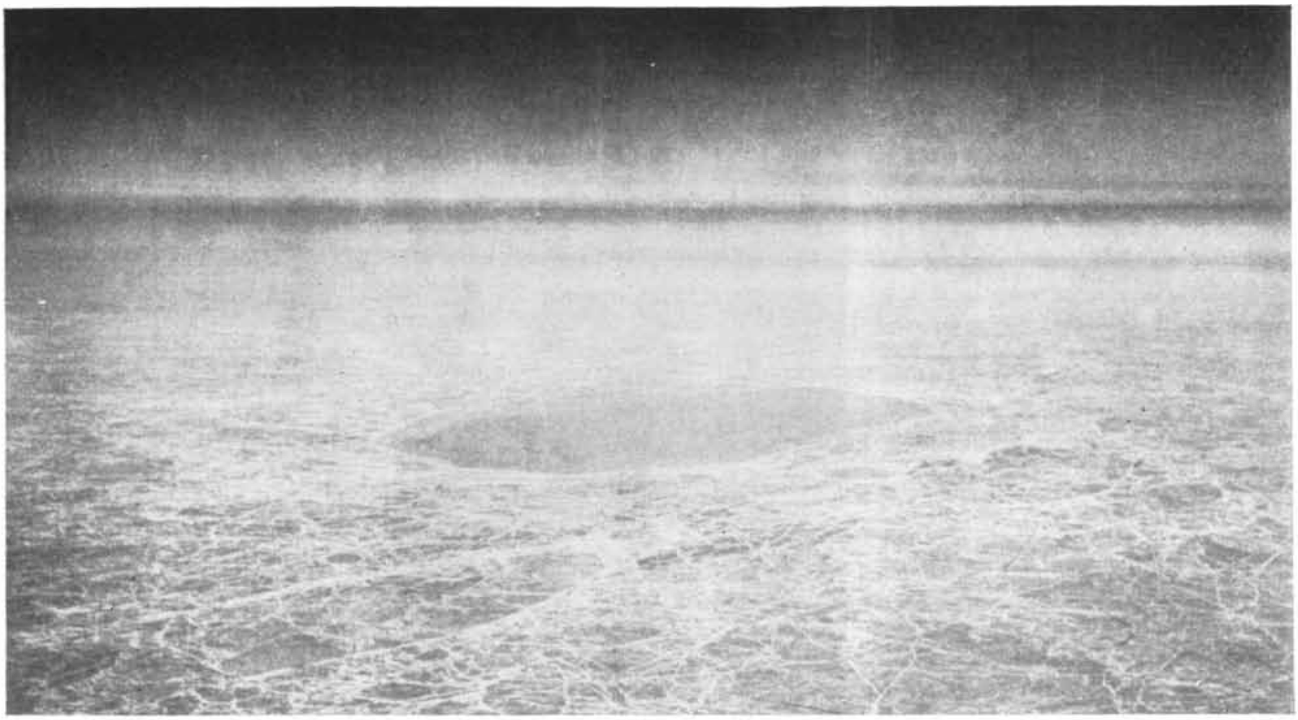
In many ways the most advanced, and most difficult, of all the reactors in the program is the other sodium reactor—the Argonne National Laboratory's Experimental Breeder Reactor No. 2 (EBR-2). Like its predecessor EBR-1, the new version will have a small core containing plutonium, surrounded by a breeder blanket of natural or depleted U-238. The core (EBR-1's was the size of a football) will contain no moderating material, for in order to achieve the highest breeding gain it is important to keep the neutrons as energetic as possible. In other words, this is a fast-neutron breeder. Such a concentrated fuel configuration is extremely hard to cool and is susceptible to severe radiation damage. This points up the primary engineering dilemma of the fast breeder: it must strike a delicate balance between unusable compactness and unworkable diffuseness.

EBR-2 will have a heat output of 62,500 kilowatts and an electrical output of at least 15,000 kilowatts. While the specific power is somewhat less than in the thermal reactors—*i.e.*, the material efficiency of the EBR-2 is low—it is hoped that the attractive breeding gain and high thermal efficiency of the fast-breeder system will make the system an economic success.

The homogeneous reactor and the fast breeder represent the boldest extrapolations among the five reactor projects. They are the most difficult, but by the same token probably offer the greatest potential return. There is an essential common sense in not putting all the effort into the most advanced systems; too much is at stake in the demonstration of workable nuclear power plants to leave out the more certain but less glamorous possibilities in favor of the more glamorous but less certain reactors.

There are other potential power reactors under study or development outside the AEC's five-year program; for example, the gas-cooled graphite reactor of the British, the very attractive uranium-bismuth circulating fuel system at the Brookhaven National Laboratory, and of course the military reactors, which taken together represent a program at least as large as the program for civilian power development. It is fair to expect that five years hence the most attractive lines of nuclear power development will be clearly drawn.

REACTOR CORE of an experimental "swimming pool" reactor illustrates the principle of pressurized water design. Plates of uranium-aluminum alloy are separated by ordinary water which serves as moderator and coolant. Above the plates are the suspended cadmium control rods. The diffuse light which surrounds the core is known as Cerenkov radiation.



FLETCHER'S ICE ISLAND, also known as T-3, is photographed from 18,000 feet as it drifts in the pack ice. This ice island is about 9 miles long and 4½ miles wide. It was named after Lieutenant Colonel Joseph O. Fletcher, leader of the first party to land on it.

CAMP ON THE ISLAND is photographed from a landing rescue plane. In the foreground is an Air Force C-47; in the distance another plane. Planes as large as C-54s have landed on the island. At one time the population of the island was as high as 12 persons.

ICE ISLANDS IN THE ARCTIC

In 1946 an Air Force plane north of Alaska discovered a single floe covering 200 square miles. Now parties land on these huge floating platforms to study the Arctic and how to survive in it

by Kaare Rodahl

The North Polar Basin, a huge sea more than 1,000 miles across, is historically the most inhospitable area on the earth. Before the 20th century many an explorer lost his life in its frigid wilderness in mankind's stubborn attempt to reach the North Pole. Today the Pole is still not exactly a busy crossroads, but airplanes fly over it fairly frequently and men have camped in its vicinity. During the past two and a half years a small group of scientists and U. S. Air Force personnel have lived in the heart of the Polar Basin—the longest occupation on record. This is an account of that remarkable settlement.

The story begins on August 14, 1946, when the crew of an Air Force reconnaissance plane on a routine flight in the Arctic Ocean north of Alaska saw a strange object on their radar scope. It looked like a large, heart-shaped island, some 200 square miles in size, in an area where no island was supposed to be. The mystified airmen named it Target X, and Washington classified it secret. Subsequent reconnaissance in clear daylight showed the object to be an icy island about 18 miles long and 15 miles wide. But the "island" was in motion! When first sighted, it was about 300 miles due north of Alaska's Point Barrow; later inspections of its position showed that it was drifting slowly northward across the Polar Basin. Yet this was no ordinary iceberg. It was a block of ice bigger than the island of Guam and almost as flat as a table.

The Air Force kept the ice island under continuous observation for the next three years. In that time T-1, as it came to be known, moved a distance of 1,400 miles, at an average rate of about 1.2 miles per day. It circled clockwise through the Arctic toward Ellesmere Island [*see map on the next two pages*]. Even from the air it was evident that the ice island was structurally different from the surrounding pack ice covering the sea. It kept its size and shape in all seasons, indicating that its ice was far thicker and more stable than the sea ice sheets around it. And its nearly flat surface was grooved with a regular pattern of ridges and shallow troughs, like a corrugated tin roof.

In the spring of 1950 Lieutenant Colonel Joseph O. Fletcher, commanding officer of the 58th Strategic Weather Reconnaissance Squadron in Alaska, decided to search the Polar Basin for other ice islands. The search was rewarded in July by the discovery of two more: a squarish island about 18 by 17 miles in size, promptly named T-2, and a kidney-shaped island of 9 by 4½ miles, named T-3. These two, like T-1, had the same flat, corrugated surface, with a general slope from one side to the other that gave the profile of each island a peculiar wedge shape, like the head of an ax.

The Canadians, hearing of these discoveries, went back through the many photographs they had made on flights in the Canadian Arctic, and they found in these pictures some 30 other tabular ice blocks, ranging in size from bergs a quarter of a mile across to islands nearly as large as the U.S.A.F. finds.

Colonel Fletcher became curious about how these islands could have originated and whether they had ever been observed before. It was obvious that they could not have been formed by the freezing of sea water, for they were much too thick. Fletcher devoted most of his spare time during the winter of 1950-1951 to searching the Arctic literature for clues. He found many references to "ice islands" by explorers. In 1918 Storker Storkerson and three other members of Vilhjalmur Stefansson's Arctic expedition actually landed and drifted about in the Beaufort Sea on an ice floe seven miles wide and more than 15 miles long; from Storkerson's description it was evidently a flat island like the present ones. In 1931 an Eskimo named Takpuk landed on what he thought was a small stationary island in the Beaufort Sea; since no such place has been located in recent flights over the area, it is probable that this, too, was an ice island that drifted away.

Fletcher at length found a strong clue to the origin of the ice islands in the log of the Polar explorer Rear Admiral Robert E. Peary. In 1906 Peary noted that the northern coast of Ellesmere Island had a glacial fringe of "shelf ice" extending for as much as 30 miles over the sea. "This fringe, which fills all the bays and extends across the whole width of north Grant Land," he wrote, "is really an exaggerated ice-foot." Peary reported that the part of the glacial "foot" resting on the water rose and fell with the tides, and in some places "great fields of ice break off from it and float away upon the waters of the Arctic Ocean."

This, then, seemed to answer the question as to where the ice islands come from. Apparently the shelf ice is a relic of a period of extensive glaciation since the last Ice Age. The glacial fringe has melted and weakened to the point where the action of tides and other forces can break off sections of it, which then float away as islands. Further study has left no doubt that the shelf ice is indeed the origin of the islands.

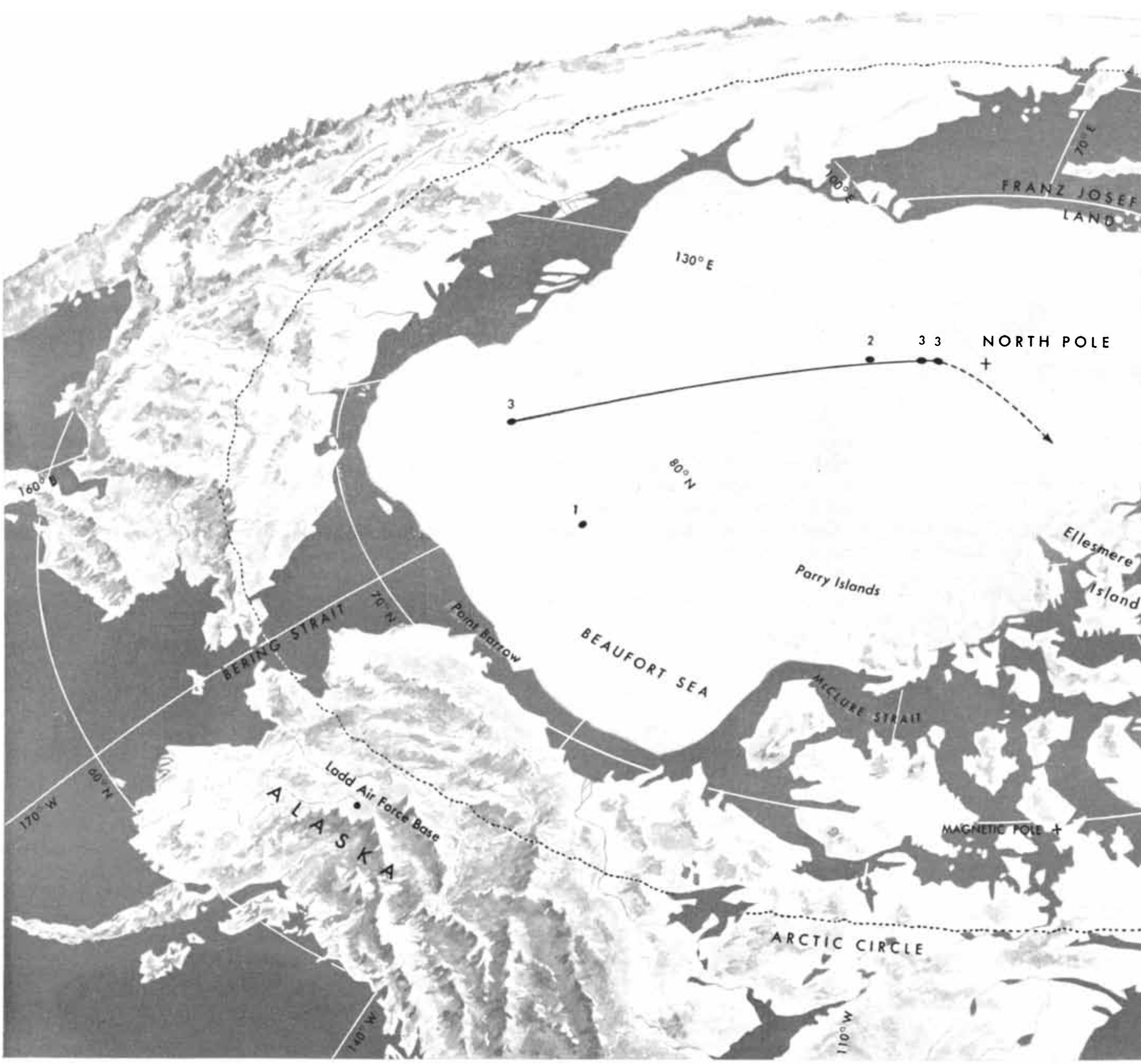
From the observations of the drift of T-1, T-2 and T-3, it became clear that the islands generally move in a clockwise course: starting from Ellesmere Island, they float westward above the northern coast of Canada and Alaska, turn north off Bering Strait, cross the North Pole and then swing southward toward Ellesmere or Greenland. They tour this course year after year, and, unless diverted by the East Greenland current into the Atlantic, they may last for generations.

Realizing that such a floe would make an excellent base for exploring little-known areas of the North Polar Basin, and for observing meteorological conditions in a region which is the birthplace of much of North America's weather, the Air Force decided to plant a party on one of the islands. Major General William D. Old, commanding officer of the Alaskan Air Command, appointed Colonel Fletcher to lead the operation, named "Project Icicle." I had the privilege of taking part in the planning and preparations and in the establishment of the base.

The first question was: Which island should we occupy? We selected T-3: although it promised the roughest landing for an airplane and was the farthest from land, it was headed for the center of the Polar Basin, whereas T-1 was stranded near Ellesmere and T-2 seemed on the way out to the Atlantic.

The time for reconnoitering and for making our landing was narrowly limited. At the position of T-3 the sun would come over the horizon, ending the long winter twilight, somewhere between the 10th and 13th of March. By the end of April foggy weather would close in. So we had only about a month of clear visibility to work in.

On March 11, 1952, the preparations in Alaska were completed, and three aircraft flew from there to our staging base at Thule, in northern Greenland, carrying the equipment and personnel—some 40 in all, including the aircrews and



PACK ICE extends as far south as the edge of the light area on this map. The number 1 marks the point where the ice island T-1 was discovered; the number 2, where T-2 was found. T-3 was discovered on July 30, 1950, at the left end of the line running across

maintenance technicians. On March 14 a C-54 reconnaissance plane took off from Thule to locate T-3. We reached the North Pole at midnight, turned left down the 180th meridian and found T-3 at 88 degrees 17 minutes North, 166 degrees 30 minutes West—much farther north than the island had last been reported. We had a good look at the island from an altitude of 100 feet, and the pilots decided that a ski landing with a C-47 was feasible.

Wednesday, March 19, was our D-day. Although our radar set was out of order, we took off as scheduled in a twin-motor C-47, equipped with landing skis as well as wheels and with an auxiliary 400-gallon gas tank in the fuselage. The initial occupation party consisted of Colonel Fletcher, Captain Marion F. Brinegar and myself. General Old and Captain Louis Erhart were at the controls of the airplane. Behind us came three four-engine C-54s, to fly top cover and transport 18,000 pounds of equipment as a start for the base.

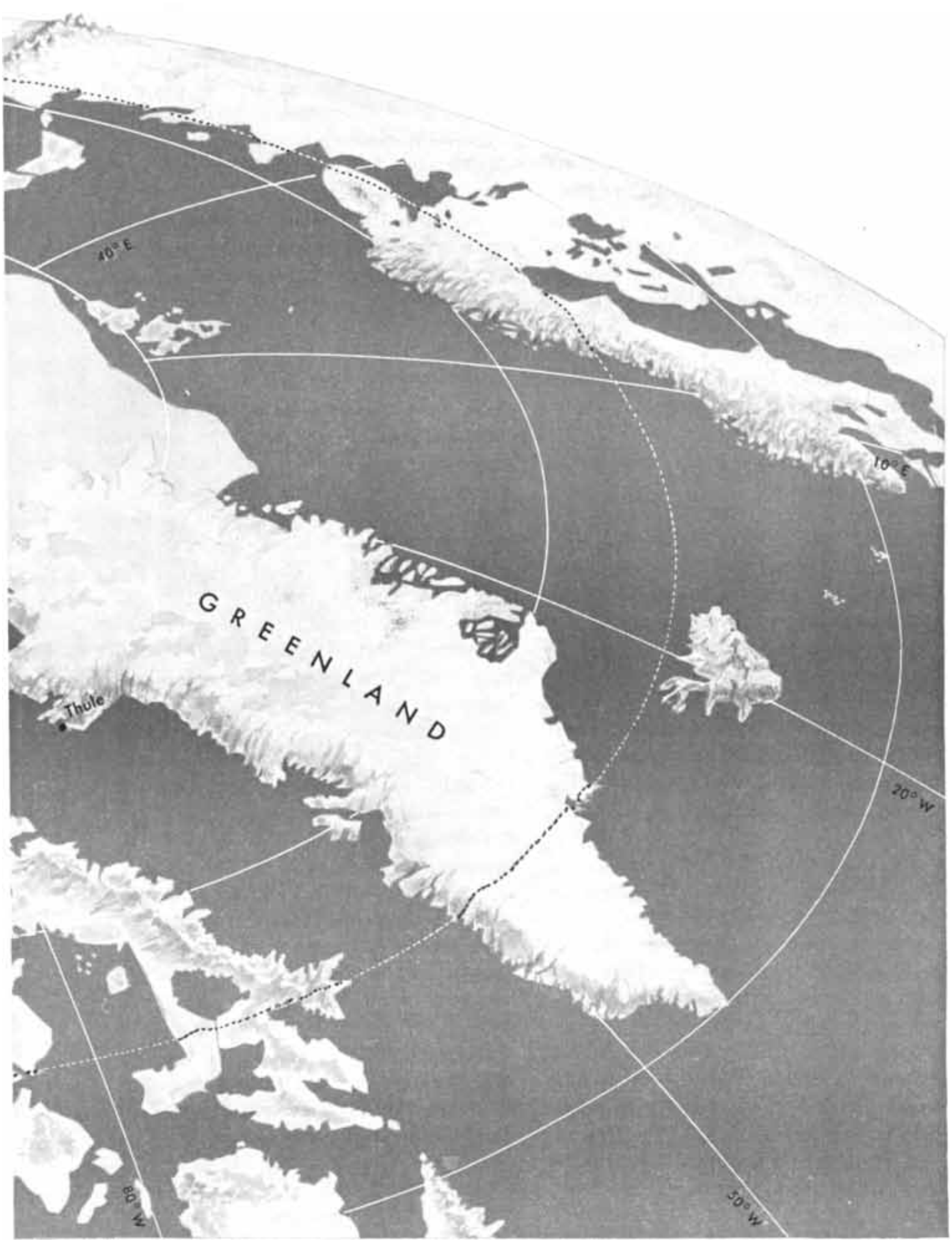
We flew across the pale sky toward the Pole, our engines streaming vapor trails. At midday we stopped to refuel from six drums of gasoline previously cached on a floe of sea ice. Then we headed north again over the interminable desert of ice, with only uncertain guides to our destination. Polar navigation is an art of its own. The magnetic compass is no help, for the North Magnetic Pole is in Canada far south of the North Pole itself. Even the gyrocompass is not entirely trustworthy at far northern latitudes; experienced polar navigators have told me that it sometimes fools them into flying in circles. And there are no landmarks whatever—only an endless stretch of white ice from horizon to horizon. The only reliable guides are the sun and the stars, when they can be seen. The nightmare of polar navigators is the hours-long daily twilight, when the sun has set and it is still too light for the stars to be visible.

The navigator had figured it would take three to four hours to reach T-3 from the northernmost point of land. But by four o'clock in the afternoon we had not sighted the island. Then the sun disappeared behind clouds, and a thin haze hid the horizon and limited visibility to one mile. We were lost. We commenced to fly a search pattern over the ice, looking for T-3, which the navigator's calculations said should be in our vicinity. Happily we soon had a radio report from one of the C-54s; it had located the island.

When we reached it, the pilots made three touchdown attempts before they were finally able to land our plane on the rough ice. As we slowly opened the door to leave the plane, a biting wind hit us in the face. We judged the temperature to be below minus 60 degrees Fahrenheit. The eight members of the party, including the plane crew, stamped through snow to the nearest ridge to get a preliminary look at the island. We were greatly surprised at the depth of the snow—up to four feet in some places. We were also struck at once by how closely the wavy surface of the island resembled Peary's description of the shelf ice off Ellesmere Island. It was corrugated by ridges perhaps 10 feet high and 100 yards apart.

Our 1,200 pounds of survival gear were unloaded from the C-47, and the C-54 that had reached the island paradropped 3,000 pounds of equipment and rations plus some drums of gasoline. Four hours after the landing the C-47 took off, leaving Fletcher, Brinegar and myself on the ice in a preliminary camp of tents and snowhouses.

Thirteen days later, after we had reported to a messenger plane circling overhead that a permanent camp was



the ice pack region. By March 14, 1952, it had drifted to the point marked by the second number 3; by May 16 of the same year it had moved to the point marked by the third 3.

practicable, the C-47 returned with a radio operator, Captain Paul Green, and a geophysicist, A. P. Crary, who was to direct the scientific work. They brought with them radio equipment, a power plant and a small meteorological station. By April 6 the C-47 and para-dropping C-54s had delivered 75,000 pounds of supplies and equipment and additional personnel, including Crary's geophysicist associate R. Cotell.

One of the early research projects was a visit by the two geophysicists to the North Pole 135 miles away—less than an hour's flight in a C-47 piloted by Fletcher and Lieutenant Colonel William Benedict. They landed on an old thick floe and spent three hours and 10 minutes measuring the depth of the ocean at the Pole (14,150 feet) and the pull of the gravity of the earth at this point. They sounded the ocean depth by exploding dynamite and timing the return echo with seismographic equipment.

On the basis of regular sextant observations of the sun and the moon, the scientists were able to plot in detail the movements of T-3, now renamed Fletcher's Ice Island. The island, it developed, moves in zigzags. Its movement is mainly due to the wind force. The geophysicists found no positive evidence of any permanent ocean current in this part of the Polar Basin, though they sounded the water down to depths of 1,200 feet with a drag-type current meter suspended through a hole cut in the sea ice.

During an excursion in the weasel, our snow vehicle, on a sunny day in May, Crary and Fletcher discovered large deposits of rocks on the eastern side of the island, about eight miles from camp. Some of them were more than a ton in weight and must have been deposited on the island when it was landfast or near the shore. Closer examination revealed that this end of the island was almost completely covered with rock and gravel.

In order to study the vertical structure of the ice, cores were taken with a four-inch ice corer. These disclosed layers of soil or dirt at about one-foot intervals down through the ice; in a 52-foot core there were 58 layers. When their ages have been determined by carbon-14 analysis, significant knowledge may be gained of the history of the ice island.

Once the corer drilled into a fresh-water lake eight feet below the ice surface. The water was under such pressure that it spouted out of the test hole like a geyser. This "underground" lake, formed by melted water accumulated in a trough between two ridges, gave us a supply of drinking water.

Crary determined the thickness of T-3 to be approximately 160 feet. Every few days he sounded the depth of the ocean from the drifting island. Generally speaking the depth ranged from 12,300 to 12,800 feet. But the echo-sounding discovered two great under-surface sea mounts rising more than 5,000 feet from the ocean floor. Next to them was a giant canyon with sheer precipices over 4,000 feet high. The floor of the Polar Basin turned out to be quite irregular.

Measurements of the ocean temperature have confirmed the finding of the Norwegian explorer Fridtjof Nansen that a current of warm Atlantic water flows into the Arctic Ocean at a depth of 1,000 to 1,500 feet below the surface. In addition the T-3 scientists discovered a persistent layer of warm water at 400 feet, the origin of which is still obscure. The oceanographic studies were eventually taken over by a group of researchers from the Woods Hole Oceanographic Institution, who joined the ice island party in the fall of 1952. Temperature measurements were made by means of cables lowered and raised with the aid of a chain-saw motor.

The observations of greatest immediate importance have been those of the meteorological station set up on the island in April, 1952. It made measurements of wind, temperature, barometric pressure and other weather conditions every six hours.

The temperature rose above freezing for the first time on May 15. By the end of June the snow on the island was thawing rapidly and there was running water everywhere. The most intensive melting took place in the period from early July to the middle of August. By then the entire snow cover had melted, and in addition one or two feet of the underlying ice. The boxes and pieces of equipment out on the ice were left standing on pedestals, since they insulated the ice beneath them from melting. There were lakes in the troughs between the ridges, and much of the water in them drained off the island. At the observed rate of melting, it appears that the ice islands must melt away in about 75 to 100 years, even if they remain in the Polar Sea.

Besides the measurements at ground level, observations have been made with instruments sent up in balloons twice a day. The meteorological observations taken on T-3 have been filling in a gap in the data needed for more accurate weather forecasts. This study of arctic meteorology will eventually throw light on the circulation of the atmosphere in the Northern Hemisphere and on the origin and cause of cyclones. It also seems probable that the observations of ice conditions and currents will permit long-range forecasts of the climate not only in North America but in Europe. The data so far collected confirm that the Arctic is warming up and the glaciers are receding.

In their explorations of T-3, observers have found a few traces of past plant and animal life, probably deposited when the ice was part of the Ellesmere shelf. There were frozen stems, twigs and fish bones, a complete fish about five inches long and the remains of what appears to have been a lemming. In one place a complete set of caribou antlers were discovered projecting from the snow, and underneath it were pieces of skin and fur frozen in the ice.

In April, 1952, tracks of a polar bear were seen on the island not far from the camp. For a while we thought that animal life near the Pole might not be so scarce as we had supposed, but during the entire summer the only living things the men on the island actually saw were eight solitary birds, identified as gulls and jaegers. The first one was seen in mid-June, and the last on August 15. There were no signs of seals or fish in the water. They did, however, fish up two specimens of zooplankton: a shrimp and a jellyfish. While the observations of the T-3 party have proved that the central North Polar Basin is comparatively lifeless, they have also shown that the waters may contain enough zooplankton to provide food in an emergency.

In the winter of 1952-1953 the marine biologist C. Horvath, representing the U.S.A.F. Arctic Aeromedical Laboratory, explored the sea life. With a net lowered into the water through holes in the pack ice he brought up both animal and plant plankton. He also caught several thousand marine crustaceans with conical wire traps made of window screens and baited with meat. His attempts to catch fish with baited hooks were unsuccessful, but he found that the crustaceans were numerous enough to strip the bait from the hooks every time he lowered his lines. The crustaceans he caught were amphipods and isopods.

During the fall of 1952 supplies, personnel and equipment were flown in to T-3 in sufficient quantities to allow the group of weather observers and scientists to survive the Arctic winter. It had been planned to land C-47 planes on the island during September while there was still daylight, but the ice on the island lakes did not become thick enough to support landings until the middle of October. It was then so dark in daytime that runway lights had to be used. In January a C-54 twice made safe landings on wheels.

While the ice island jerked and twisted through the long winter night, battered from all sides by pack ice during storms and blinding blizzards, the crew of specialists proceeded with their investigations in comfort and peace. The little settlement grew to 12 persons, who collected much important data on the meteorology, oceanography, geophysics, glaciology and biology of the North Polar region.

Because T-3 is now close to Ellesmere Island, it has been evacuated temporarily; Ellesmere has its own meteorological station. However, the huts and equipment on T-3 have been left there, and it will undoubtedly be reoccupied when it has moved to a more useful position. Probably it will begin a new circle through the Polar Sea which will take several years to complete. Provided it escapes the East Greenland Current, it may serve as a floating scientific laboratory for a generation to come. In any case, there will be other ice islands to occupy; man may even crack off new islands for his use from the shelf ice of Ellesmere Island!

The T-3 experiment has demonstrated that man can survive the killing cold and numbing winds of the desolate North Polar region, but only if he is supplied with the best of equipment. Living off the land seems to be out of the question, except that the zooplankton may prove usable as a supplement to the rations taken along. A concentrated ration of maximum nutritional value per unit of weight should be developed. In addition, the T-3 experience has suggested the need for a new type of portable, efficient stove which an individual can use as a source of heat for survival on the polar pack ice. There is also a need for new equipment and clothing that can withstand the "wet cold" of summer in the Arctic, for the problem is entirely different from that posed by dry cold.

It is comforting to know that survival in the Polar region does not require superhuman qualities or efforts. One needs only practical experience and knowledge, suitable shelters, adequate clothing and sufficient food. The North Pole has lost the terror of the unknown.

A. P. CRARY, a geophysicist who directed the scientific work of the first expedition to Fletcher's Ice Island, makes observations from an icy hillock near the edge of the island.

SEMIPERMANENT CAMP on Fletcher's Ice Island was photographed by Crary in June, 1952. At the left is the weasel, the tracked vehicle with which the party explored the island.

SHELF ICE (*foreground*) floats out over the sea from the mountainous coast of Ellesmere Island (*background*). Large pieces of this shelf ice break off to form ice islands.

Kwashiorkor

This word borrowed from an African tribe refers to the most severe and common nutritional disorder of man. Only recently discovered, it is caused by a deficiency of protein in the diet

by Hugh C. Trowell

In 1929 an English woman physician working among tribes in the Gold Coast of West Africa encountered a puzzling disease. It seemed to attack only young children, and it was usually fatal. The victim slowly lost energy and appetite, lay miserably in bed, ate very little and passed loose stools containing undigested food; eventually his face and legs became swollen with fluid, his hair lost its color and curl, rashes broke out on his skin and death soon followed.

Because the victims were most often babies that had been weaned from the mother's breast to an unbalanced diet, the physician, Dr. Cicely Williams, judged that the disease was due to malnutrition. She described it as a new form not previously known to the medical profession, and she attributed it to the people's unsatisfactory diet of potatoes, yams, cassava and bananas. Dr. Williams named the disease *kwashiorkor*, as the Ga tribe called it.

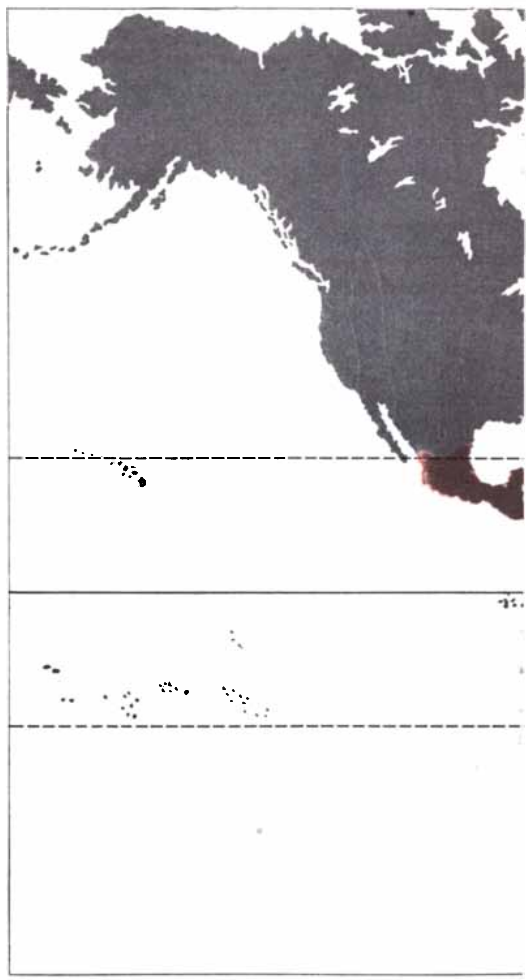
When she reported her discovery to European authorities, many were skeptical; they considered it hardly likely that African peasants could have recognized a disease which had escaped the notice of Western medicine. One nutritional expert in London decided, on the basis of the rash, that the disease was pellagra. But Dr. Williams, though unable to continue her study because she had to leave the Gold Coast to go to Malaya, insisted that it was a new disease, and defended her view with great vigor. Time was to prove her right. It was also to show that kwashiorkor afflicts a great deal more of the world than just the Gold Coast of Africa.

In 1930 I encountered this disease in the Kenya Colony in East Africa, but I did not hear of Dr. Williams' reports until several years later. Then I unfortunately listened to the experts and decided that it was a curious mixture of pellagra and nutritional edema; I called it "infantile pellagra." At about that time it was discovered that pellagra was due to a deficiency of nicotinic acid. Some of this vitamin was sent to me. It came; it was tried; almost all the patients nonetheless died.

I returned to England to hunt in the medical libraries of London. There I found, in independent accounts published by various tropical workers in obscure journals, one report after another of a disease very similar to kwashiorkor. The names and circumstances were different, but slowly it became apparent that L. Normet's cases of *bouffissure* ("swelling") *d'Annam* in Indo-China (1926) were much the same as A. Castellanos' cases of *pelagroide beriberico* in Cuba (1935). The earliest descriptions of this disease were given in 1906 by A. Czerny and A. Keller in Germany and J. P. Correa in Mexico. Altogether the search of the literature yielded some 40 different names for what was evidently the same disease.

The investigators often recognized that the symptoms were those of malnutrition. Yet the patients did not respond as expected to feeding. About half of them died even though they were fed whole milk combined with liver extracts and all the known vitamins. Some of the observers therefore concluded that the disease must be some kind of infection: malaria, hookworm or an attack by some other tropical bug that caused the victims to waste away.

I clung, somewhat obstinately, to the idea that the disease was due to malnutrition. Perhaps kwashiorkor was an advanced, incurable stage of this condition. I suggested that it should be called "malignant malnutrition," for I was still losing a third of my patients. Soon afterward kwashiorkor stopped being "malignant" and became curable. The cure was discovered quite by accident. Workers in Uganda, where milk is scarce, had sent to England for milk powder to treat kwashiorkor patients. By mistake the



GEOGRAPHICAL AREAS reporting kwashiorkor are outlined in color on this

British sources sent not powdered whole milk but powdered skim milk. It was given to the patients anyway, and miraculously most of them recovered from the disease. The reason for the superiority of skim milk to full-cream milk was at once apparent: skim milk seldom produced diarrhea, which suggested that it was digested better than whole milk.

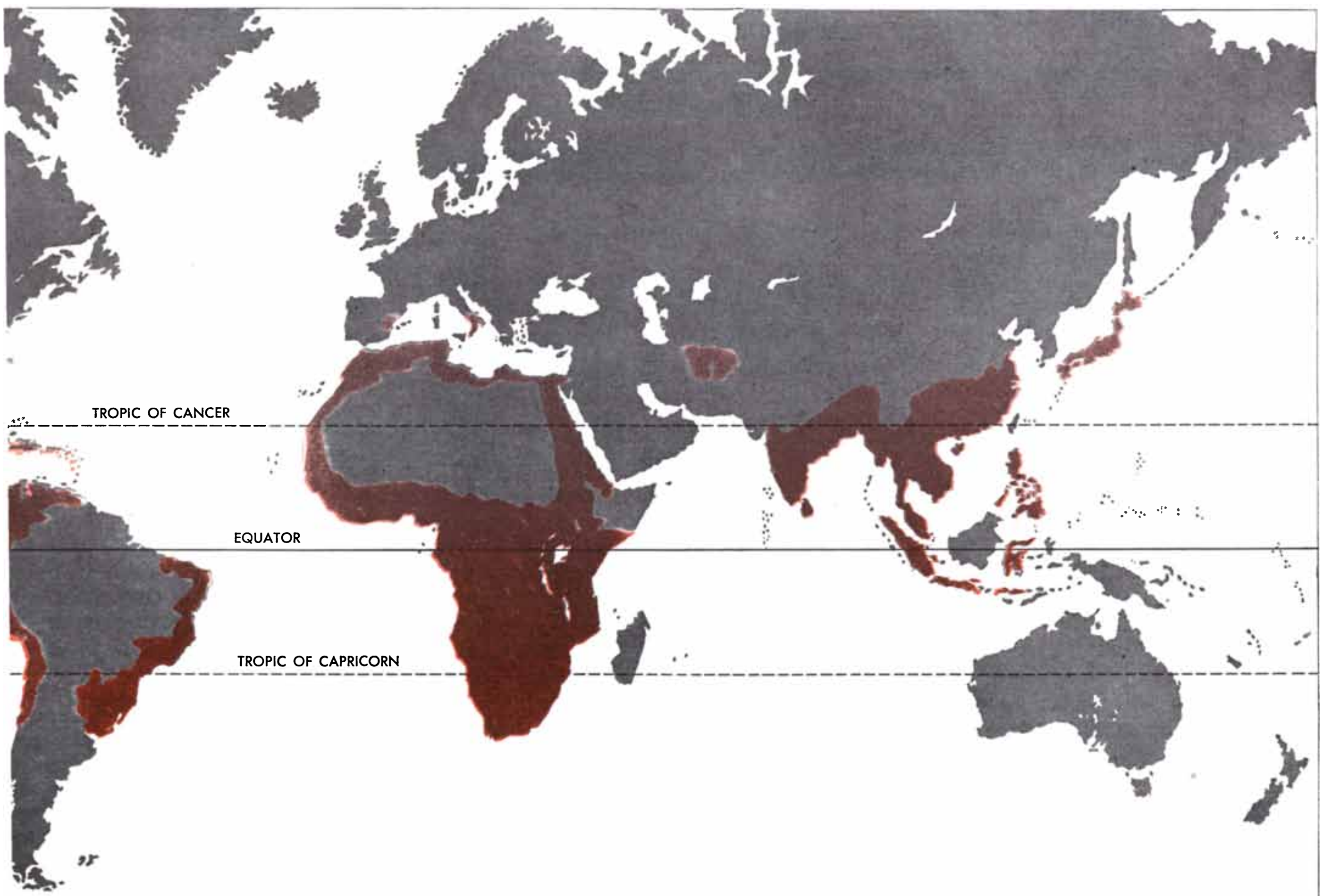
By this time we had begun to have a good notion of the true cause of kwashiorkor. The Uganda workers, and others in Central America, had learned that the blood of patients with the disease was low in protein (serum albumin). And there were other clues that also pointed in the protein direction.

One of the difficulties in analyzing the disorder had been that victims show almost no abnormalities on post-mortem examination. The only thing unusual about their organs is a fatty liver, but this condition is present in many fatal diseases. During World War II, however, we in Africa began to hear reports of some extremely interesting findings by nutrition investigators in Canada, Britain and the U. S. Several experimenters there had produced fatty livers in animals by feeding them a diet deficient in the amino acid methionine (a component of protein) or lacking choline (a fraction of the vitamin B complex).

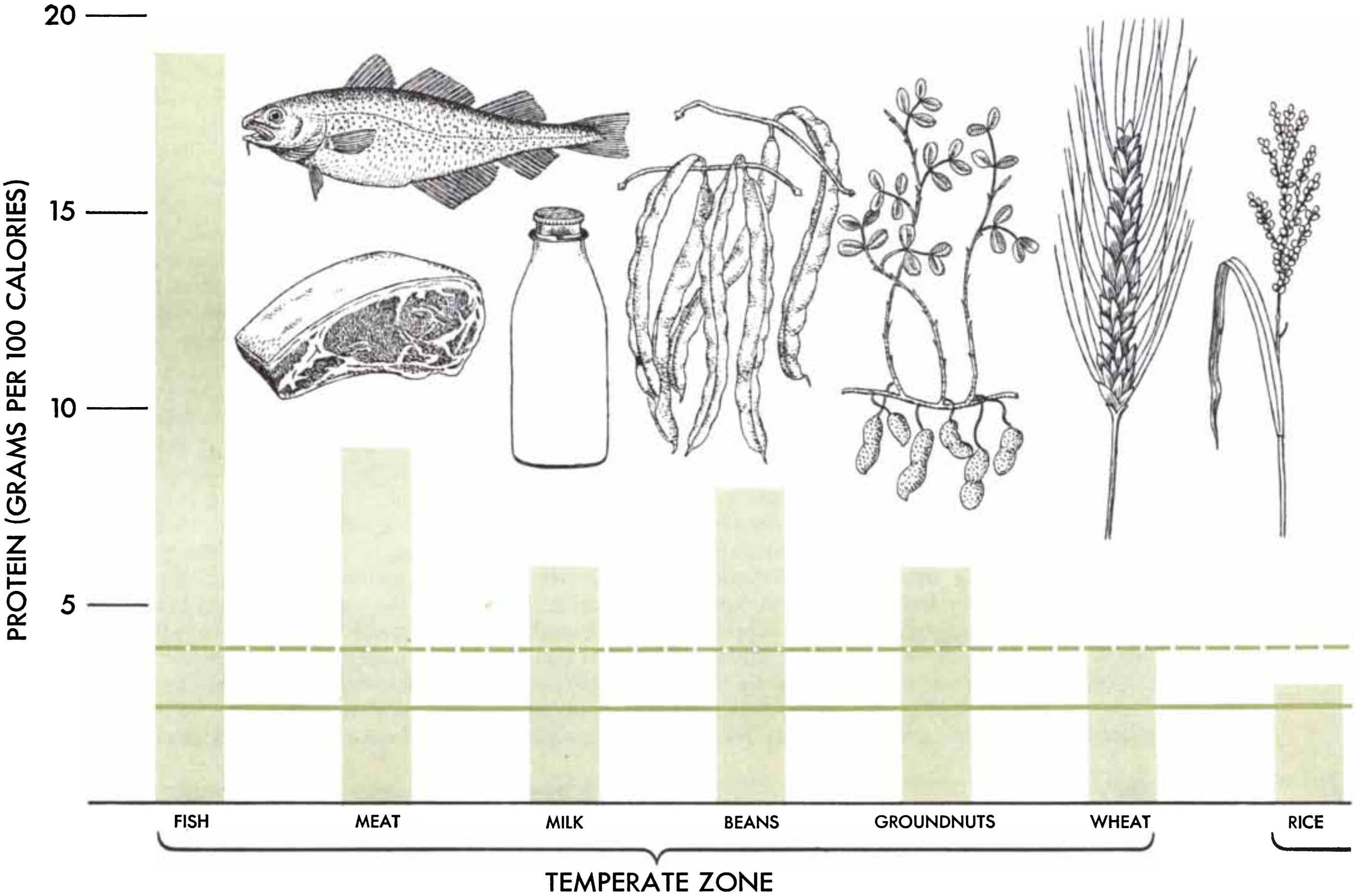
Attempting to enlist the help of U. S. workers on my kwashiorkor problem, I sent them post-mortem liver samples and X-rays of the intestines of victims of the disease. Unfortunately these were impounded by the censor as possible avenues of illegal communication! I had better luck with samples sent to Harold (now Sir Harold) Himsworth, secretary of the Medical Research Council of Great Britain. Himsworth decided that the effects of kwashiorkor on the liver were the same as those he had produced in animals by certain diet experiments. He became greatly interested in the kwashiorkor problem, and has been the main support of our work on this disease at the Mulago Hospital in Uganda.

Shortly after Himsworth's report supporting the idea that kwashiorkor was a dietary disease, still more conclusive confirmation came from a series of brilliant investigations carried out by the brothers Joseph and Theodore Gillman of Johannesburg. They developed an instrument with which it is possible to remove safely a thread of liver tissue from a living patient. By this means they were able to study the effects of various diets on kwashiorkor patients and to determine which diets would cause fat to disappear from the liver. Their tests left no doubt that the disease is due to malnutrition.

Until recently we have not heard much about protein deficiency. In the temperate regions of the world, where most hospitals and biological research are concentrated, malnutrition has been considered synonymous with deficiencies of vitamins rather than proteins. This is understandable, since the chief staple in the temperate belts is grain—a food relatively well endowed with protein but poor in certain vitamins. Diseases such as scurvy and rickets, now known to be due to deficiencies of vitamins, have been recognized for thousands of years



map. The information on which the map is based was gathered by the World Health Organization and the Food and Agriculture Organization. The disease probably occurs in every tropical country of the Americas, Africa and Asia and in many temperate countries.



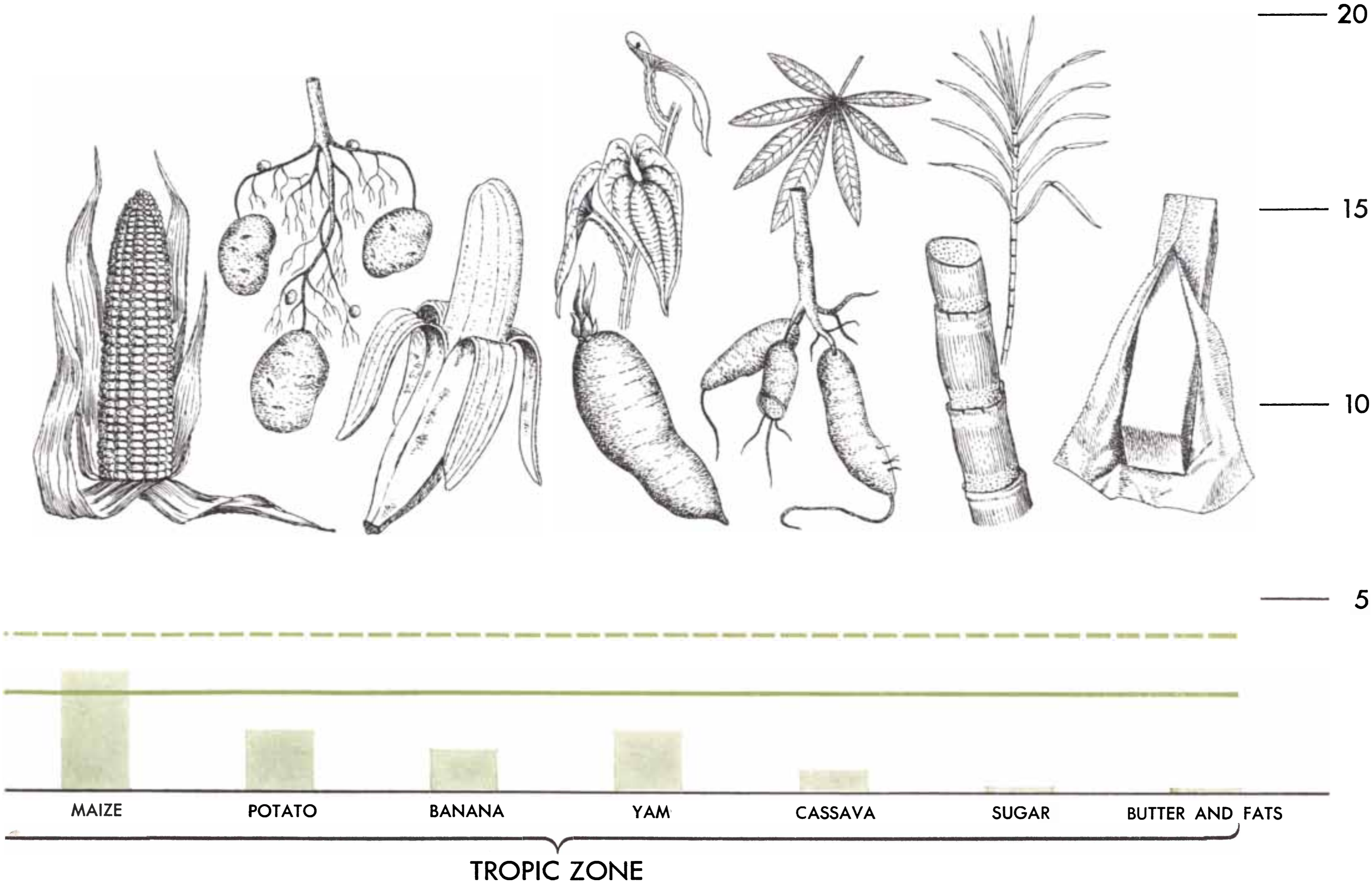
PROTEIN-CALORIE RATIOS of various foods are compared. Meat, for example, has a high ratio of protein to calories; banana, a low ratio. The staple foods of the temperate zone are bracketed at the left; those of the moist tropic zone, at the right. It will be seen

in the civilized world. Protein deficiency has gone unnoticed for at least two good reasons: (1) in the temperate regions the ordinary diet includes protein-rich foods, such as fish, meat, milk and beans, and (2) protein deficiency is difficult to distinguish from plain starvation.

In the tropics, on the other hand, the common staples of the diet (mainly fruits and vegetables) are poor in protein. Potatoes, bananas and many other tropical foods are largely starch; they often contain less than 1.5 grams of protein per 100 calories (against six grams per 100 calories in cow's milk and four grams per 100 calories in wheat). Now starches, sugars and fats can supply all the calories and energy a person needs, and a man may seem well fed on 2,500 to 3,500 calories of these foods per day; at least he will not be hungry, even though his body may be short of protein. A grown man needs some 65 to 80 grams of protein per day. But a protein deficiency is not so easy to detect as a vitamin deficiency, which manifests itself in certain specific and well-recognized symptoms. The most conspicuous symptom of acute protein malnutrition is edema. The same accumulation of fluid and swelling occurs, however, in an undernourished person starving simply from lack of enough calories. It is this parallelism that has misled nutritionists. Protein malnutrition has hitherto been confused with simple undernutrition; both conditions have been lumped together as "nutritional edema." We know now that we must distinguish between "hunger edema" and edema due to protein deficiency. Hunger edema can be cured merely by giving more food. Protein malnutrition must be treated by adding protein-rich foods to the diet.

Proteins are extremely complex substances. Whereas it is possible to write the chemical formula of a vitamin on a small sheet of note paper, it would require several volumes to depict clearly and in complete detail the atomic structure of some proteins. Moreover, these complex structures are not static; the proteins, forming the building blocks of all animal cells, are in constant movement and flux—they group, break apart and group again. And this is not all. Each protein requires a certain combination of amino acids. A deficiency of a single amino acid may produce a disease. Probably in kwashiorkor there is a shortage of many essential amino acids, and these deficiencies may differ according to the specific diet. Further complexity arises from the fact that certain vitamins and growth factors (*e.g.*, vitamin B_{12}) are closely associated with protein: possibly the lack of one of these factors is mainly responsible for the kwashiorkor disease picture. Indeed, kwashiorkor itself seems to be only one variety of protein malnutrition; there are many others.

Since 1944, when protein deficiency was discovered to be the culprit in kwashiorkor, systematic studies have been made of its effects on various organs and tissues of the body. John Davies, who joined me in Africa, found that protein malnutrition caused the secretory granules to disappear from the pancreas, so that no pancreatic digestive enzymes were produced; Margaret Thompson later showed that these enzymes reappeared in the intestines when milk protein was fed to patients. Rex Dean discovered certain peculiar



that the staples of the temperate zone are protein-rich and those of the tropic zone protein-poor. Adults require a dietary minimum of about 2.5 grams of protein per 100 calories (*solid horizontal line*); infants, about 4 grams of protein per 100 calories (*dotted line*).

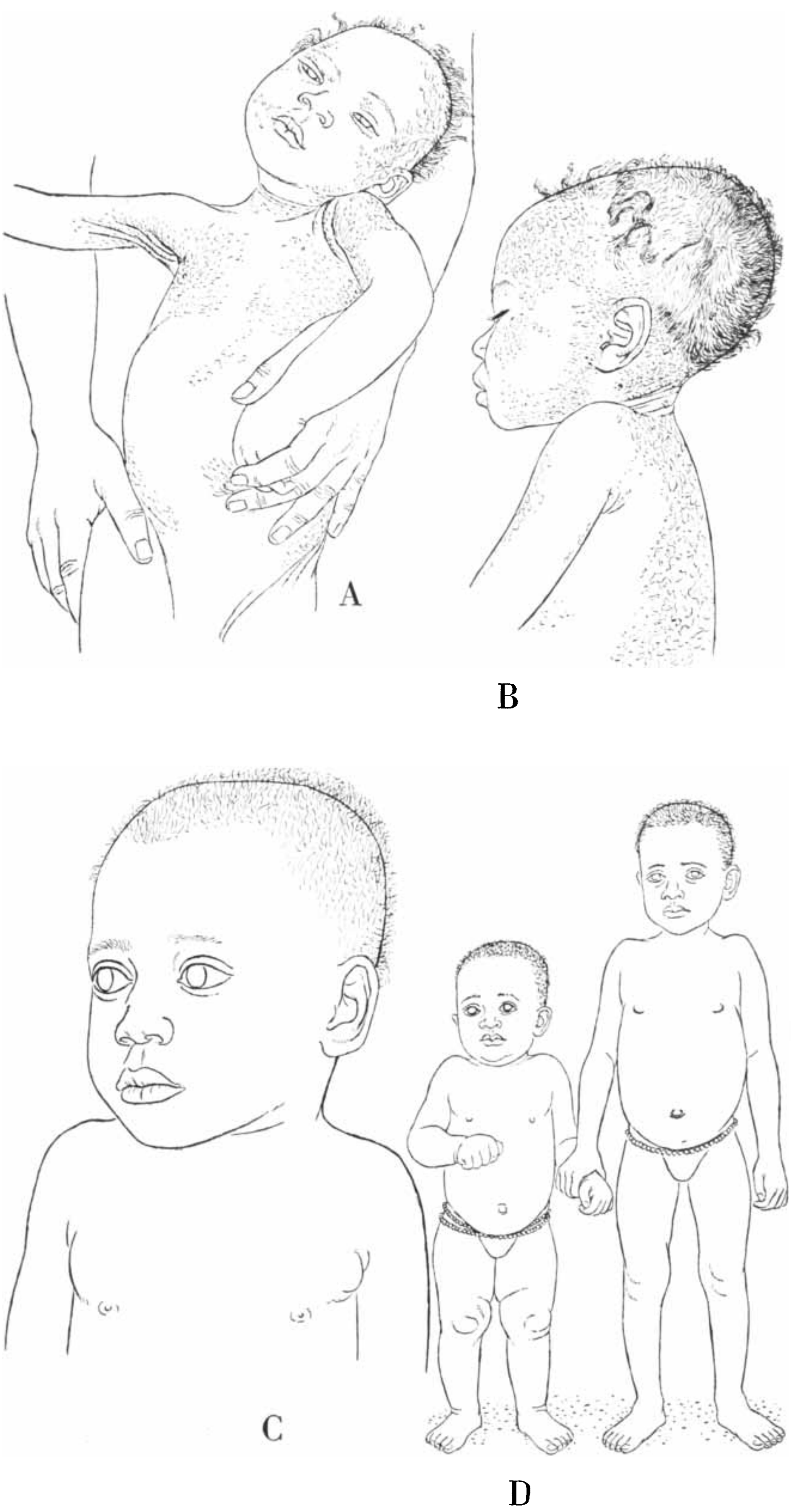
changes in the blood and tissues of patients suffering from kwashiorkor. Protein enters into the composition of all body cells, all hormones and all enzymes. It is probable that many of these are affected by protein malnutrition, even when the deficiency is not serious enough to cause acute illness. There is a growing body of evidence that chronic protein deficiency may cause cirrhosis of the liver and predispose to cancer in that organ. At the moment a good deal of interest is directed to investigation of the endocrine glands of adults who have been subject to protein malnutrition.

How widespread is protein malnutrition over the world? Is it confined to the tropics? Is it almost exclusively a childhood disease or do many adults also suffer from it? A series of surveys and conferences, initiated largely by the World Health Organization and the Food and Agriculture Organization, has made it possible to say something about the geographical distribution of the disease. Kwashiorkor probably occurs in every country in the tropical belt around the world, and now that the disease has become more widely recognized, cases of it have recently been reported in Rome, Barcelona, Santiago, cities of Japan and many other cities in temperate regions.

Severe cases, which are easy to diagnose, are uncommon; even in the most seriously affected regions and at the most susceptible age (the second year of life) it is doubtful that more than 1 per cent of the children become obviously ill. It is likely, however, that in many parts of the world the majority of young children suffer some protein malnutrition. In almost all backward regions children grow extremely well during the first few months of life while they are nursing, but after that their growth is retarded, they cease to be lively, black curly hair becomes soft and brown and they show slight signs of kwashiorkor. Doubtless other deprivations and infections play their parts, but many experts now believe that the principal cause of this failure of growth of body and development of intelligence is an inadequate intake of protein.

As for adults, in most parts of the world the common diet seems to meet the minimum protein requirement—roughly estimated to be about 2.5 grams of protein per 100 calories. But in the moist and warm tropics there are many areas where the protein content of the diet is marginal or below par. Occasionally in adults one sees a clinical picture somewhat like that of kwashiorkor in childhood, or intermediate between kwashiorkor and hunger edema. Work carried out by Eric Holmes in our hospital has indicated that to correct chronic protein malnutrition in adults requires many months of very high protein feeding—as much as 150 grams of protein a day.

It should not be supposed from the foregoing that protein malnutrition is generally prevalent among either children or adults in all tropical countries. People of good income and education eat enough protein, even in the tropics. So do many of the poorer classes in areas of uncrowded population and dry climate, where some cereals are grown and animals are kept. It is rather in the moister tropics, where grains store poorly and the staple articles of diet are protein-poor, that kwashiorkor is common in



SYMPTOMS of kwashiorkor were observed in African children. In one severe case (A) they were a rash, wasting of the limbs and mental apathy. In another (B) these symptoms were accompanied by large areas of peeling skin. In a third case (C) the hair of the patient was pale, soft and scanty. At the lower right (D) a normal child of eight months is compared with her sister who is three years of age and suffering from kwashiorkor. The younger child weighed 19 pounds; the older one was only slightly larger and weighed 23 pounds.

childhood and protein malnutrition is probably chronic in many adults.

In these areas the prevention of the disease demands action along many lines. Firstly, all medical personnel and their ancillary services in nursing and public health should be instructed concerning kwashiorkor. This is no small problem. Secondly, the general public must be instructed in the disease. Thirdly, more protein-rich foods should be made available, especially to young children and pregnant and lactating women. It should not be forgotten that vegetable protein is probably almost as good as animal protein, and it will always be far cheaper. In really poor parts of the world everything should be done to increase the production and consumption of a varied diet containing much vegetable protein. It would be a great help if the large surplus of skim milk left from the manufacture of butter in the temperate regions of the world could be reduced to a preservable powder and sent to the tropics. To prepare, pack, transport, distribute and market this powder where it is needed will not be easy. Much will depend on the price and on how well powdered skim milk can compete in prestige and palatability with local sources of vegetable protein.

The treatment of severe cases of kwashiorkor has improved greatly in recent years. It is now clearly understood that whole cow's milk is digested poorly and often provokes a fatal attack of diarrhea. Small feeds of skim milk powder, mixed with a little water and mashed banana and sugar, are often well tolerated. If the patient is not doing well, pure milk protein may be given for a few days, until appetite has returned and digestion has recovered. Intravenous injection of protein or amino acids has not proved successful, for very little protein can be given in this manner. Severe cases are often fed by a tube passed down the gullet into the stomach.

Treated thus in hospital, 90 per cent of the cases of kwashiorkor now recover. I can remember the time when more than half of our patients died. Almost all severe cases still die if they cannot get hospital treatment. This still remains the disease of the poor infants of the world—a disease barely recognized, mentioned in few textbooks, demonstrated to few medical students. Of kwashiorkor Jack Chisholm of the Capetown Medical School and M. Autret, of the Food and Agriculture Organization reported to the WHO in 1952: "It is the most severe and widespread nutritional disorder known to medical science."

Kodak reports to laboratories on:

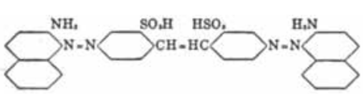
A disazostilbeneaminodisulfonate for precision titrimetry... a new material for the base of our business... snap shooting in depth

Waterman's find

This is how come *4,4′-Bis(2-amino-1-naphthylazo)-2,2′-stilbenedisulfonic Acid Disodium Salt* became Eastman Organic Chemical No. 7000.

We had run across several papers by a chemist in the water supply department of a large city who was bothered by the shortcomings of a certain tool of his trade, namely the indicator methyl orange. This has a rather weak color change which occurs perceptibly only at pH 4.6 and is therefore no good for alkalinities below 150 ppm in acid-carbonate titration. In the interests of precision titrimetry, he had felt, it is better to have a pH indicator change from a light color to a dark color as an endpoint is reached, instead of the other way around. In the disazostilbeneaminodisulfonates he found what he was looking for. A number of dyes of this series gave useful color responses in the broad pH range between 8 and 4. Among the several dyes investigated in this class was an obscure item known to dye men as Hessian Purple N Extra, or more simply, Direct Purple.

Whether he tried to buy it out of a dye catalog and failed, he doesn't say. At any rate, he made some by tetraazotizing *4,4′-Diaminostilbene-2,2′-disulfonic Acid* (Eastman T 4613) and coupling with *2-Naphthylamine* (Eastman 174) to get his indicator:



This starts from a deep red, shows a first transition at pH 4.0 to a faint mauve, turns emphatically purple at pH 3.8—a long sight more emphatically than methyl orange ever did—and finally goes over to a bluish purple at pH 3.0. Such behavior is reported a lot more useful for the acid titration of sodium carbonate than even that of our *Methyl Orange-Xylene Cyanole Solution* (Eastman A 2216), which was developed back in 1922. We saw our duty clearly before us to spare analysts from doing their own tetraazotizing and coupling. Thus Eastman 7000. It's used as a 0.1% solution.

Is Eastman 7000 *of special importance to us? No more so than the rest of the some 3500 organic chemicals we stock. They're all cataloged in our List No. 39 which you may have by writing to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

P(olystyrene) B(ase)

The first Kodak film on a base other than cellulose ester is now on regular sale. This is an historic and portentous pronouncement only to those who have devoted their careers to the manufacture of photographic film. Those engaged in the preparation of full-color printed illustrations will be pleased, though possibly not set trembling with excitement over the news: using this new *Kodalith Ortho PB Film*, they will no longer have to turn to bulky glass plates to avoid register difficulties from the size change of film with relative humidity. Those interested in photography in a more general way may be curious to know what's up.

Kodalith Ortho PB Film has a .005″ base of extruded polystyrene. This material is optically clear and as free from visible blemishes as cellulose ester film had become about the time of the Harding administration.

Extruded polystyrene can be produced in rolls of the proper length and width for efficient emulsion coating. It can be held sufficiently uniform in thickness at the thickness required for proper strength, toughness, rigidity, and suitability as photographic film base.

None of which would justify turning to it but for the fact that when you coat a pelloid on it and then put a photographic emulsion on the other side and then cut it up and then expose it in a camera and then put it through sundry processing baths and then dry it and then store it through wide swings of temperature and humidity and then measure how much size change has occurred in the image it carries, you find it is about three times as dimensionally stable as cellulose ester film. Furthermore, what little change has occurred is the same in all directions.

Where we go from here we prefer not to say at the moment. (We have competitors.) The subject is far more complex than the finding of a dimensionally stable sheet plastic, for a plastic with gelatin bonded to it is a far different proposition mechanically from the same plastic by itself. Gelatin is doubtless the most exasperating structural material known to man. Under some conditions of extremely low humidity we have seen it develop enough pull to gouge glass. Fortunately, after 75 years of experience with it and almost as long with plastics, we've accumulated a few ideas and quite a few boys to work on them.

Anybody who has been looking for a high-contrast film that probably won't change dimension by more than 0.02% for a 10% change in relative humidity is invited to purchase a box of Kodalith Ortho PB Film *from his Kodak Graphic Arts Dealer.*

Personal

Your Kodak dealer is now in a position to offer you a top-quality stereo camera at the convenient price of $84.50, and he may be able to extend payment terms that make it even more convenient.

An additional $12.75 buys our battery-powered viewer. If you want to splurge $23.75, you get a plug-in viewer with a brightness control and color-corrected optics. $4.65 pays for a 20-stereo-pair roll of *Kodachrome Film*, the processing and mounting of the results in *Kodaslide Stereo Mounts*, and even return postage.

The *Kodak Stereo Camera* has four shutter speeds. You select one, set for "bright," "hazy," or "cloudy-bright," and then focus for "close-ups," "groups," or "scenes." There is a spirit level visible in the viewfinder. You can't go wrong unless you try very hard.

Prices include Federal Tax where applicable and are subject to change without notice.

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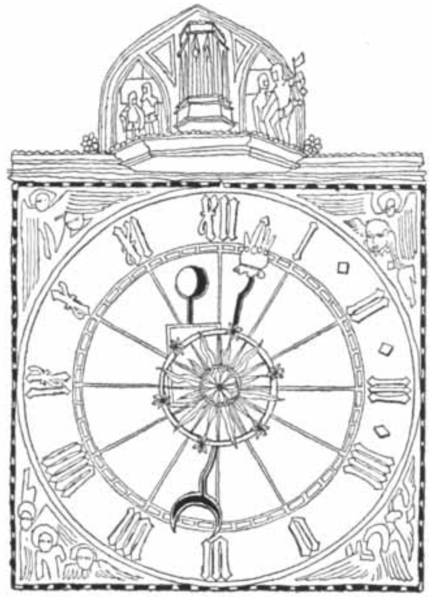
SCIENCE AND



Nobel Prizes

The great chemical theorist Linus Carl Pauling of the California Institute of Technology was awarded the 1954 Nobel prize in chemistry. The citation recognized his long, pioneering studies of the nature of the chemical bond and his work in unraveling the structure of complex molecules [see "The Structure of Protein Molecules," by Linus Pauling, Robert B. Corey and Roger Hayward; SCIENTIFIC AMERICAN, July].

A native of Portland, Ore., Pauling has been at Cal Tech since 1922, except for periods of study abroad and visiting professorships at other universities. He is director of the Gates and Crellin Laboratories at Cal Tech. Although he has had passport difficulties with the State Department, Pauling said he foresaw no trouble about getting to Sweden to accept his prize.

The Nobel award in physics went to an equally famous scientist, Max Born, and to Walther Bothe. Born's citation said the award to him was "for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wave function." Bothe was given a share of the prize for his invention of the coincidence method of detection and measurement of physical events, which has become a universal technique in physics.

Born was dismissed from the University of Göttingen by the Nazis in 1933 and went to Great Britain, where he held the chair in mathematical physics at the University of Edinburgh. Now 72, he has retired to live in Bad Pyrmont, a suburb of Heidelberg. Bothe has been at the Max Planck Institute in Heidelberg since 1934. He will be unable to go to Stockholm to receive his share of the prize because he recently lost a leg.

The Nobel prize in medicine was awarded to John F. Enders, Frederick C. Robbins and Thomas H. Weller, former collaborators at the Harvard Medical School, "for their discovery of the ability of the poliomyelitis virus to grow in cultures of different tissues." Before their work the virus was known to grow only in the nervous systems of human beings or other primates. Their tissue culture technique has brought the control of poliomyelitis within sight.

Enders, the senior member of the group, was born in 1897 in West Hartford, Conn., and received his higher education at Yale and Harvard. He is director of research on infectious diseases at the Children's Medical Center in Boston.

New Commissioner

The appointment of John von Neumann to the Atomic Energy Commission, following soon after the naming of Willard F. Libby, places two scientists on the Commission for the first time. Von Neumann, a mathematician, has been research professor at the Institute for Advanced Study since 1933. Commenting on the appointment, the New York *Times* said: "President Eisenhower appears to have made a useful gesture of conciliation toward the large group of scientists who have been unhappy about the Oppenheimer verdict." The full membership of the AEC is now: Lewis L. Strauss, Joseph Campbell, Thomas E. Murray, Libby and von Neumann.

Von Neumann, known as the founder of the theory of games, was one of the first to apply mathematical techniques to problems of business and military strategy. During World War II he served as consultant to the Army, the Navy and the Office of Scientific Research and Development. His most recent work has been chiefly in the field of high-speed computers and their application to complex problems such as long-range weather forecasting. He contributed to the development of the hydrogen bomb.

As a Commissioner von Neumann will have to give up research and take a leave of absence from the Institute for Advanced Study. He believes, he said, that all scientists whose work has made them

THE CITIZEN

familiar with atomic energy matters have an obligation to take a turn in shouldering the administrative responsibilities.

To replace von Neumann on the AEC's General Advisory Committee, President Eisenhower appointed Edwin M. McMillan, professor of physics at the University of California. Also named to the GAC were W. C. Johnson, professor of chemistry at the University of Chicago, and J. W. Beams, professor of physics at the University of Virginia. The place vacated a few weeks earlier by Libby was filled by I. I. Rabi, whose term expired in June, 1954.

Nuclear Society

The first professional society concerned exclusively with atomic energy was organized last month. Called the American Nuclear Society, its membership will be open to engineers and scientists of any nationality engaged in nuclear technology. One of its chief purposes is to promote interchange among all branches of nuclear research.

The society's first meeting will be held next June. Pending election of officers, W. M. Breazeale of Pennsylvania State University is serving as acting secretary.

The 29-man organizing committee included representatives from universities, government laboratories and industry. Among the committee members were Karl Cohen of Walter Kidde Nuclear Laboratories, G. Failla of Columbia University, K. H. Kingdon of General Electric Research Laboratory, J. D. Luntz of *Nucleonics* magazine, W. G. Pollard of the Oak Ridge Institute of Nuclear Studies, W. E. Shoupp of Westinghouse Electric Corporation, Philip Sporn of the American Gas and Electric Company and Alvin M. Weinberg of the Oak Ridge National Laboratory.

Good Idea

In May, 1939, four years before the first atomic pile was built, and only five months after the announcement of uranium fission, physicists in a French laboratory set forth a detailed and reasonable idea for a nuclear power reactor. During World War II they obtained a Swiss patent on their invention. This intelligence was brought to public attention last month by the journal *Nucleonics*.

The reactor, the first on record, was

designed at the National Center for Scientific Research in Paris. Its inventors envisioned a pile of uranium slabs separated by small iron chambers through which heavy water, the moderator, would circulate. A radium-beryllium mixture in the center of the core was to furnish neutrons for starting the chain reaction. The moderator was to act as coolant, circulating through an exchanger where its heat would generate steam for turbines. The design called for movable disks covered with cadmium to control the chain reaction. A layer of iron bricks around the core was to reflect escaping neutrons back into the pile, and the whole assembly was to be enclosed in a concrete shield.

The patent application noted that thorium was another possible fuel; that helium, carbon, paraffin or ordinary water might be used as moderators; that fission products would have to be removed periodically and the depleted fuel replaced. It mentioned that radiations from the core would have many applications, particularly in medicine.

Science Budget

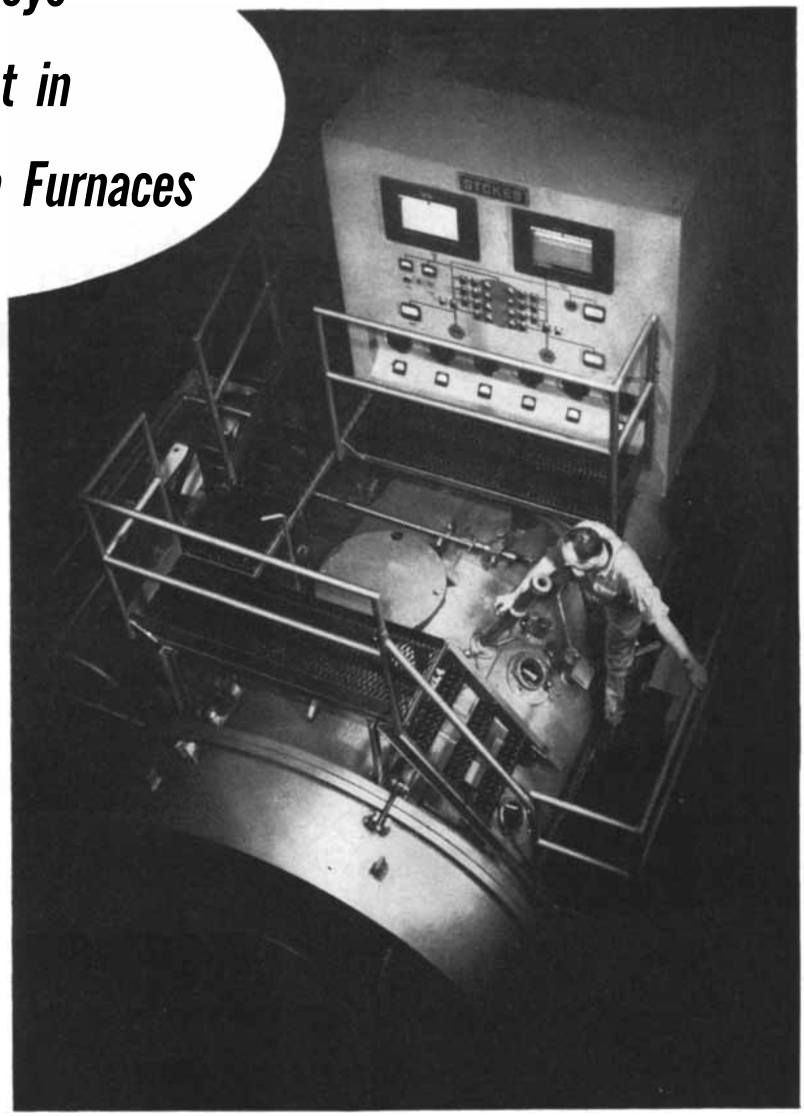
In the current fiscal year, which ends June 30, 1955, the U. S. Government is spending $2 billion on scientific research and development, a decline of about $200 million from the year before. Cuts in spending for new plant and for applied research and development account for the decrease. The allowance for basic research this year is $131 million, an increase of $10 million. These are some highlights of the National Science Foundation's third report *Federal Funds for Science*, issued last month.

Of the 1955 total $1.5 billion will be spent on physical sciences, $211 million on life sciences and $37 million on social science, including $18 million for collecting general-purpose statistics. The Department of Defense will disburse about 75 per cent of all the funds and the Atomic Energy Commission 13 per cent. The National Advisory Committee for Aeronautics, the Department of Health, Education and Welfare and the Department of Agriculture account for some three per cent each.

The basic research budget has been increasing slightly during each of the past three years. For basic work in biology the sum this year is $34.6 million; in the physical sciences, $94.4 million; in the social sciences, $2 million.

The report shows that Government spending for research and development has increased 20-fold since 1940, and

High-temperature Alloys now Melted and Cast in Stokes High-Vacuum Furnaces



A Stokes high-vacuum melting furnace of 1000-pound capacity at Utica Drop Forge & Tool Corporation, Utica, N. Y. The furnace is to be used for the melting and casting of high-temperature alloys for jet engine rotor blades.

Vacuum furnace melting and casting is the economical method for producing many new metals, with greatly improved properties. Alloys that can stand up in rocket engine combustion chambers and advanced jet engine turbines, metals essential for the construction of nuclear reactors, still other high-purity metals with properties not previously attainable . . . these are just a few of the more than thirty new elements vacuum processing has added to the industrial spectrum.

Vacuum-melted high alloy steels have greater tensile, yield, and impact strengths than conventionally-processed metal, plus greater stress-rupture strength at elevated temperatures, less creep, less brittleness. High-purity iron, processed in vacuum, has 60 to 75% greater stress-rupture strength and 400% more elongation than conventional metal. In anti-friction bearings, vacuum-processed steel has shown an increase of 300% or more in fatigue strength, and given a whole new perspective to the subject of wear-resistance.

Moreover, vacuum processing of alloys conserves critical hardening elements, since there is minimum loss of these metals during melting. More usable metal is obtained from each melt, and virtually all of the scrap can be salvaged by vacuum melting.

STOKES is *building* vacuum furnaces to process these high-purity metals in quantities up to 2000 pounds, and *planning* 5000-pound units. STOKES vacuum furnaces reflect the practical experience accumulated in fifty years of building vacuum equipment. An interesting NEW brochure is ready for mailing on request!

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Sea Change

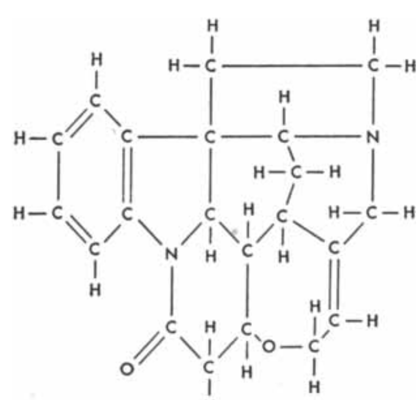
Almost everyone knows that the world has been growing warmer for the past 40 years or so. The warming has had some peculiar effects on the oceans, according to M. J. Dunbar, a zoologist at McGill University.

Dunbar reports in the journal *Arctic* that the rise in temperature has speeded up the circulation between arctic and tropical waters. One result has been to warm up markedly the climate of northern regions in the path of the Atlantic Gulf Stream: Iceland, Norway, the Faeroes Islands, the west coast of Greenland. Enormous numbers of codfish now inhabit the waters off west Greenland and Norway.

Another effect has been to reduce the depth of the cold layer of water on the surface of the Arctic Ocean. Dunbar believes that the peak of the current solar warming cycle was reached in 1945, but if the cycle rises again soon (and Dunbar thinks it may) the climate of the Arctic will suddenly become milder and moister.

Synthetic Magic

To an organic chemist an unknown compound is like a watch to a small boy: he is irresistibly impelled to take it apart and see how it is made. Unlike the small boy, the chemist is equally enthusiastic about putting it together again. This cycle has now been completed on strychnine, one of the most complicated molecules ever to be assembled synthetically. If chemists were surprised to hear that the feat had been accomplished, they were not the least surprised to hear who had done it. The trick was turned by R. B. Woodward of Harvard University, who in the past 10



Structure of strychnine (see above)

Norton materials for high temperature processing

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2 x 10^7	H-Bomb Ignition
4,000	Arc Light
3,500	Carbon Sublimes
3,370	Tungsten Melts
3,300	Oxy-Acetylene Flame
3,100	Rocket Engines (Combustion Gases)
3,000	Tungsten Lamp Filaments
2,900	Oxy-Hydrogen Flame
2,300	Direct Nitrogen Fixation
2,000	Calcium Carbide Furnace
1,900	Blast Furnace
−273	Absolute "Zero"

Temperature range of Norton electric furnace materials

C° Melting Point	Temperature of Electric Arc Furnace 4000° C – 7230° F	F° Melting Point
3540	ZIRCONIUM CARBIDE ZrC	6400
3300	FUSED THORIA ThO_2	5970
3140	TITANIUM CARBIDE TiC	5680
3060	ZIRCONIUM BORIDE† ZrB_2	5540
3000	BORON NITRIDE BN	5430
2900	TITANIUM BORIDE† TiB_2	5250
2700	FUSED ZIRCONIA ZrO_2	4900
2620	MAGNORITE* Fused Magnesia MgO	4750
2450	NORBIDE* Boron Carbide B_4C	4440
2300	CRYSTOLON* Silicon Carbide SiC	4170
2000	38 ALUNDUM* Aluminum Oxide Al_2O_3	3630
1900	REGULAR ALUNDUM Aluminum Oxide Al_2O_3	3450

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†Experimental Materials

*Trade-Marks Reg. U.S. Pat. Off. and Foreign Countries

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years has also synthesized quinine and cortisone.

Strychnine, an alkaloid first isolated in 1818, is a "tangled skein of atoms" whose structure was not unraveled until several years ago. Then Woodward tackled the job of synthesis. His solution, which requires 30 steps, will have no practical value. The limited medical requirements for the compound can be satisfied more easily and cheaply by extracting it from the plants that synthesize it naturally.

Working with Woodward on the problem were Michael P. Cava, W. D. Ollis, A. Hunger, H. U. Daeniker and K. Schenker. They reported their process in *The Journal of the American Chemical Society.*

Titanium Plate

Even at nearly $5 a pound, titanium is in increasing demand because of its great corrosion resistance, strength and light weight. Where resistance to corrosion is the important factor it would be much more economical to use cheaper materials covered with a thin layer of titanium. But there has been no practical means of electroplating the metal. Now Leo Goldenberg of Chemical Associates has developed such a process, according to the journal *Industrial & Engineering Chemistry.*

Goldenberg, who has demonstrated his method on a laboratory scale, uses soluble titanium anodes in a bath of molten magnesium chloride. The plating is carried out in an atmosphere of inert gas and at a temperature of 1,600 degrees. The inventor says he has obtained fully covering titanium deposits up to two thousandths of an inch thick. They adhere strongly to steel undersurfaces; heating the plated pieces to a temperature of nearly 1,800 degrees does not remove the coating nor does bending cause it to separate. Goldenberg believes that thicker deposits can easily be made.

Titanium surfaces are impervious to corrosion by fresh or salt water, fruit acids or human body fluids. These qualities make titanium-plated steel ideal for such applications as marine propellers, turbine blades, chemical and food processing vessels, containers for liquid metals, medical and surgical equipment.

Skin Deep

In the nuclei of women's skin cells is a small, hemispherical body not found in men's cells. This fact, which has been known only since 1949, is beginning to find applications in medicine. Last

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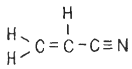
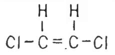
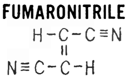


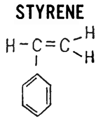
1, 2-DICHLOROETHYLENE



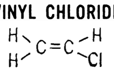
FUMARONITRILE



STYRENE



VINYL CHLORIDE



The "Acrylonitrile Road" is perhaps one of the most promising routes for researchers to new copolymer resins, coatings, adhesives.

Acrylonitrile is the most versatile and reactive polymer-former available in commercial quantities. Check these characteristics:

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month came a report that it has thrown new light on a type of cancer growth.

The distinguishing body, called the sex chromatin, was discovered by Murray L. Barr, a microscope anatomist at the University of Western Ontario. It is believed to be connected in some way with the sex chromosomes. Whatever its nature, it is now considered a reliable indicator of sex. Many physicians are using this simple skin test to determine the true sex of pseudo-hermaphrodites.

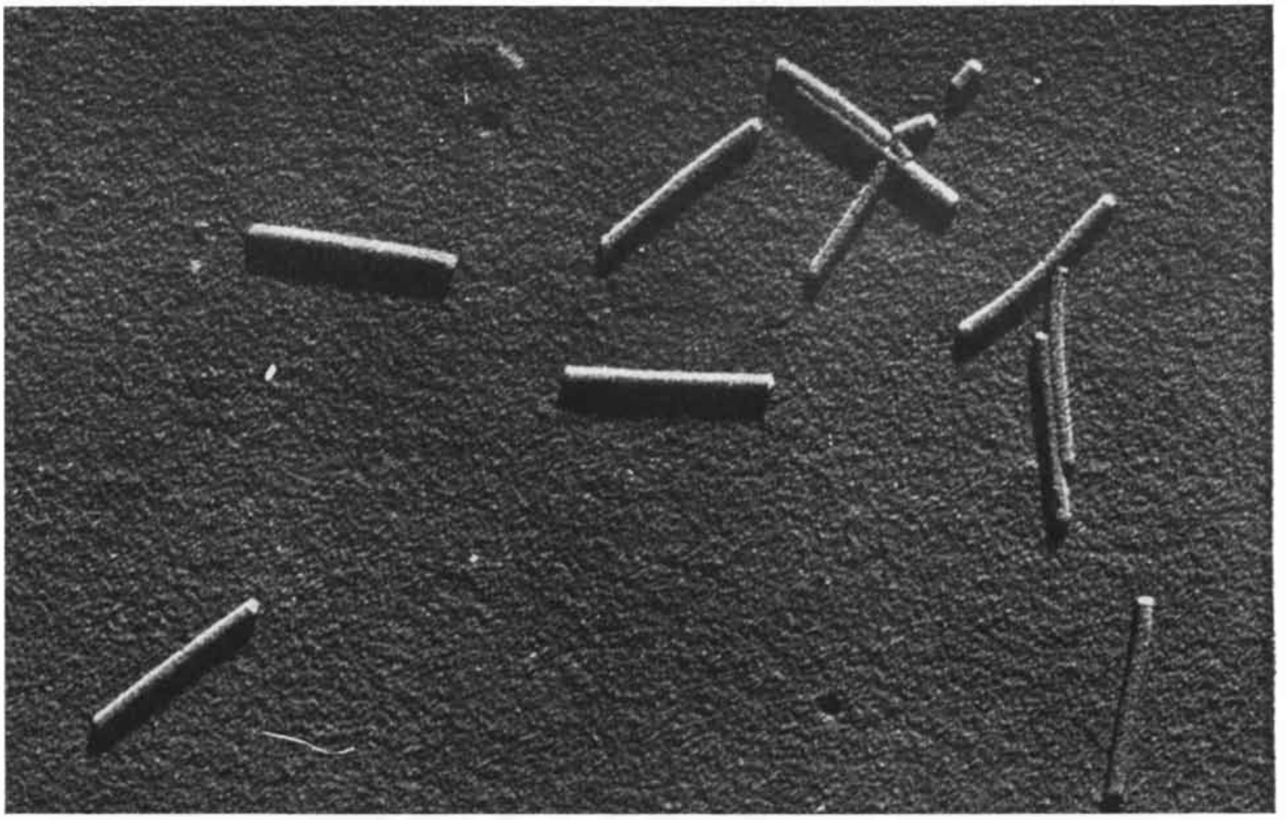
W. F. Hunter and Bernard Lennox of the Postgraduate Medical School of London undertook to determine the sex of the mysterious tumors called teratomas. Some students argue that teratomas originate from foreign tissue, such as an abortive twin embryo absorbed during fetal development. Hunter and Lennox tested epidermal cells in teratomas from several men and women. Those of the women were all female. In the male tumors, however, they found both male and female cells, indicating that these tumors cannot be "ordinary" growths.

Horticulture v. Culture

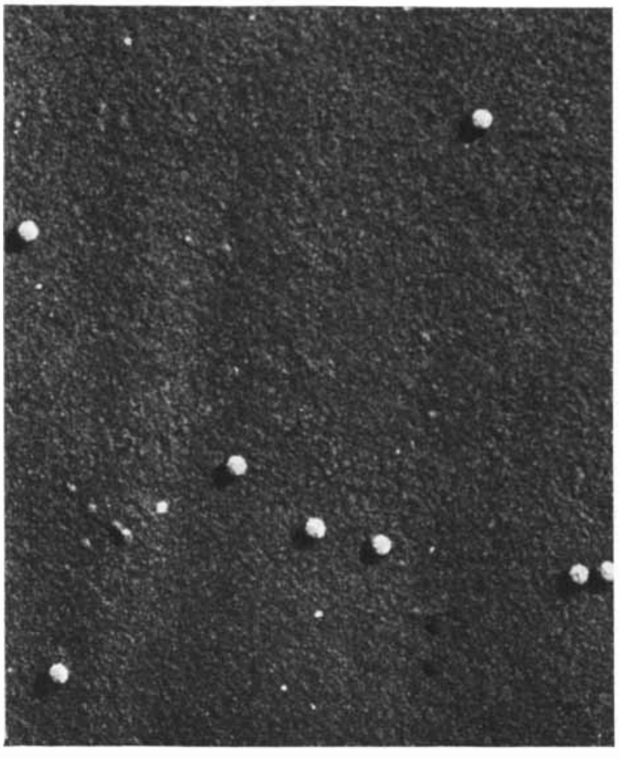
Harry J. Fuller, professor of plant physiology at the University of Illinois, recently became depressed about the cultural level of graduate students in his department. To find out how little they knew, he prepared a short general information test and sprung it on 15 unsuspecting Ph.D. candidates (in horticulture, agronomy, botany and zoology) before word of his activity got around the campus. The test consisted of 10 names, to be identified as specifically as possible. The items, and the number of graduates (out of the 15) who gave satisfactory answers in each case were:

The Renaissance–6
The Reformation–5
The Monroe Doctrine–2
Voltaire–5
The Koran–10
Plato–7
The Medici Family–1
The Treaty of Versailles–11
Bismarck–4
Magna Carta–2

One student, a graduate of one of the largest state universities, could give no acceptable answers. Ten of the candidates had never even heard of the Medicis; seven were equally innocent about Magna Carta. "Perhaps," says Fuller in a letter to *Science*, "we are overtraining both undergraduate and graduate students to the detriment of their education."



TOBACCO MOSAIC VIRUS is rod-shaped. When fragments of the rods are seen end-on, they are hexagonal. This electron micrograph, which enlarges the virus particles some 93,000 diameters, was made by Robley C. Williams of the University of California.



TOMATO BUSHY STUNT VIRUS is spherical or hexagonal. This micrograph by Williams enlarges the particles 85,000 diameters.

BACTERIAL VIRUS of the T-4 strain has a tail. This micrograph by Williams and Dean Fraser enlarges particles 65,000 times.

THE PHYSICS OF VIRUSES

The structure and function of the smallest living things are presently studied by physicists using a wide variety of physical methods and tools, among them the cyclotron

by Ernest C. Pollard

A virus is an extraordinary combination of vigorous life and complete inanition. While inside a host, the virus is intensely alive, so much so that a gram of virus turns over an amount of energy equivalent to that produced by five full-grown men. But between invasions, say while it lies on a kitchen table top, the virus can be thought of as essentially no different from an inert grain of sugar. This double existence affords a great scientific challenge. On the one hand viruses in the inert phase can be studied at leisure with the electron microscope and by other physical means. On the other, their behavior in cells can be examined as a primitive kind of life.

Looking at viruses, a physicist is strongly attracted to probing their mysteries with his powerful modern tools. Physics is reaching into many realms of nature—astronomy, geology, chemistry and so on. Perhaps the time is ripe for applying physics to biology. Can physical principles shed light on the phenomena of life, as they have on so many other fundamental questions? More specifically, can the laws of quantum mechanics, electricity and statistics explain living systems?

The viruses seem an exceptionally good place to start this interrogation. They are very small, and therefore presumably simple. They seem to possess a minimum of biological attributes; in fact, perhaps only one property of life—self-duplication. When a physicist looks at them closely, however, it does not take him long to realize that their apparent simplicity and lack of character is deceptive. Only in terms of large biological organisms are viruses simple. In terms of physical systems, such as the hydrogen atom or a swinging pendulum, they are indeed complex. Nevertheless the physicist still finds them attractive.

We shall start by reviewing what is believed to be the life history of a representative virus. In doing this we intend to use a physicist's prerogative and generalize rather rashly. This rashness is quite justified because we are concerned with describing a kind of system rather than a particular system. And indeed one of the astonishing features of modern biology, as seen by a physicist who approaches it from a different background, is the degree to which generalizations can now be made. At all events, the virus we shall select as representative is the bacteriophage. Many virus workers consider this bacterium-infecting particle typical at least of animal viruses.

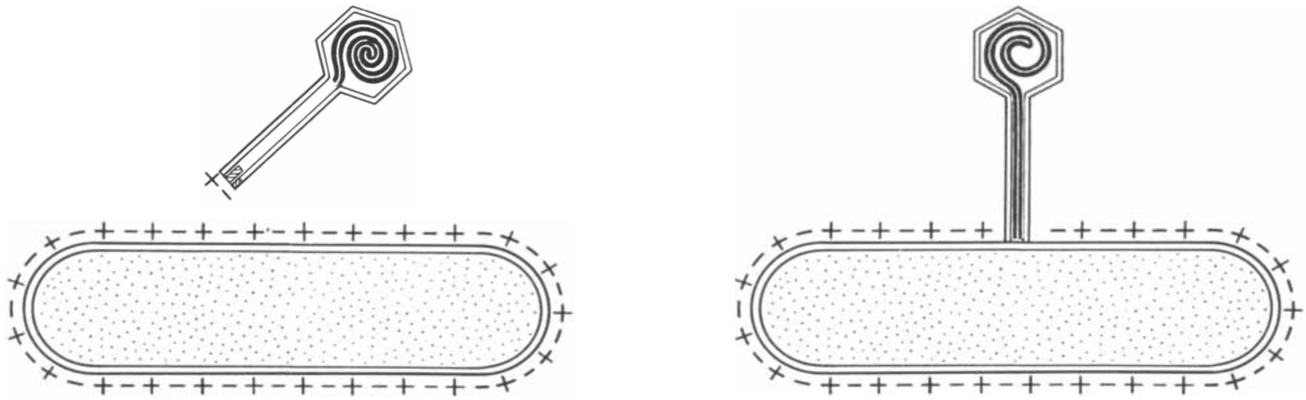
Career of a Virus

Consider the approach of such a virus to a host bacterium [*illustrations on the next two pages*]. On the surface of the bacterium are a set of electrical charges, distributed in a pattern which constitutes part of the bacterium's personality. On the "tail" of the virus is a complementary set of charges distributed in a similar pattern, so that plus can be attracted by minus. Buffeted and swung about by a heavy bombardment from the molecules of the liquid medium, the virus is pushed toward a bacterium. When the end of its tail comes within the field of force of the bacterium's surface, the two are pulled together and held tightly. Now, if the temperature is high enough, an enzyme in the virus's tail goes to work to clear a hole in the tail and in the wall of the bacterium. Through the opening the inner substance of the virus, which must be long and thin in molecular shape, begins to move into the bacterium. It is quite likely that contractions of the virus's outer membrane help to start this injection process. Once part of the thread of material is inside the host, molecular bombardment on it will push it about in the roomy interior. The virus substance may also separate into two long molecules. In any event, the essential part of the virus gains entry. It is a remarkable fact that the coat, which protected the active part of the virus in its inert phase, is left outside.

Now the active stage of the life history of the virus begins. In a very short time—a matter of seconds—the virus substance compels the host bacterium to halt its own growth and switch to manufacturing parts for new viruses. At first there is no sign whatever of these incipient offspring. But somehow, in a very dramatic way, the assembly of parts is going on. We know that many of the parts are made from very simple chemical compounds, not preformed units of the bacterium itself. About midway through this "latent period" of reproduction, recognizable components of viruses begin to appear. Finally, at the end of about 20 minutes, the bacterium's cell wall bursts open and about 300 full-fledged virus particles are released into the surrounding medium. They are just like the parent virus, with the same ability to infect bacteria.

Under the Electron Microscope

Now how does physics enter into this picture? In the first place, it is most important to know just what is being multiplied. In other words, what is the virus like? The description of a virus, still far from complete, is a task in which physics has aided very materially. The most direct and dramatic information is given by the electron microscope. In reality a virus can be identified surely only by its ability to infect. But Ralph G. Wyckoff, Thomas F. Anderson and Robley C. Wil-



BACTERIUM IS INFECTED by a bacterial virus. In the first drawing the electrical pattern of the bacterium (*bottom*) is represented by plus and minus signs. The tail of the virus (*top*) has a complementary set of charges that attract it to the bacterium. In

liams, the pioneers in the art of electron microscopy, worked out a method for shadowing concentrated preparations of virus with metals which made it possible to see individual particles. To make sure that these particles were the virus itself, most careful checks had to be made. The plant viruses were among the first reliably recognized. It is easier to prepare strong concentrations of plant than of animal viruses, and a greenhouse of plants is a less formidable project than 10,000 infected eggs. Various preparations of the virus of the tobacco mosaic disease were subjected to examination by the electron microscope and at the same time to the test of infectivity. It became clear that the "infectious principle" of tobacco mosaic virus was a rod-shaped object some 3,000 Angstrom units (an Angstrom unit is one ten-millionth of a millimeter) long and 120 Angstroms thick. When other plant viruses were submitted to the same examination, some proved to be rod-shaped, some more or less spherical.

In the meantime viruses were also being studied with another physical instrument, the ultracentrifuge. This instrument can determine the size and shape of a virus from the speed with which it drifts through a solution or a porous membrane when whirled with a given centrifugal force. The ultracentrifuge confirmed the findings of the electron microscope, and the virus emerged as a real particle.

Their Sizes and Shapes

This combined use of the electron microscope and of the processes of sedimentation and diffusion has permitted description of a great many viruses. They are significantly simple in shape. The three most common shapes seem to be those of a rod, a sphere (more precisely a polyhedron), and a tadpole with a polyhedral head and a tail. The tails vary greatly in length: some are so short that they escaped detection at first; others are three times as long as the head. The tadpole shape is characteristic of bacterial viruses. The poliomyelitis and rabbit papilloma viruses seem to be spherical, and so does at least one form of the influenza virus. The spherical, or polyhedral, viruses are generally about 350 Angstroms in diameter. Some of the larger animal viruses, such as vaccinia, have a rhomboidal shape and a diameter of about 3,000 Angstroms.

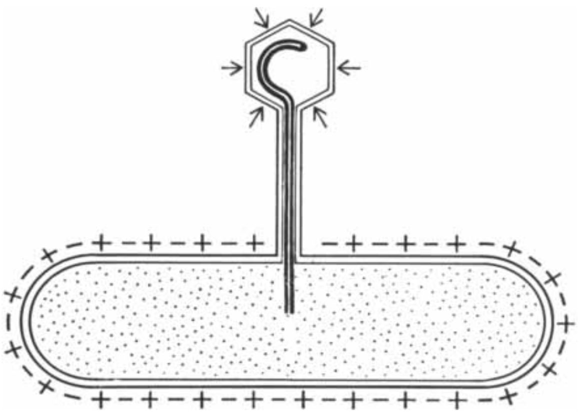
The measurement of the sizes and shapes of so many viruses is one of the triumphs of physics applied to virus study. All the methods of study of these submicroscopic objects are physical, and it is very gratifying that such widely divergent methods as electron microscopy and sedimentation have produced consistent findings.

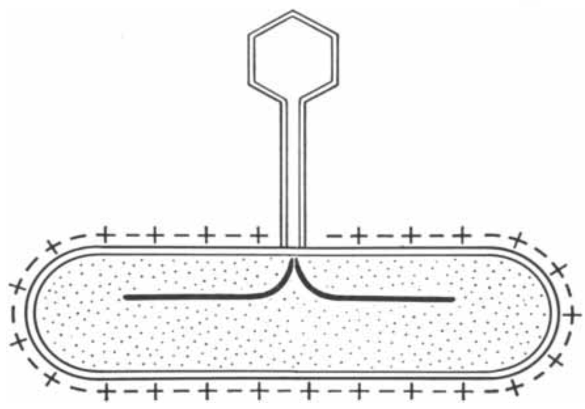
Anderson and Williams have recently developed refined methods to assure that viruses are not distorted or mutilated by surface forces when they are dried for examination under the electron microscope. Anderson's technique involves drying the viruses without passage through the surface film of the liquid, and Williams' method is very rapid freeze-drying. Both methods preserve the original shape of the virus. Anderson has been able to obtain remarkable three-dimensional pictures of viruses attached to bacteria by their tails: they look like pins in a pincushion. Williams has shown that most of the viruses that seemed spherical are really polyhedral.

Another new technique of great interest is the slicing of viruses by very delicate microtomes. When the extremely fine blade of such an instrument cuts through cells, there is a good possibility that it may section a virus if there are many present. Some significant pictures of the internal structure of the herpes simplex virus have been obtained by Councilman Morgan and his group at the Columbia University College of Physicians and Surgeons. Before long it should be possible to relate this structure to the virus's activities.

How does a virus attach itself to a cell? Max Schlesinger and Max Delbrück proved some time ago that as soon as a bacterial virus and a bacterium collide, they stick together. Theodore F. Puck and his co-workers at the University of Colorado have learned that the process of attachment depends to a large degree on the amount of ionization of the solution surrounding the bacterium and virus. Following this up, Puck showed that the attachment process has two stages. First, charged amino groups on the virus are drawn by electrostatic attraction to carboxyl groups on the bacterium. Then enzymes seem to take a hand in making the two stick together, for this second stage of attachment is sensitive to temperature, as all enzymatically controlled reactions are. When the quantitative relationship between attachment rates and the strength of ionization is worked out, it will open up a new method for gaining information about both the bacterium and the virus.

The two major constituents of bacterial viruses are protein and nucleic acid. Many kinds of evidence have suggested, though not actually proved, that as a general thing the protective coat of viruses is made of protein and the active part is the nucleic acid. The most impressive evidence was the work done with radioactive tracers by A. D. Hershey and M. W. Chase at the Carnegie Institution of Washington Department





the second drawing an enzyme dissolves a plug in the tail of the virus. In the third drawing the inner substance of the virus enters the bacterium, probably pushed by contractions of the outer membrane of the virus. In the last drawing the infection is completed.

of Genetics in Cold Spring Harbor, N. Y. They found that radioactive phosphorus taken up by virus-infected bacteria was incorporated in the new generation of viruses, while radioactive sulfur was not. Phosphorus is a component of nucleic acid, and sulfur a component of protein but not of nucleic acid. Another indication that the virus protein does not enter the bacterium, while nucleic acid does, was that all the radioactive sulfur could be detached from the bacteria by mechanical shaking, whereas phosphorus could not. Further, an enzyme capable of digesting nucleic acid did not damage the virus unless something violent was done to the virus, presumably breaching its protective protein coat. Thus Hershey and Chase were able to show that the virus must be in at least two parts—one containing the nucleic acid and the other the protein.

Probing with a Cyclotron

A completely different approach to the problem of virus structure has been developed by the author and his co-workers at Yale University, notably F. Forro, D. J. Fluke, A. E. Dimond and C. Woese. Probing viruses with energetic radiations, we inactivate various properties of bacterial viruses separately and thereby deduce something about the size and location of the part of the virus structure that is responsible for each element of behavior.

A fast charged particle ionizes molecules along or near its path. Ionization, usually through removal of electrons, releases a large amount of energy, which will break chemical bonds and cause changes in the molecules. If the changes occur in molecules responsible for the hereditary functions of an organism, they may destroy the ability to perform those functions. As a matter of fact, it has been known for many years that large doses of X-rays will inactivate viruses. A number of workers have studied viruses by this means.

In 1949 the author and Forro decided to explore viruses with deuterons from a cyclotron. These particles travel in straight lines and ionize heavily. We found that the effects on viruses varied with the energy of the bombarding deuterons. A bacterial virus pierced by a fast deuteron does not necessarily lose its ability to infect. In general the amount of damage to the virus's functions depends on the amount of energy lost by the bombarding particle, *i.e.*, the extent of ionization of the virus substance. The suggestion that the virus possessed some sensitive internal part set in motion a whole research program at Yale. Various kinds of ionizing radiation were set to work inactivating a series of viruses, and various properties were studied. The results are beginning to permit a detailed description of virus structure.

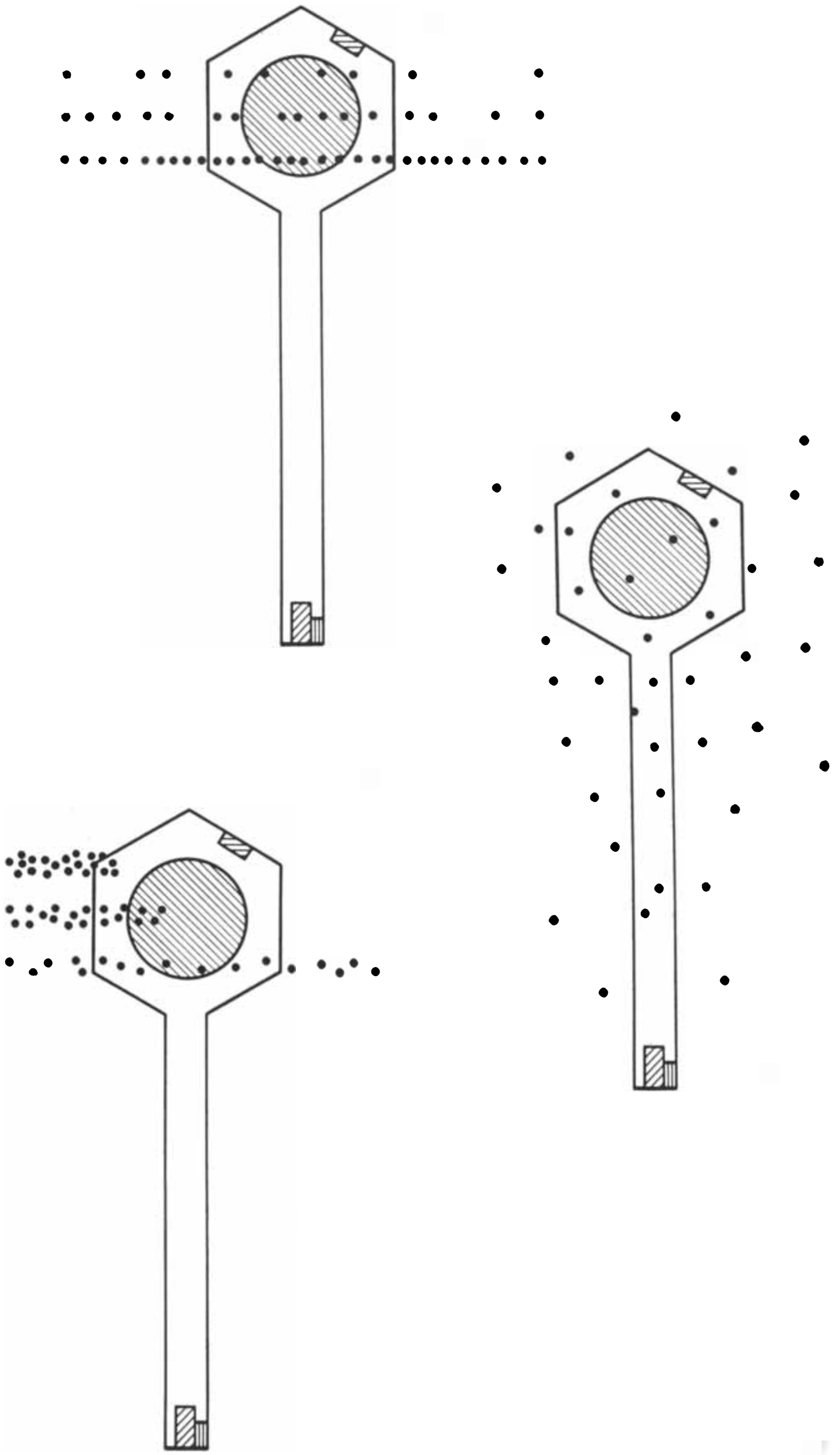
Functions of a Virus

A bacterial virus has several properties: it can attach itself to a host cell (or even a glass surface); it can infect and multiply in a host cell; it may be delayed in carrying out its reproduction; it may kill a cell without multiplying; it can give rise to antibodies in animals, and it may combine with antibodies. All these properties can be influenced by ionizing radiations.

Suppose we select for study four properties, assumed to reside in different-sized units within the virus. If we bombard the virus with deuterons, which pass through its various points at random like raindrops hitting a surface, we expect the largest units within the virus to receive the most hits [*see upper illustration on next page*]. Thus the relative sensitivity of the four properties to this bombardment gives us a measure of the relative sizes of the areas in which the properties reside. We can also get some measure of the thickness of each of these units by varying the density of the bombarding beam. If the area is thin, deuterons may pass through without producing ionization. But an increase in the density of bombardment in this case should increase the probability of ionization; in other words, if a given property becomes more vulnerable as the radiation dose is raised, we know that the unit in which it resides must be thin.

The virus may be bombarded in such a way that little regions of ionization are produced all through its volume [*middle illustration on next page*]. In this case the size measured is not an area but a volume. Finally, there is a very pretty technique which varies the depth of the bombarding particles' penetration into the virus [*lower illustration on next page*]. In this way various centers of activity in the virus can be located. The technique requires preparation of single layers of viruses with very clean surfaces.

Almost all the functions of the bacterial virus known as T-1 have been studied by these means. The most sensitive property of the virus is the ability to reproduce in bacteria; that is, this ability is most easily destroyed by radiation. Next is the ability to kill bacteria; this property is about a third as sensitive as the ability to infect. After these in order of decreasing sensitivity come the abilities to interfere with the growth of another virus, to attach to a host bacterium, to combine with antibody and to attach to glass. It was found that the region



PARTICLE BOMBARDMENT is used to study the structure of viruses. The schematic viruses in these drawings are assumed to have four properties, each associated with a structure differentiated by crosshatching. In the drawing at upper left three deuterons pass through the virus, each leaving a trail of ions. Obviously the function most frequently inactivated by this ionization will be associated with the structure of largest area. In the drawing at center right a more random electron beam produces ionization throughout the volume of the virus. This technique reflects the volume of the structures rather than their area. In the drawing at lower left electron beams of three different energies penetrate the virus to three different depths. Here the low-energy beam will not affect the function associated with the large structure in the center, the beam of higher energy will affect it to some extent and the beam of highest energy will affect it to a greater extent. This latter technique provides information about the location of structures within the rest of the virus.

responsible for infectivity corresponds to about one fifth of the volume of the virus. This unit must be long and thin, which means that it must be coiled up in some way. The unit carrying the killing property is apparently smaller, and the unit that can cause interference, still smaller. The unit responsible for attachment seems to be 80 Angstroms long and 80 thick, while the one responsible for combining with antibody has the same length and a thickness of 25 Angstroms.

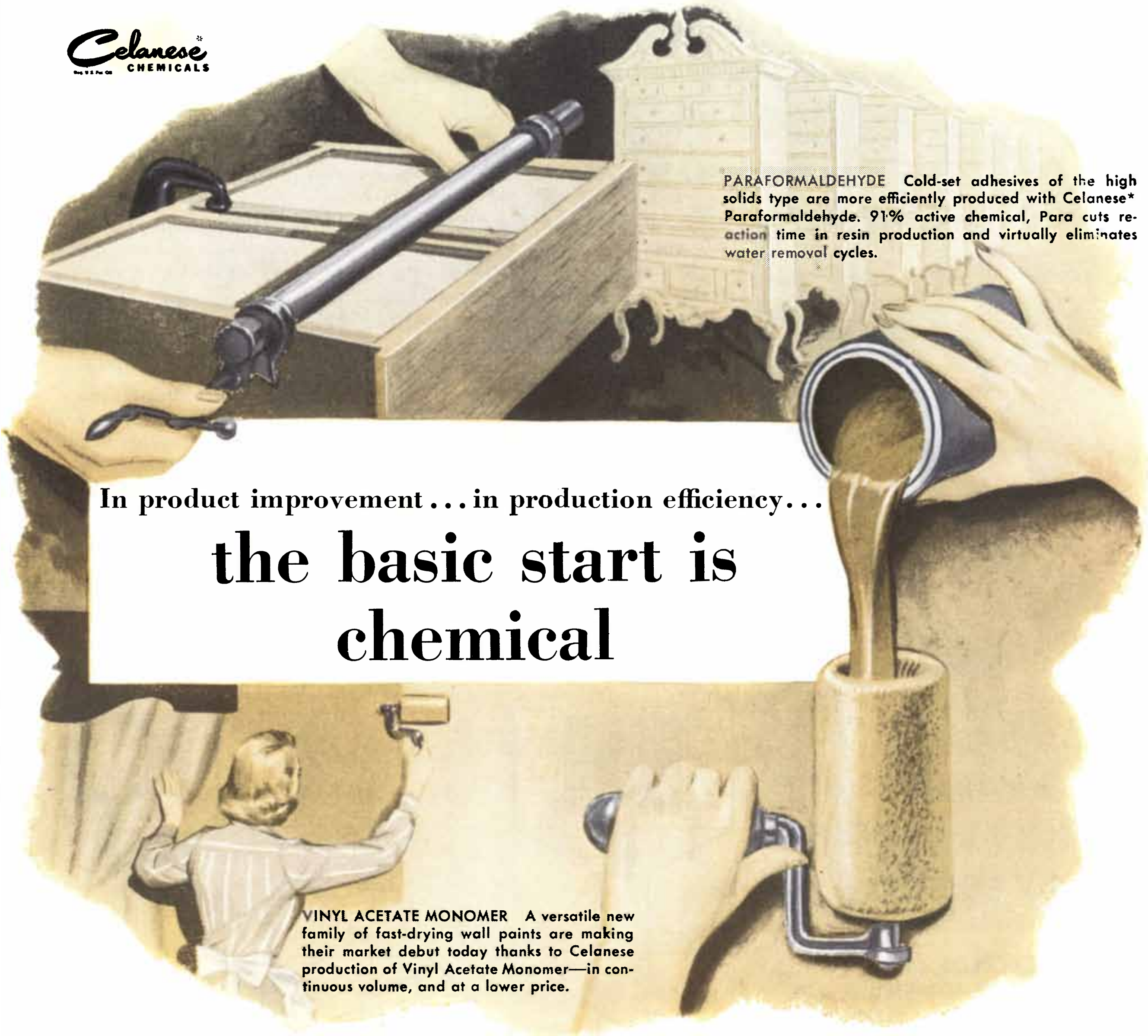
The infectivity unit lies 150 Angstroms deep within the virus—a confirmation of the fact that this virus has a coat of protein. The unit involved in extension of the latent period of reproduction also must lie inside the virus. None of the infective parts can reside in the tail, for it is only 150 Angstroms thick.

Picture of a Bacterial Virus

Putting all these facts together, we arrive at a general picture of the virus [*see diagrams on page 68*]. The author receives much good-humored criticism because the summarizing picture seems different each time it is drawn. One can only answer that each successive model of an atom or a molecule drawn between 1900 and 1920 looked different from the ones before, but each brought investigators closer to the truth. If the present guesses about the interior structure of viruses serve no other function they at least remind us of the miracles of organization that have to be performed inside the virus.

Looking at the picture, we see a long unit, coiled up in the head and pointing into the tail, which is responsible for the virus's ability to infect bacteria and for governing the rate of its multiplication, and which must carry the hereditary features of the virus. The tail is plugged by an enzyme, which probably has the function of opening a hole in the skin of the bacterium. Once the hole is opened, enzymes in the bacterium liquefy a passage through the tail and permit material to flow from the bacterium into the head of the virus. This probably produces a rise of pressure which starts pushing the coiled-up part of the virus head into the bacterium. After the thin string of material has got part way into the host, local bombardment of it by the molecules of the host helps to draw it in rapidly.

The coat of the virus is made up of compounds with a molecular weight of about 23,000 times the weight of a hydrogen atom. The construction of this coat is a challenge to investigation. In-



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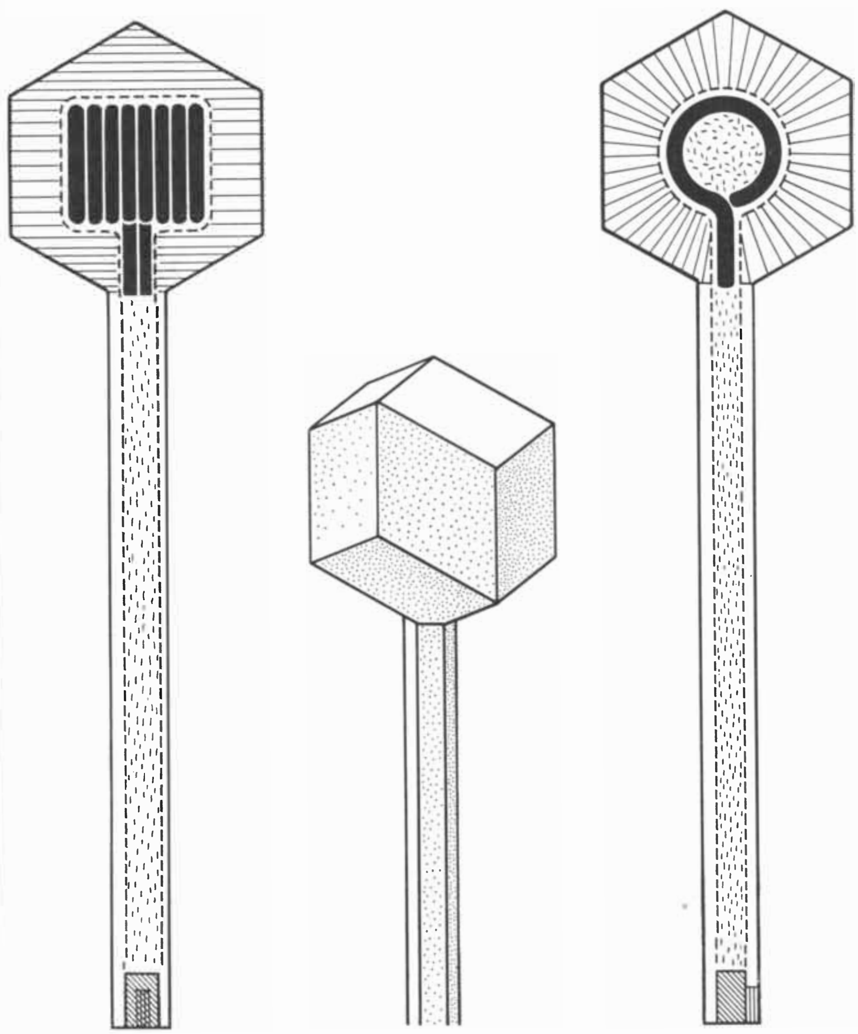
deed the whole virus model cries out for quantitative physical analysis to determine whether the suggested mechanisms violate any physical principles.

Pictures of some other viruses can be constructed, though they are much less complete. In the case of the polio virus the sensitive infectivity unit seems to be bulky, not long and thin. Its coating must either be essential to reproduction or else very thin. In the influenza virus the units that agglutinate red blood cells seem to be paired and to have a molecular weight of about 250,000.

In principle any radiation or comparable physical agent can be used to probe viruses as we have done with the cyclotron. Their infectivity has been examined, for instance, with ultraviolet light of single wavelengths; these experiments have suggested that while most of the property of infectivity resides in the virus's nucleic acid, some of it is connected with the protein. Ultraviolet light will lengthen the latent period of virus reproduction, and it turns out, surprisingly, that the property of reproduction appears to be regulated by nucleic acid alone, rather than by nucleic acid and protein. In other words, the mechanism responsible for how fast the virus works seems to be separate from the one that determines whether it works at all. Thus the present evidence indicates that the virus contains a part which is solely concerned with speed of reproduction and a different and more complex part which is concerned with faithful duplication of itself.

The activation of "proviruses," causing them to become viruses, is another property that is sensitive to ultraviolet light absorbed both by protein and by nucleic acid. The ultraviolet studies, telling something about what viruses are made of, and the deuteron studies, disclosing their sizes and shapes, obviously should provide many valuable clues to



STRUCTURE of the T-1 bacterial virus was inferred from bombardment experiments of the kind depicted in the illustration on page 66. In the center is the exterior model of the virus. At left is a cross section; at right is a second cross section at 90 degrees to the first.

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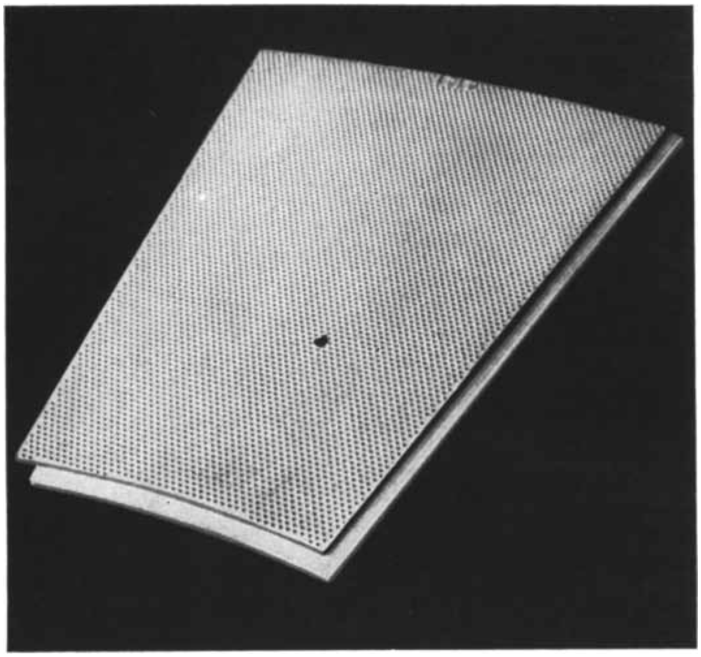

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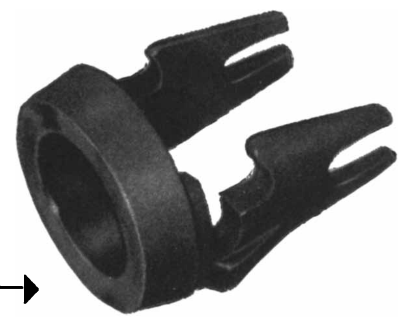

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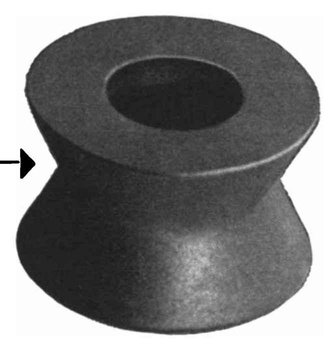

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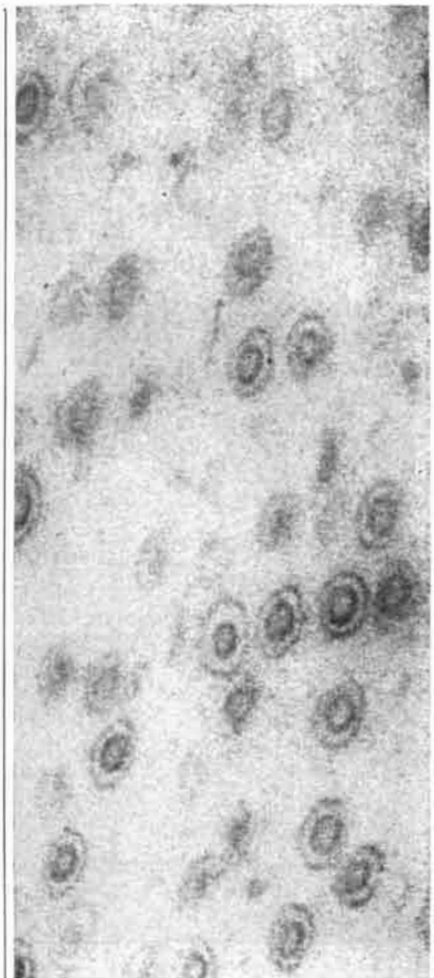
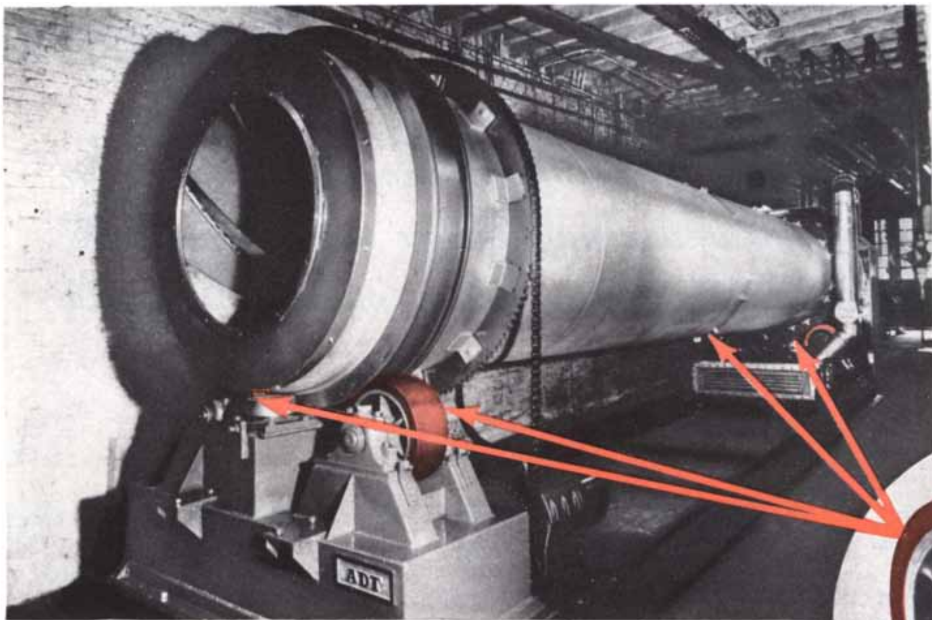
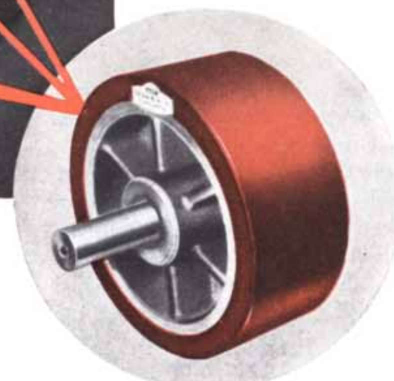


HERPES SIMPLEX VIRUS particles are sliced through in this electron micrograph made by Councilman Morgan and his associates at the Columbia University College of Physicians and Surgeons. The particles, which are enlarged 108,000 times, appear to have an outer membrane and an inner core.

biochemists and microbiologists who are investigating life at this fundamental level.

To at least one physicist viruses are fascinating beyond any other system in nature. It would not be fair to lure other physicists into this kind of work, however, without a word of warning. As in all other applied branches of physics, the investigator must give up a purely physical approach and lose himself in the whole biological problem. He must learn to think not merely as a physicist but as a broad scientist. If he does this, he will find great interest and challenge in the viruses. He will feel the excitement of testing the value of his beloved physical principles in fields where they have never before been applied. Indeed, he will hate to leave the laboratory, and will wait impatiently for the morning while his experimental subjects live out the consequences of the experiments he has devised the day before.





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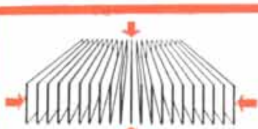

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Mycenae, City of Agamemnon

It flourished some 1,000 years before the rise of classical Greece. New discoveries of its magnificent tombs shed light on one of the great civilizations of the prehistoric world

by George E. Mylonas

Mycenae, the home of King Agamemnon, storied leader of the Greek expedition against Troy, has slowly yielded to modern archaeologists evidence that it was the capital of one of the great civilizations of prehistoric times. Sung in Homer's *Iliad* as a city "rich in gold," Mycenae flourished and perished long before Homer and the Greece we know. It gave birth to much of the brilliant art and culture that was to make the glory of historic Greece. Yet until a little more than a century ago ancient Mycenae was practically unknown as a city: its material reality was preserved chiefly in the account of a second-century traveler named Pausanias who had looked at its ruins and reported that he had seen the grave of Agamemnon.

The disinterment of Mycenae began dramatically in 1876 when Heinrich Schliemann, famed as the excavator of Troy, sent his telegram to King George of Greece announcing the discovery of Agamemnon's grave and bones. At the hilltop site of the ancient city in the Peloponnesian peninsula Schliemann unearthed a circle of five royal graves and the walled citadel of the town. Further investigation was to show that the bones could not be Agamemnon's, for the graves had been made at least three and a half centuries before the siege of Troy (beginning of the 12th century B.C.). But Schliemann's discoveries brought the neglected ruins to the attention of the world and started an exploration which was to lead to surprise after surprise. Gradually, in three quarters of a century of spasmodic digging, there has emerged a thrilling picture of Mycenae as a wellspring of culture and power in the pre-Hellenic world of the Late Bronze Age.

While Schliemann himself thought he had found most of what there was important to find at Mycenae, Greek archaeologists, notably Chrestos Tsountas, went on patiently digging out the ancient palace, the cemeteries and the houses of the city. For a time this site was overshadowed by the epoch-making discoveries of Sir Arthur Evans on nearby Crete, where he brought to light another great Bronze Age civilization. Then in 1918 to 1923 Alan J. B. Wace of Cambridge University brought Mycenae back into the limelight by a brilliant series of excavations which yielded an

HILLTOP CITADEL of Mycenae was unearthed in 1876 by Heinrich Schliemann. He thought he had found the grave of Agamemnon, but this was disproved when it was shown that the grave had been dug three and a half centuries before the siege of Troy.

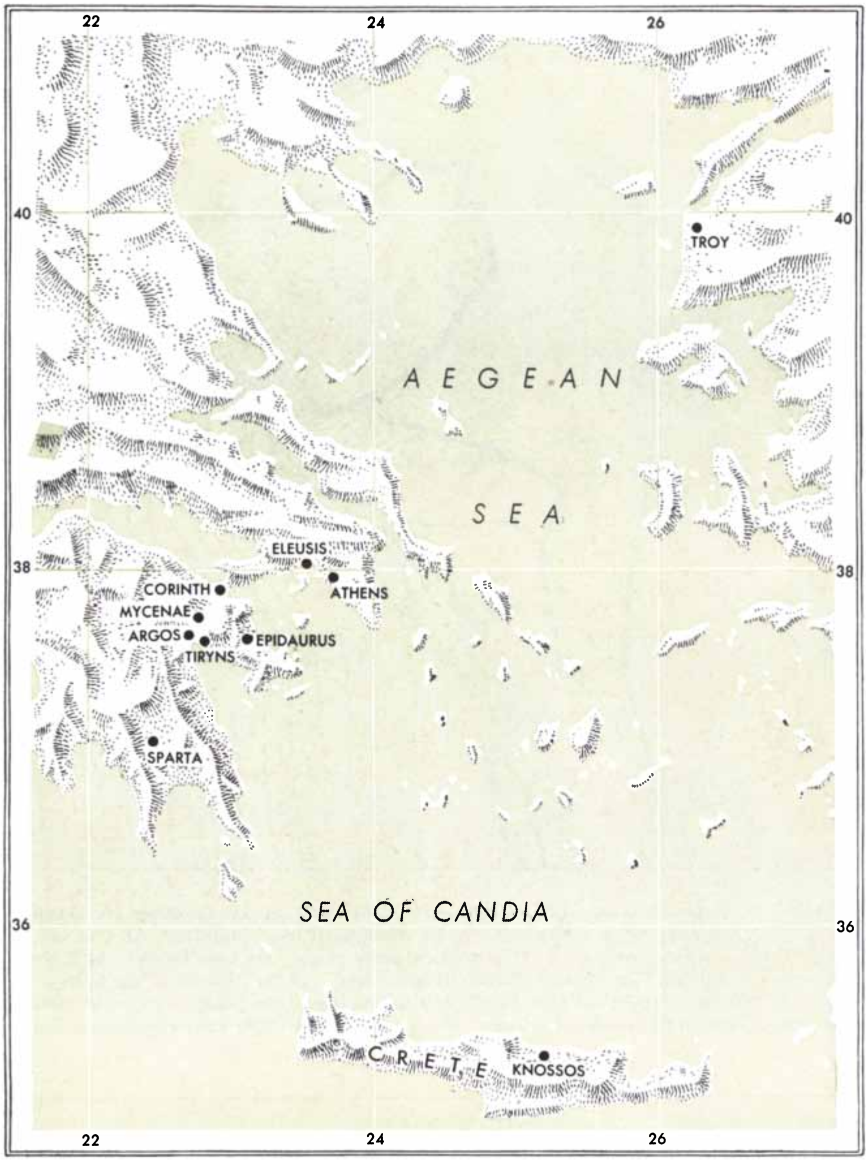
unexpected wealth of information regarding the accomplishments of Mycenae's pre-Homeric people. The discoveries proved that by 1600 B.C. Mycenae was the center of a rich culture which for at least two centuries paralleled that of Crete, and that after the destruction of the latter around 1400 B.C. Mycenae became the leader of the Greek world.

The Mycenaeans built vaulted stone tombs which as engineering feats have been compared with the pyramids of Egypt; they covered the walls of their palaces with gay frescoes brilliant in color and rich in imagination; they developed pottery and gem-carving to a fine art; they created a religious mythology, a philosophy of life and even sports (*e.g.*, boxing) which contributed to the development of our Western culture. Although Mycenae was destroyed by warfare around 1100 B.C., its traditions survived and helped shape the way of life of classical Greece.

After Wace's fruitful excavations of the early 1920s the experts thought that Mycenae had yielded all its treasures, that no more great discoveries or surprises remained. They were wrong. For more than a quarter of a century the site was pretty much let alone, but archaeologists inevitably came back to it. They still had many unanswered questions: Was the Mycenaean culture originated in Crete and brought to Mycenae by Cretans? Were the Mycenaeans illiterate, as Homer's heroes are supposed to be? How much did the culture of Mycenae resemble that described in the *Iliad* and the *Odyssey?* These and many other questions might be answered by further exploration of the site.

In the summer of 1950 Professor Wace and the Greek Archaeological Society of Athens resumed intensive digging. Wace decided to explore the prehistoric cemetery beyond the walls of the citadel and the houses in the previously untouched Lower City. He was quickly rewarded. Among his important new discoveries were four houses which have been worth three summers of work.

One is a burned house that seems to have belonged to an oil merchant. In its basement were found a number of oil jars and some 50 stirrup jugs, all standing in their original positions. The jugs, stopped with clay stamped with the seal of the owner, had been deliberately broken open when the house was put to the flame, so that their contents would help the fire. In the basement of the same house were discovered some 38 clay tablets covered with the tantalizing signs



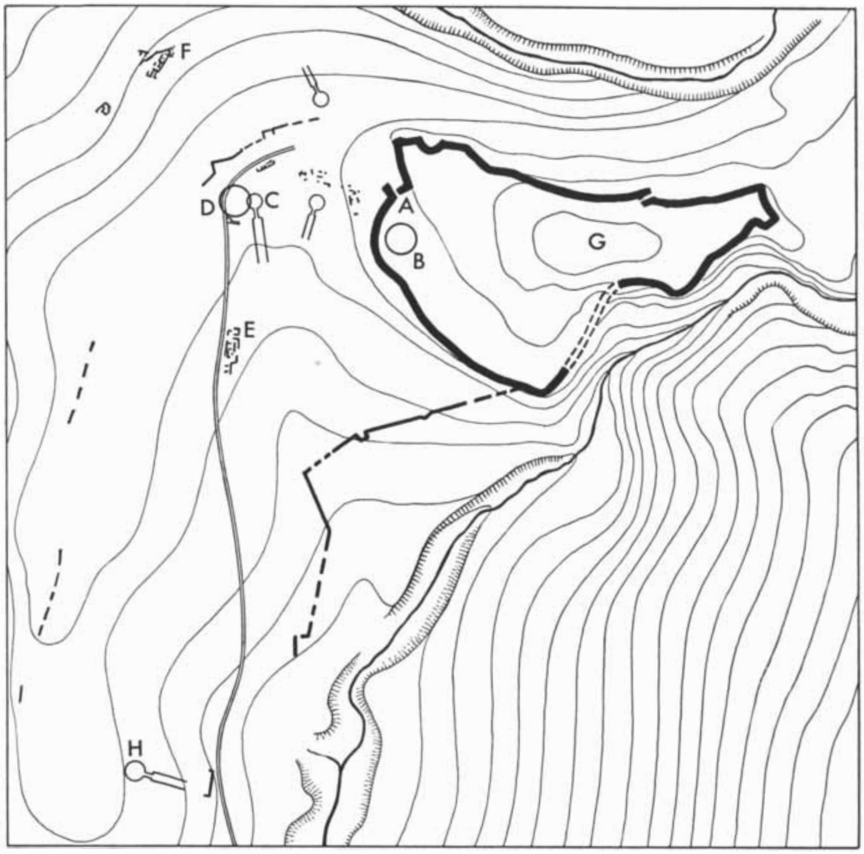
SOME GREAT CITIES of classical Greek and prehistoric times are located on this map. From Mycenae on the Peloponnesus Agamemnon led his famous expedition against Troy.

of Linear Script B, a script which seems to be on its way to decipherment [see "The Language of Homer's Heroes," by Jotham Johnson; SCIENTIFIC AMERICAN, May]. These tablets, found in a private house, prove that even ordinary citizens were literate in the Mycenaean Age.

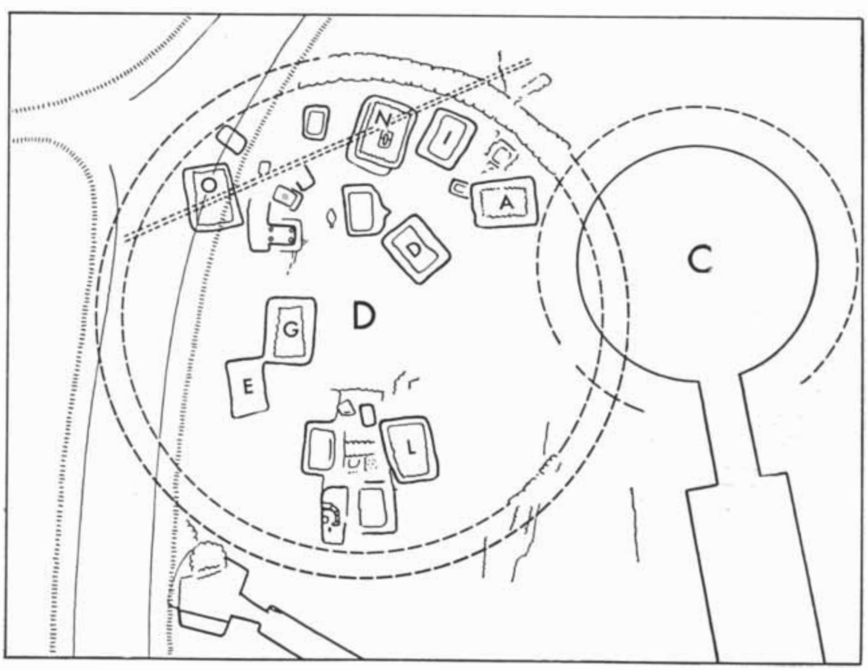
The second house, of which only two rooms have been excavated so far, has yielded a unique treasure of carved ivories of exquisite workmanship and detail. The ivories were probably used as inlays for furniture and caskets in a manner described fully in the Homeric poems. Many of them are in the shape of the characteristic figure-of-eight Mycenaean shield; hence the house has been named the "House of the Shields." Other ivories are in the form of lions, and one represents the helmeted head of a Mycenaean warrior. A series of fine stone vases also were found in the rooms.

The basement of the third house, also destroyed by fire, contained an ivory plaque bearing the representation of two sphinxes of excellent craftsmanship; this will be known as the "House of the Sphinxes." Vases in the house were marked with seal impressions from a signet ring with a design of a man standing between two wild goats. On the back of the impressions a few signs of Linear Script B are inscribed, again proving the use of the script for common purposes.

All three of these houses must have belonged to wealthy citizens. The existence of large and rich houses beyond the citadel walls proves that in the 13th century B.C. Mycenae enjoyed peace and prosperity. Since the citadel was



CITADEL of Mycenae (*heavy line at the upper right*) and its surroundings are mapped. At A is the Lion Gate. At B is the grave circle discovered by Schliemann. At C is the so-called "Tomb of Clytemnestra." At D is the new grave circle (*see map below*). At E is the "House of the Shields," the "House of the Oil Merchant" and the "House of the Sphinxes." At F is the "House of the Wine Merchant." At G is the site of the palace within the citadel. At H is the so-called "Treasury of Atreus." The modern road (*left*) runs almost due North.



NEW GRAVE CIRCLE (*large D*) and "Tomb of Clytemnestra" (*large C*) are shown in greater detail. The smaller letters label the graves discussed by the author. The first grave, discovered in the restoration of the "Tomb of Clytemnestra," is at A. The double dotted line at the top of the grave circle is an aqueduct which delayed the excavation of Grave N.

not burned, Wace has suggested that the houses were destroyed in a civil war, perhaps the feud of Atreus and Thyestes, known to us from the mythology of Greece.

The fourth house apparently belonged to a wine merchant. In its basement were found many wine jars and a drinking horn with a magnificent painted representation of an octopus.

While Wace was engaged in his efforts to bring to light the Lower City of Mycenae, Lady Luck stepped onto the scene. The Greek Service for the Restoration and Preservation of Ancient Monuments was restoring the so-called "Tomb of Clytemnestra," Agamemnon's queen—a tomb which cannot actually be hers because it dates from the second half of the 14th century B.C. After the restoration of the dome it was decided to pour earth over it to show the original appearance of the mound over the tomb. In taking earth from the adjacent area one of the workers found a piece of worked stone, then a second piece and a third. When the three pieces were put together, they formed a tombstone similar to those found by Schliemann in his grave circle. On the stone was a carving of a wild bull being attacked by hunters. It became evident at once that below the stele a grave must be awaiting exploration. The grave and its contents were soon revealed. It was similar to the royal shaft graves explored by Schliemann, and its contents were as rich and varied. Two skeletons were found in it, and a rich assortment of furnishings: some 26 vases, a number of bronze swords and daggers and some gold ornaments decorated in repoussé work and reminiscent of those found by Schliemann.

Needless to say, this accidental discovery created great excitement. Archaeologists the world over wondered whether a new group of graves was about to be exposed. Within the month—November, 1951—the director of the archaeological district, John Papademetriou, and I visited the site and studied the grave. While exploring its immediate area, we noticed three stones which seemed to have been worked, and what was more exciting, they seemed to be set on a curve instead of a straight line. Could we hope that they were part of a circular enclosure similar to Schliemann's grave circle? That question was answered in January, 1952. Though the north wind came down from the top of Mount Elias in icy blasts and snow flurries were in the air, high hopes drove our digging. A week's work was sufficient

GRAVE G proved to be one of the richest excavated within the new grave circle. It contained four skeletons and the gold cup and death mask that are shown on the next page.

to prove that the stones actually formed part of a grave circle.

The new circle is outside the citadel and some 400 yards west of the Lion Gate. Its excavation was entrusted by the Greek Archaeological Society to Papademetriou and a committee of three professors of archaeology: A. Keramopoulos and S. Marinatos, of the University of Athens, and the author, of Washington University in St. Louis. Papademetriou and I began the excavation of the circle on July 3, 1952.

At the beginning the work was dishearteningly fruitless. But early in the morning of July 9 prospects brightened considerably. We found the remains of another tombstone, standing on its original base. The village aqueduct had to be diverted before we could dig under this stele, but we moved on meanwhile to another point with high expectations. And then we had our first grave. It was dug into solid rock; a pit 8½ feet long and 6⅔ feet wide had been cut in the rock and filled with earth and broken stone.

The fill had to be removed carefully, two to four inches at a time, and thoroughly sifted for its contents. As the successive layers were slowly stripped away, one thought kept gnawing at us: Would the grave prove to be intact or had it been plundered long ago? So many, many times long and strenuous

Gold rosette from Grave O

Death mask from Grave G

Sword from Grave D has a hilt of gold

Reconstructed vase from Grave N

Gold cup from Grave G

work is rewarded with an empty grave! Then our fears turned to joy. The tops of vases, still standing undisturbed, began to appear, and finally human bones. When the floor of the grave had been cleared, we looked at a sight which archaeologists had hoped to see since the days of Schliemann.

The grave contained a single skeleton, stretched on its back and laid on a layer of pebbles. Vases had been placed at the head and the feet. One arm bone was still encircled with a gold band; a gold belt girdled the pelvic area, and near the right elbow lay a triangular bronze dagger.

We were to find richer graves than this, but nothing matched the thrill of the first one. Excitement reached its zenith when the King and Queen of Greece visited the excavations and helped remove some of the vases from the grave.

The second grave discovered in the circle was larger (more than 12 by 9 feet) and more elaborate. It contained four skeletons and a rich assortment of gifts. Among them were two gold cups, a death mask made of an alloy of gold and silver, a good number of bronze swords and daggers and many vases beautifully decorated in brilliant colors. The excavation also yielded information on how these shaft graves were roofed. It seems that after the shaft was dug narrow walls of stone were built to a height of about three feet above the floor, wooden beams were laid across these walls, small stone slabs were placed on the beams and the slabs were covered with a layer of clay to make the roof watertight. Then earth was dumped on this to fill up the remaining six feet of the shaft, and it was capped at ground level with a small mound. A funeral feast was held over the spot, and the bones of the animals consumed were left in the mound. (Such a funeral feast is described in detail in Homer's account of the burial of Patroclus in the *Iliad.*) Finally a tombstone was erected on top of the mound.

By the end of September, 1952, we had unearthed seven shaft graves and still had covered only a third of the grave circle. During the summer of 1953 eight additional large shaft graves were explored. Interest steadily grew as the work proceeded. Even the earth that filled the shafts proved exciting, because it was studded with broken pottery of exceptional artistic merit. Each grave had its own contribution to make, its treasures to add to our collection. For instance, Grave E (the graves are all identified by letters) yielded a number of bronze vessels and a stunning surprise. As we lifted two fallen roof slabs we were confronted with a spectacle never to be forgotten: a mass of gold ornaments arrayed in a pattern that shone forth brilliantly under the rays of the sun. Grave D produced, among other things, a sword which is a truly royal weapon: its bronze blade, over three feet long, is engraved with griffins; its hilt is of gold, decorated with quadruple spirals and the heads of bulls and

Two gold diadems are from Grave O

Bowl of rock crystal from Grave O has the shape of a duck

lions, and its pommel is of ivory. Grave I also yielded a bronze sword with an ivory pommel, and in addition a dagger with a handle of rock crystal, gold ornaments and jars and goblets of clay and silver—presumably filled originally with food for the trip of the deceased to the lower world. We know that at least one of them contained oil, because when our vase mender heated the broken pieces of clay to join them together, the odor of oil filled the repair shop.

Grave N, the grave by the village aqueduct, yielded a quantity of vases, 14 of which were found on its roof. The grave held the skeleton of a warrior, and beside it two large swords with ivory pommels, a bowl of bronze and two bronze daggers. The bones of another skeleton were found brushed aside with its belongings to make room for the last burial. Among these belongings were a bronze sword with ivory pommel, two daggers, a spearhead, a gold cup and numerous gold bands decorated in repoussé. The spearhead and the daggers were enveloped in cloth; this piece of cloth, dating from the closing years of the 17th century B.C., is the oldest surviving from the ancient Greek world.

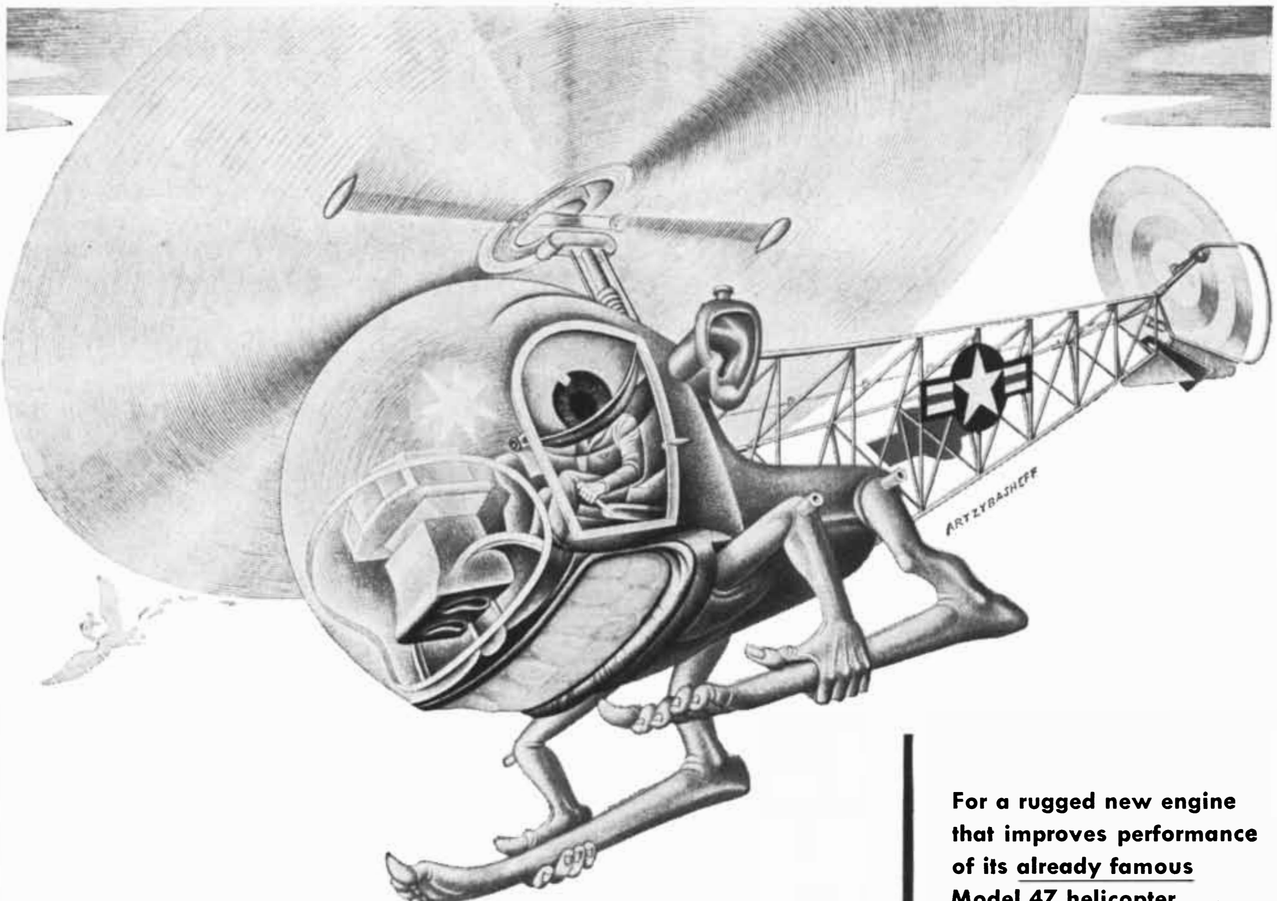
Grave L, one of the largest discovered (over 13 feet long), stirred great expectations. Its fill was crammed with a multitude of fine vases. When the first roof slabs on one side were lifted, they revealed a mass of piled bones, beautifully decorated bands of gold and the remains of a bronze dagger. But the rest of the grave floor yielded nothing but a few crushed bones. We soon determined that the grave had been robbed, perhaps in the 16th century B.C., before the collapse of its roof. We even uncovered the very hole in the wall of the grave through which the robbers had made their entry. Under a small pile of stones and earth that had fallen from the hole we found a sword and a number of knives and daggers.

Mycenae does not allow disappointments to last for long—certainly its new grave circle does not. We had scarcely swallowed this disappointment when we came upon one of the richest graves. It belonged to a princess. Still lying on the skeleton's chest were a long gold necklace and another of amber. Two gold bands were around the brows. There was a beautiful rosette of pure gold which apparently had been pinned on the shoulder. But the most exciting find was a bowl of rock crystal in the form of a duck. Its delicate design, amazing workmanship and size (more than five inches in the longest dimension) make it a unique find of the Mycenaean world.

The objects found in the new shaft graves of Mycenae make a priceless collection, but they form only a part of the vast amount of information that these excavations will yield when the collection has been analyzed and interpreted. We have learned from the skeletons that the Mycenaeans buried in these graves averaged about 5 feet 9 inches in height—tall for a Mediterranean people. We even know what they looked like, for in a small circular amethyst gem found in one of the graves an artist had engraved a portrait of a Mycenaean warrior. How he could have made this tiny engraving in a stone only half an inch in diameter, without a magnifying glass or any diamond tool, is a mystery.

The graves in the newly discovered circle evidently belong to the ruling families of Mycenae. Their names we shall never know, for they were buried at least four centuries before the time of which Homer sang. Yet some facts are clear. The new finds prove that these people were not Cretans but Greeks in the historic sense, that they were mighty warriors and that they ruled over a civilization whose richness casts a fresh light on the world of the Bronze Age.

PORTRAIT of a bearded Mycenaean warrior was found in Grave T. It is skillfully engraved on a half-inch disk of gem amethyst.



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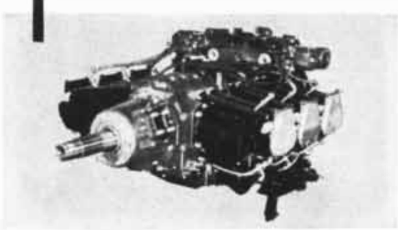

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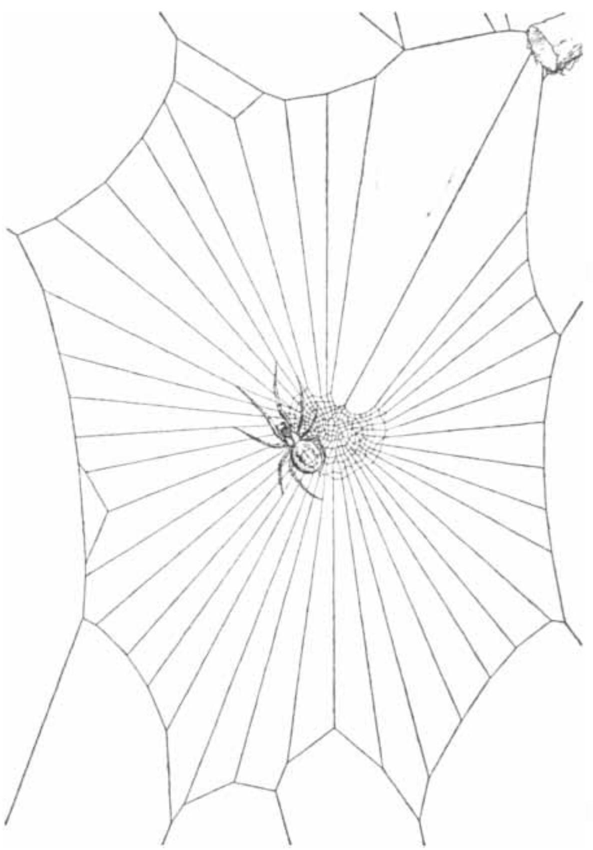
Spider Webs and Drugs

The regularity of the delicate structures made by spiders is one of the wonders of nature. Now abnormalities in these patterns are used to study the mechanism by which drugs produce their effects

by Peter Witt

The members of the zoology department were dead tired. For days they had been trying to make a motion picture film of a spider building its web. Night after night they had waited up in the laboratory to catch their subject in its intricate construction job, but the perverse little creature had refused to perform for their cameras. Each morning they had fallen asleep with exhaustion, only to find on awakening an hour or two later that the spider had spun a beautiful web during their sleep.

In desperation a delegation of the zoologists finally came to my pharmacology department (we were all colleagues at the ancient University of Tübingen in Germany). Could I supply them with a drug which would stimulate the dilatory spider to spin its web when they wanted it to? As it happened, the zoologists found me in a mood of despair that matched their own. I had been experimenting with various drugs to try to find out whether they differed in their effects on human beings. My test drugs (marihuana, mescaline, morphine, scopolamine, Benzedrine) had evoked wonderful responses in my subjects—fantastic dreams, weird visions in color, laughter, tears and all sorts of emotions. But the experiments had failed to yield any answer to my question about specific differences among the drugs.



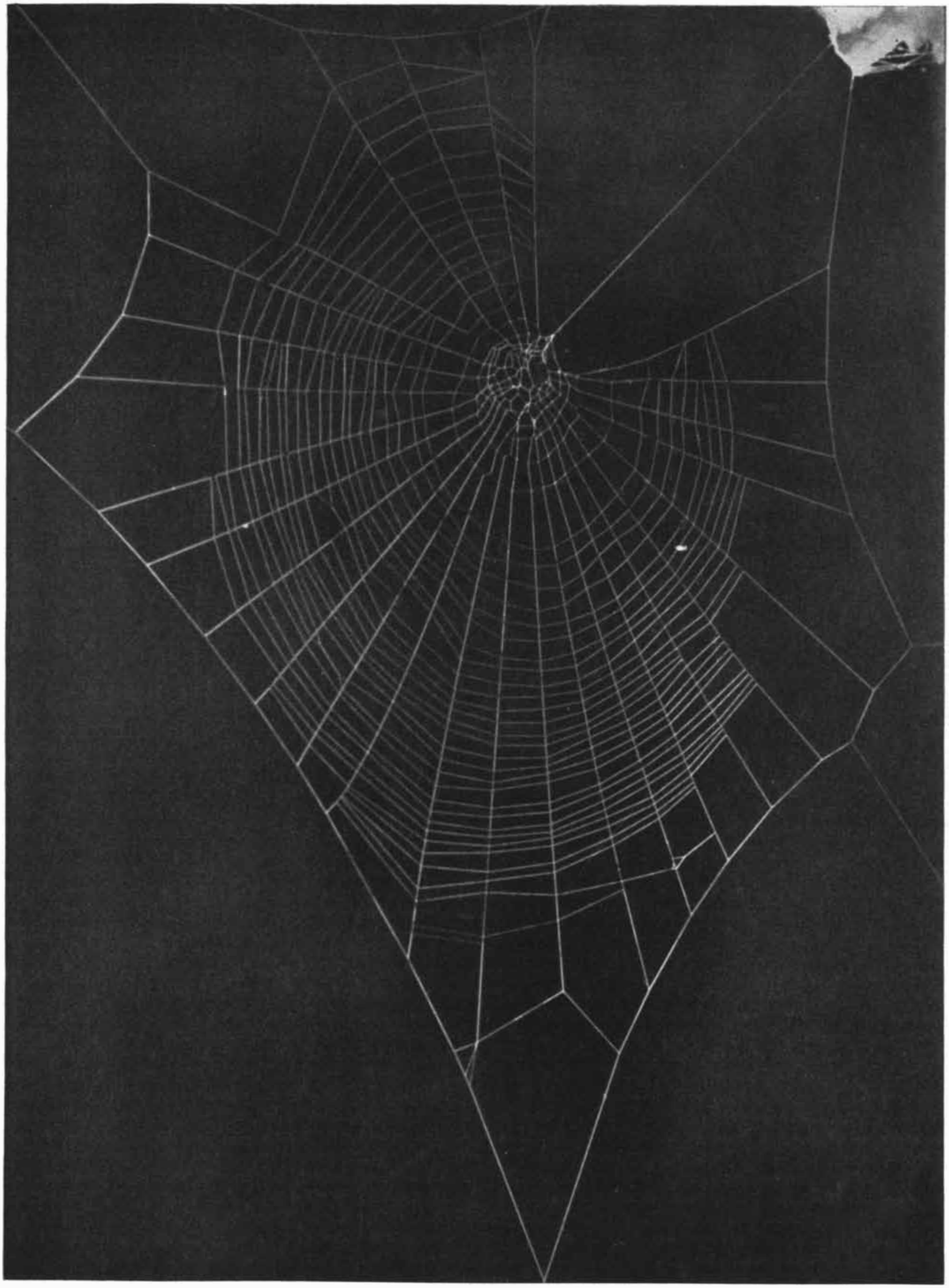
SPIDER *Zilla x-notata* makes a small platform in the center of its web before spinning the main spiral from the outside in.

Naturally I pointed out to the zoologists that I had not the slightest idea how the drugs would affect spiders. Nevertheless I gave them samples of several drugs to try. The next morning my zoology friends returned with news which, though rather disappointing to them, was highly exciting to me: The drug they had administered to the spider had not accelerated its performance, but it had caused the animal to spin a web of a strange shape never seen before.

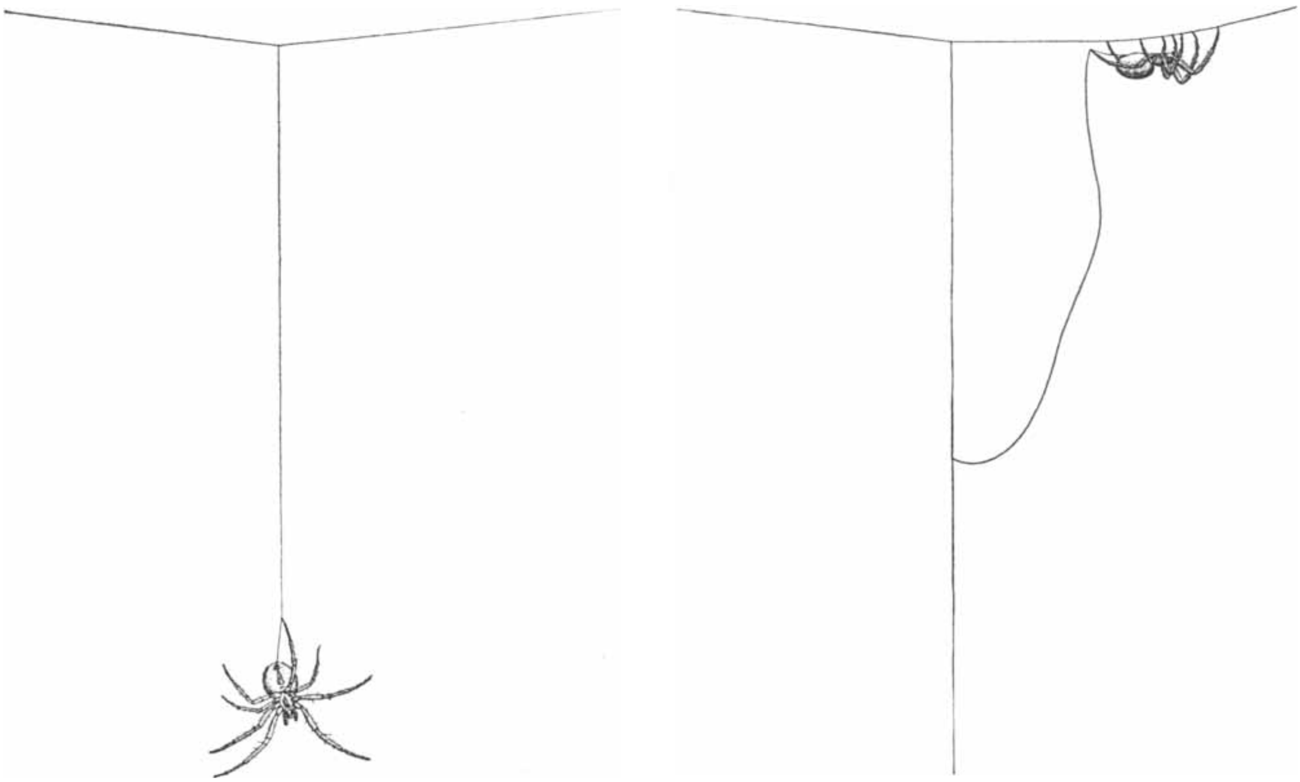
I at once decided to transfer my experiments from human beings to spiders. Human subjects are moody, complicated, variable and apt to carry over memories from one experiment to the next. Spiders promised to be much simpler subjects for testing the effects of drugs on the central nervous system. Furthermore, they might yield information which could be put to practical use. If spiders responded differently to different drugs, they would afford an easy test for identifying a small amount of an unknown drug—for instance, in cases of accidental or deliberate poisoning.

Fortunately Professor Hans M. Peters and his colleagues in the zoology department had given much study to the web-building of spiders, including the webs' geometric shapes, and we joined efforts in what was to prove a fruitful collaboration.

To begin at the beginning, let us see why and how a spider builds its web. The spider we selected for our experiments is *Zilla x-notata*, which spins an orb web. To a spider the sense of touch is what the sense of sight is to man—its most important means of livelihood. Its web, of course, is its tool for catching food. The Zilla spider sits just off a corner of this structure with two forelegs resting on a "signal" thread running from the outer edge to the center of the web. The whole web can be looked upon as a projection of its legs, waiting



ABNORMAL WEB is spun by a spider under the influence of a sleep-inducing drug. The abnormality consists in the omission of the longest threads. Here the web has been made visible by exposing it to ammonium chloride, which condenses on the threads.



WEB IS BEGUN by Zilla. The spider spins a horizontal thread, returns to its middle and spins a vertical thread (*first drawing*). The spider then fastens a third thread at the middle of the vertical one and climbs back to the first thread (*second drawing*). It

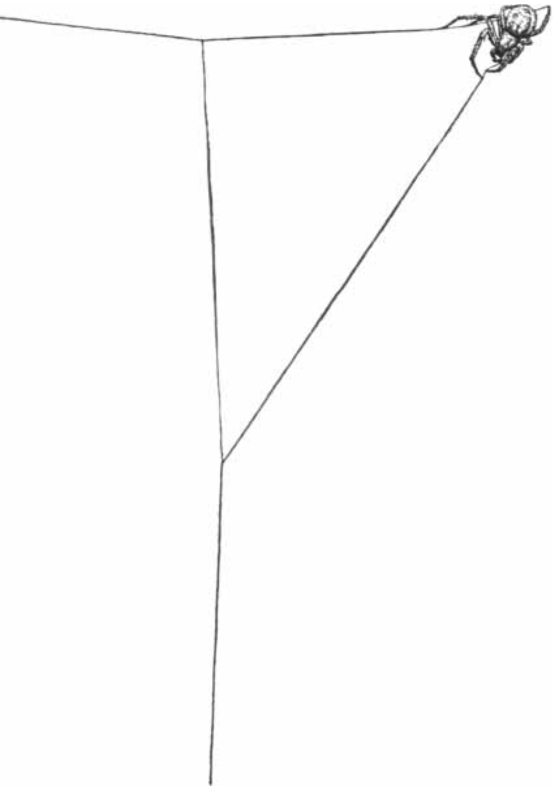
tensely to communicate any vibration to the spider. The moment a fly's vibrating wings touch the threads of the web, the spider pounces on it, paralyzes it with its poisonous bite and binds it with a sticky thread. Then it proceeds at leisure to suck the juices from its prey.

That touch rather than sight guides the spider was proved by an English amateur scientist who discovered that a tuning fork vibrating with the same frequency as a fly's wings also provokes the spider's assault; so will a vibrating dummy of a fly. On the other hand, if the signal thread is cut so that the spider cannot feel vibrations of the web, it will pay no attention to a fly crossing the web directly in front of it.

If its web is destroyed day after day, the spider will build a new web every day. Normally it spins each web in the same way and in the same pattern. It usually chooses a window or some other frame as the support. First it attaches an end of thread, which it secretes from its thread-forming gland, to one point on the frame; then it may move horizontally along the frame, paying out more thread and dragging it behind, until it has reached a second point a suitable distance from the first. There it pulls the thread tight and fastens the end at the second point. Now it moves back along this "bridge" and spins a new thread perpendicularly from the middle of it, forming a T. Dangling by this thread, the spider steadily extends it by spinning more length until it reaches a fastening point. This completes the first stage of the web construction. The first stage may take any of several other forms, depending on the shape and nature of the site. But the following stages are always the same. The spider proceeds to spin radial spokes from the center to the outer framework of its web. If it has started with the T described above, it climbs back up the vertical member and along the arm of the T to its starting point, all the time letting out new thread. There it pulls the new thread tight across the diagonal of the triangle [*see drawings above*]. This forms a radial member of its web. In like manner the spider goes on spinning new bridges and radii until it has completed a peripheral frame connected to the center by many radial threads. The angle between these radii is remarkably uniform; most of the spacings do not vary by more than one or two degrees. However, the Zilla spider leaves extra space around one spoke which will serve as the signal thread [*see diagram on page 80*].

Now the spider proceeds to build the cross members that connect the spokes. It does this by spinning a thread which starts near the outer frame and spirals in toward the center (after it has first laid a temporary thread across the spokes to hold them in position while it moves over them). For this so-called "catching spiral" the spider spins an especially delicate thread covered with a thin layer of sticky fluid. Zilla draws the spiral thread from spoke to spoke around the web until it reaches the one next to the signal thread; then it turns and goes back the other way, thus leaving a free sector around the signal thread. As it fills in its web, the spider measures the distance from thread to thread with its legs and probes the tension of the lines to make sure there will be no loopholes through which a fly may escape.

There are some mystifying features about the spider's construction of its spiral. For instance, one would suppose that for the sake of efficiency the animal would begin by spacing the turns of the spiral close together near the periphery, where the radii are far apart, and would



then fastens the third thread diagonally between the first and second (*third drawing*).

widen the interval between the turns as it moved toward the center. But the spider does exactly the opposite: it narrows the spaces between the spiral turns as it approaches the center. Possibly the reason for this strange behavior is a disposition to minimize the distance it must climb from spoke to spoke; however, there seem to be a great many factors involved in the spider's construction of its spiral, and we have only begun to find them out. As will be seen, it is mainly in the spinning of the spiral that spiders show the effects of drugs.

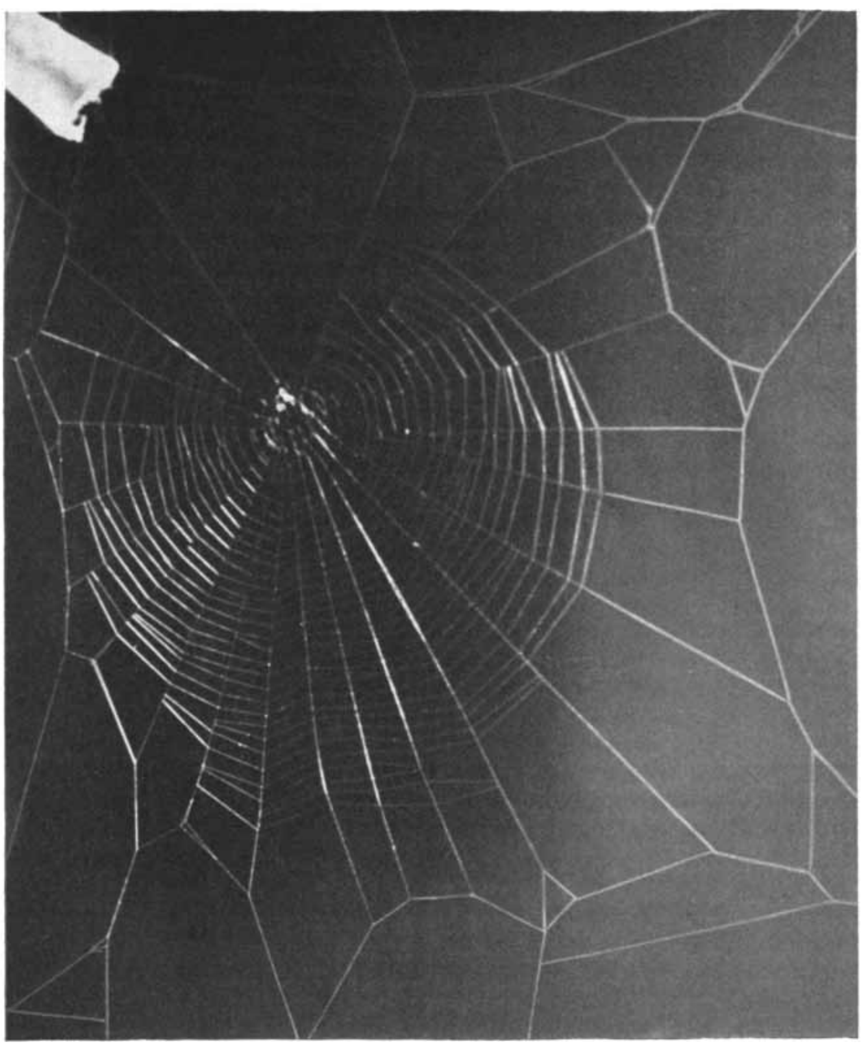
We know that every species of spider makes its own kind of web, and that it builds its characteristic kind by instinct; when a baby spider spins its first web, even if it has never seen a web before it makes one just like its forebears', except on a smaller scale. The drive to build a web is in direct proportion to the spider's hunger. A hungry spider will spend enormous amounts of energy building webs day after day. In our experiments we keep the animals on a diet which is sufficient to keep them healthy and reasonably satisfied with their captivity but is spare enough to make them build a web every night. We use female spiders, because males, being only half the size of females and requiring less food, build webs much less often.

We chose Zilla as the test animal partly because this spider lives outside its web. It will adopt a paper bag as its home and thus is easy to keep captive. To capture a Zilla spider I bait it out of its hiding place in the garden or a window by touching its web with a tuning fork. While it is attacking the fork, I lay a paper bag on the signal thread. When the disappointed spider returns from its fruitless sally, it enters my paper bag without even noticing that its house has been changed. I can fasten the bag to the corner of a portable wooden frame, and thereafter the spider will build web after web on the frame, always returning to the bag as its home. A large array of such frames hangs in front of the enormous window of my laboratory. Each contains a spider.

A spider's web, needless to say, is no easy thing to study. The threads are so thin and delicate that they can hardly be seen, and they break at the slightest touch of a clumsy human finger. Nor will a web keep for any length of time. Because the gossamer threads are difficult to photograph, even with the best modern camera, H. Homann in Germany conceived the excellent idea of thickening the threads by dusting them with a material that does not bother spiders. A glass bowl filled with a solution of ammonia gas in water and another bowl with a solution of hydrochloric acid are placed under the web. The rising vapors from the bowls combine in the air to form fine crystals of ammonium chloride. In 20 minutes the crystals have covered all the threads with a fine white layer, so light that it does not make the delicate filaments sag but thick enough to make every thread stand out clearly when the white-coated web is photographed against a black background with light from the side.

It is important to see every part of the web, for the changes induced by the drug experiments are subtle. The delicate pattern of the finished web is the result of a precise and complicated pattern of movements by the spider. When a spider's central nervous system is drugged, it departs from this pattern, as a man intoxicated by alcohol weaves an erratic course down the street. The spider's errant movements leave their telltale tracks in a distorted web. And we were delighted to discover that each drug always produced its own distinctive aberrations in the spider.

To administer drugs to spiders without alarming them took a little doing. After many experiments, one of our medical students, Dieter Wolff, found a convenient way. A fluid containing the drug, sweetened with sugar to conceal the drug's taste, is injected into the hind part of a fly, where the spider is accustomed to tap the juices. The fly is cut in half, but the spider is lured to it by a tuning fork simulating the vibrations of its wings. Spiders apparently find the taste of the sugar delicious, for they have taken every drug offered in this way.



MARIHUANA produces this effect in the web of Zilla. There is a relatively large space between the framework of threads around web and the peripheral turn of the spiral.

When we began to test the effects of drugs, one of the first things we noticed was that a spider made drowsy by a sleeping drug would skip the spinning of the longest and most difficult radial threads—those to the corners of the frame. This left conspicuous gaps in its web [*see photograph on page 81*].

Of the many other effects, most of which we cannot yet even begin to interpret, I shall mention three which seem especially significant. Benzedrine causes the Zilla spider to spin a spiral which has the usual over-all shape but tends to zigzag like an unsteady walker [*see photograph on page 86*]. We strongly suspect that under the influence of Benzedrine the spider loses its ability to locate precisely the points at which it should fix its spiral. Marihuana, in contrast, produces no disturbance of the sense of direction, but it does cause the spider to omit the first part of the spiral: the animal starts closer to the center and leaves the outer part of the web uncovered by cross members [*see photograph at left*]. This effect is peculiar to marihuana—it is always produced by that drug, and only by that drug, as far as I know.

The third drug of special interest is scopolamine, which in human beings produces hallucinations and strange disorientations. Scopolamine destroys a spider's sense of direction almost com-

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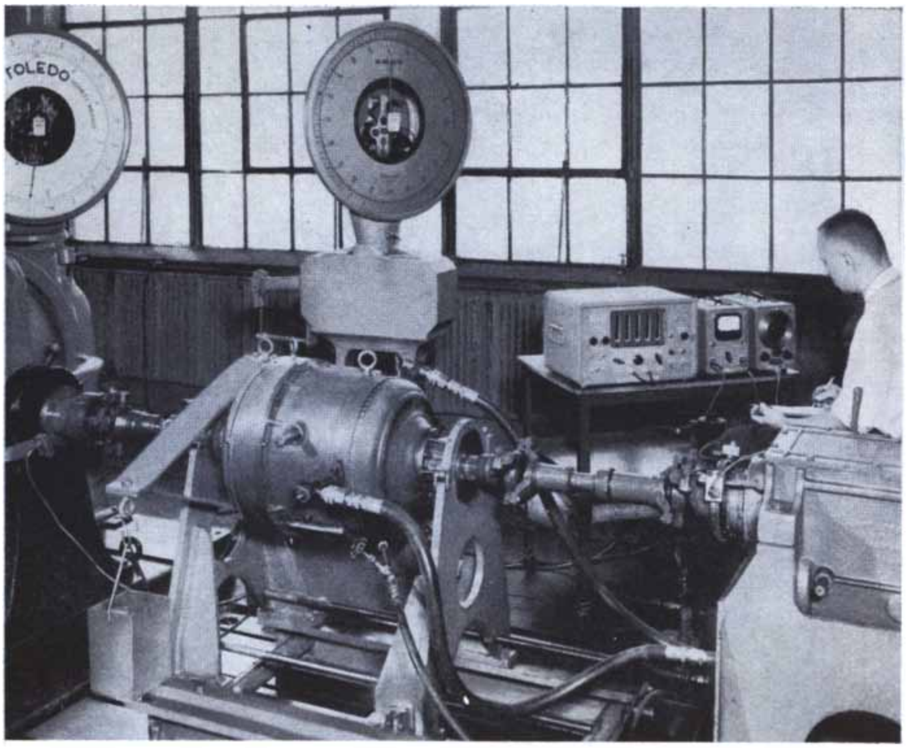

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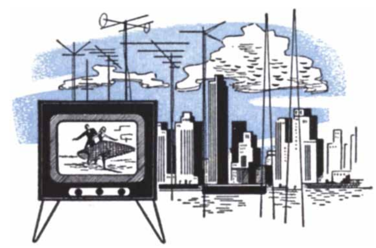

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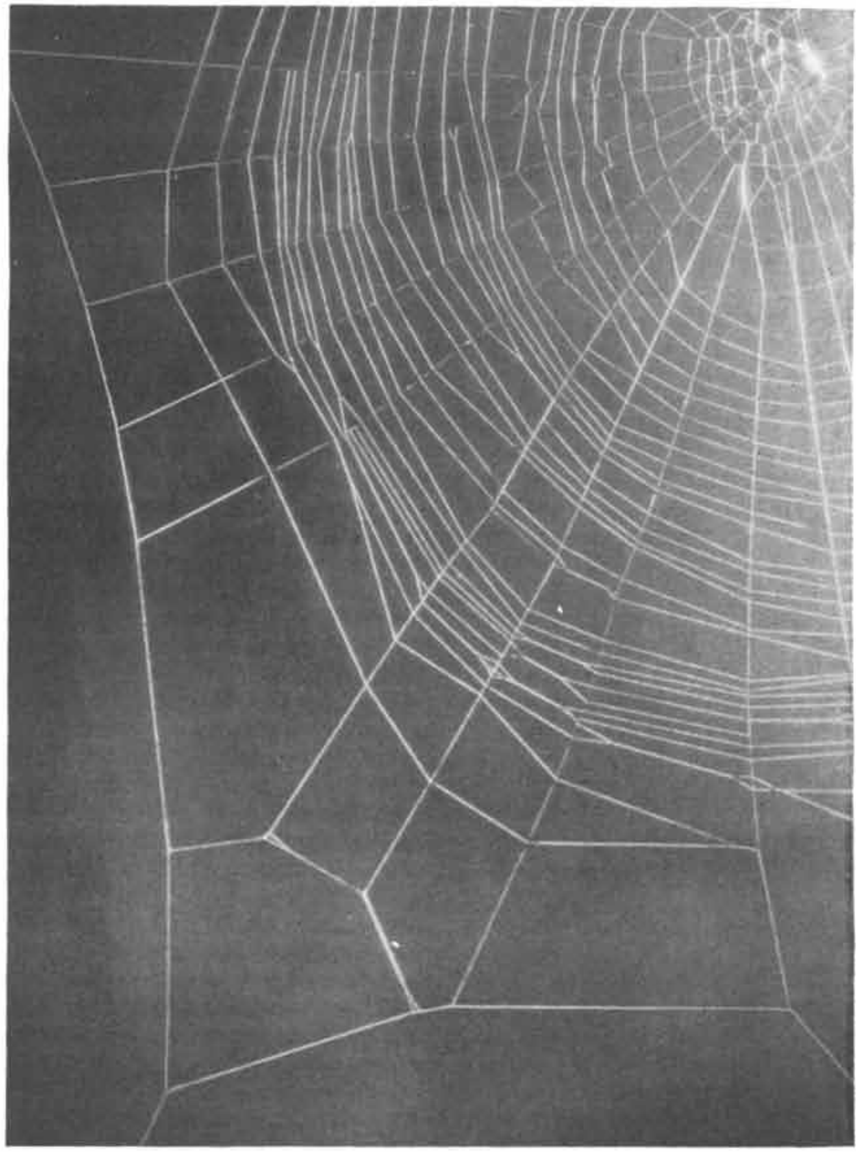

BENZEDRINE produced another effect, shown in a section of the web. The spiral is erratic. When scopolamine is administered, the spiral runs smoothly but in false directions.

pletely. Its spiral no longer takes regular turns around the center but may go off in false directions.

How far can the effects on spiders be compared to effects of the same substances on human beings? This question will never be answered fully, as we cannot interview a spider to find out what it feels and experiences. We can only compare superficially some of the known facts. It is likely that a general disturbance of the functions of the brain shows its effect in distortion of the sensitivity of touch in the spider, as it distorts vision in man. The strange and colorful visual hallucinations that a man experiences under mescaline may take the shape of haptic (touch) hallucinations in the spider. Yet the general course of an intoxication may be alike in both; for instance, the effect may come and go in waves. This is the way scopolamine affects man, and such a rhythm may be responsible for the fact that a spider under the same influence periodically loses and regains the correct direction in building a spiral. But these are mere speculations.

Why should we work with that strange animal, the spider, instead of some familiar higher animal more like man? The answer is that we cannot interview higher animals about their experiences any more than we can spiders, but the little spider gives us every day in its web an objective and measurable report on the state of its health and its nerves. When we have learned how to interpret it, we shall be able to read a most interesting story in that precise and complicated structure.

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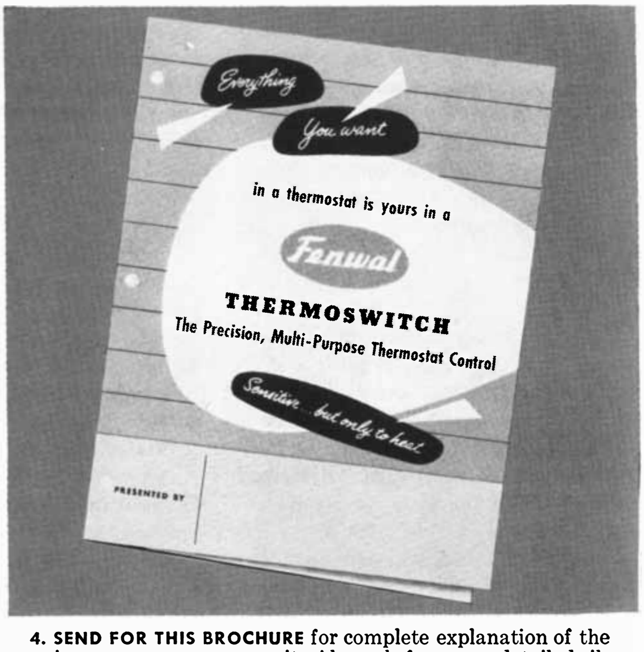

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THE ULTIMATE ATOM

When a positive electron is emitted by a radioactive nucleus, it may briefly join with a negative electron to form "positronium." This simple system confirms the logic of quantum electrodynamics

by H. C. Corben and S. DeBenedetti

"Elementary" is a delightfully ambiguous word. It can mean that which is easily understood ("Elementary, my dear Watson") or that which is so fundamental that it is not understood at all. It is in the latter sense that sub-atomic particles are called elementary. What is elementary depends on the century in which the word is used. Thus it was applied to earth, air, fire and water as "elements," then to the elements of the periodic table, then to the protons, neutrons and electrons of which these elements are composed. At the present moment the word elementary is used to describe not only protons, neutrons and electrons but also positrons, photons, neutrinos, mesons and a host of other recently discovered particles.

When we look at this complex array of elementary particles and try to understand how they fit together to form our universe, we find them anything but elementary in the Sherlock Holmes sense. One fact that prevents us from giving up the jigsaw puzzle, however, is that three pieces of it fit together very well indeed. Electrons (particles with negative charge), positrons (identical with electrons except that the charge is positive) and photons (quanta of electromagnetic radiation) can be described very well by the theory of quantum electrodynamics.

For example, this theory predicts that in the visible spectrum of the hydrogen atom there should be a frequency difference of a certain value between two neighboring lines. It has been found experimentally that the actual shift agrees with the theoretical calculation to within less than one megacycle per second. This, in a sense, is an accuracy of one part in a billion, for the frequency of visible light is roughly a billion megacycles per second. Thus we can see that the theory of quantum electrodynamics is one of the most accurate descriptions yet devised of any portion of man's sense-experience.

Plainly it would be nice to be able to apply this precise tool to a simple atom involving only electrons, positrons and photons—a system uncomplicated by the presence of protons, neutrons and other poorly understood particles that make up ordinary atoms. This dream of atomic physicists has, in fact, come true. In the rapid chain of events that follows the release of a positron by a radioactive atom, there has been discovered a fleeting system which consists only of a positron and an electron. They revolve around each other to form an electrically neutral atom, held together by the electrostatic attraction between their opposite charges. This short-lived atom has been named positronium. Electrically it is like what used to be the lightest atom—hydrogen—but a positron takes the place of the proton. Since a positron is no heavier than an electron, the positronium atom weighs only about one thousandth as much as the hydrogen atom. On the scale of atomic weights the nearest integer to describe the weight of positronium is zero.

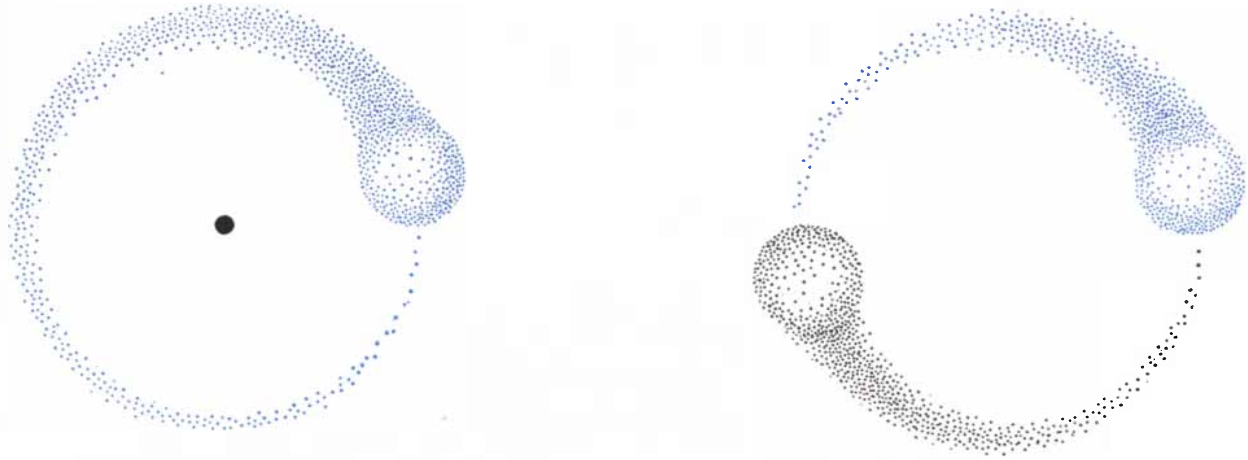
In positronium both the electron and the positron move around their common center of mass. Consequently the average distance between the two particles is twice that in the hydrogen atom, where the electron circles a relatively stationary proton. This means that the wavelength of a line in the positronium spectrum should be almost exactly twice that of the corresponding line from atomic hydrogen.

It will be a long while before such radiation is observed, however, for it is possible to make positronium only in incredibly small amounts. A positronium atom never lives as long as a millionth of a second; indeed, most of these atoms have a life of less than a billionth of a second. A brief instant after positronium is formed, the electron and positron annihilate each other and the atom disappears. The mass of the two particles is converted into electromagnetic energy, two or three photons emerging from the position where the atom was located.

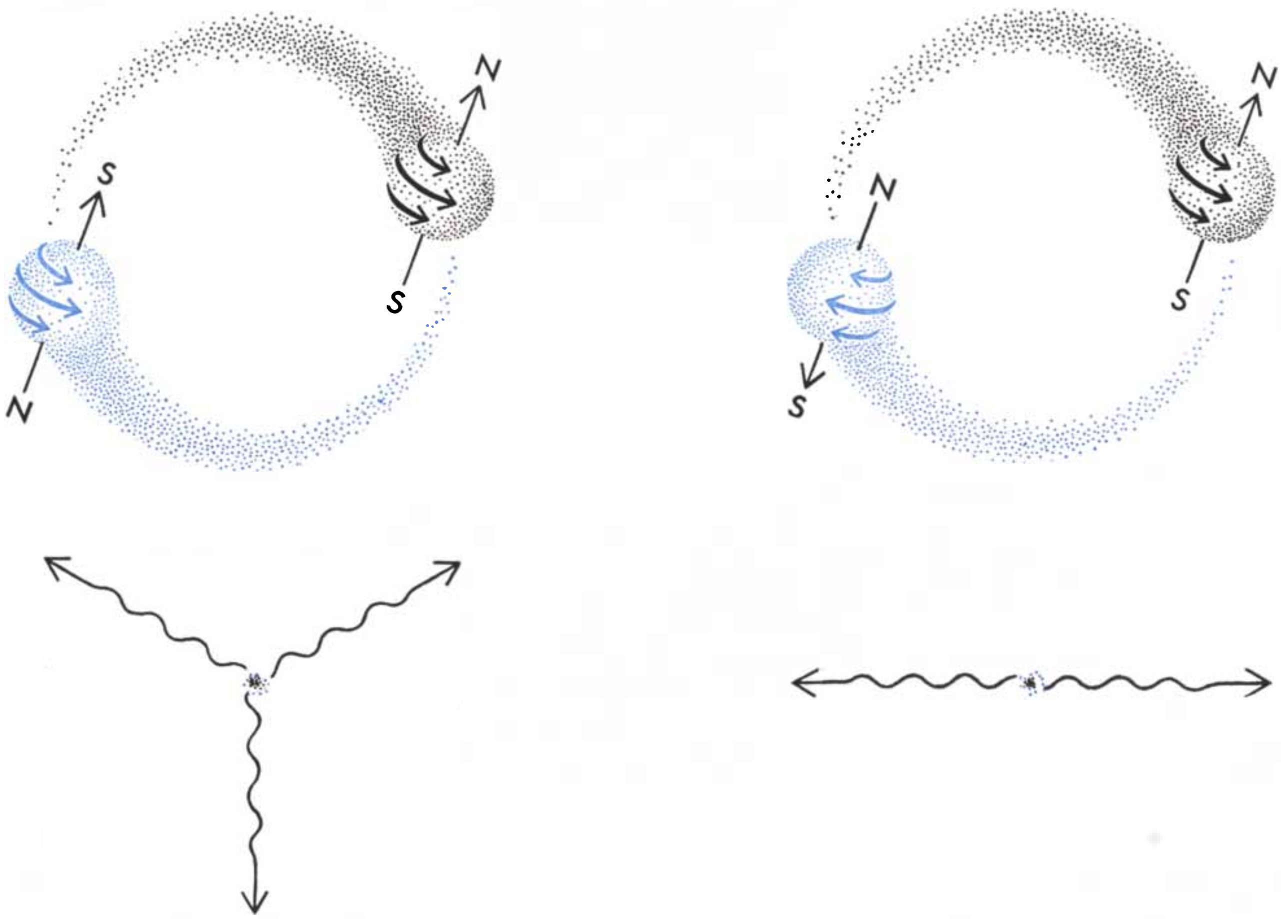
That at least two photons must be emitted is easy to see from the principle of conservation of momentum. Just as, when a gun is fired, something has to take the recoil of the bullet, so when positronium is annihilated, something has to take the recoil of any photon that is radiated. Another photon, emitted in the opposite direction with the same energy, satisfies this requirement. As we shall see, positronium sometimes prefers to emit three photons, dividing the energy among them. In principle it could also blow up into four, five or even more photons, but the chance of this occurring is always very small and at present it is not possible to observe it.

In any case, the sum of the energies of the photons that come out has to be equal to the energy derived from the masses of the destroyed electron and positron ($E=Mc^2$). The energy amounts to about a million electron volts, so that if two photons are emitted, each has about half a million electron volts of energy. They have the energy of, and actually are, gamma rays, like those emitted from excited atomic nuclei.

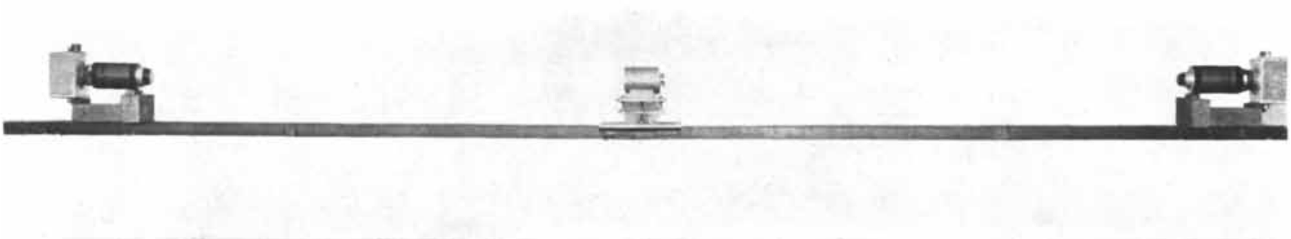
To observe these products of the phenomenon we may simply put a substance emitting positrons in a container and place two gamma-ray counters symmetrically on opposite sides of the container [*see illustration on page 90*]. The counters are connected to a coincidence circuit which gives a signal (a click and a flicker of light) when and



ATOMS of hydrogen and positronium are compared in these schematic drawings. In the hydrogen atom (*left*) a negatively charged electron moves about a positively charged proton 1836 times heavier. In the positronium atom (*right*) a negatively charged electron and a positively charged electron, or positron, move about each other. This atom lives for less than a millionth of a second.



TWO VARIETIES of positronium are ortho-positronium (*left*) and para-positronium. In the ortho form the directions of spin of the electron and the positron are parallel, while the magnetic poles are opposite. In the para form the directions of spin are opposite, while the magnetic poles are parallel. Ortho-positronium disintegrates into three photons. Para-positronium disintegrates into two.



ANNIHILATION of para-positronium is detected by two scintillation counters (*left and right*). The positronium is made by a bit of positron-emitting sodium 22 (*center*). The counter circuit is designed so that it registers an event only when photons pass through both counters at once. Since para-positronium decays into two photons and ortho-positronium into three, only the former is detected.

only when each counter is being traversed by a gamma ray at the same time. This happens whenever a positronium atom breaks up and emits two photons in the direction of the counters.

What we are witnessing is not the formation of positronium but the annihilation of a positron and an electron. A positron from the radioactive source meets an electron in the wall of the container; the partners dance around each other for something like a tenth of a billionth of a second, and then they destroy each other. Each such event, provided it takes place precisely on the line between the counters, produces a click and a flicker in the apparatus. The experiment is unambiguous, easy to perform and impressive to watch. Lights flicker and counters click as if in a Hollywood movie of a nuclear laboratory.

This experiment is known as two-quantum annihilation. The emission of three photons can be detected with another apparatus using three counters, all placed in the same plane as the positron source and all connected to a coincidence circuit so that a light flickers only when the three counters are tripped simultaneously.

Why should positrons sometimes be converted into two photons and sometimes (much more rarely) into three? A natural guess is that there are two varieties of positronium. If that is so, the theory of quantum electrodynamics predicts that the two-photon variety should have an average lifetime of 1.25×10^{-10} seconds, and the three-photon kind, a lifetime of 1.4×10^{-7} seconds.

By our clocks these times are quite short, but the longer of them (of the order of a millionth of a second) can be measured rather accurately with modern electronic equipment. It was indeed by the detection of the positrons' mean life of 1.4×10^{-7} seconds that Martin Deutsch, of the Massachusetts Institute of Technology, discovered positronium. It is a curious fact that this atom was discovered, and can be studied at all, only through the evidence of its death.

Deutsch's experiment consisted in measuring the time elapsing between the birth of a positron, which gives a signal when emitted by a radioactive source, and its annihilation. What gave proof of positronium's existence was the fact that positrons sometimes survived for a certain characteristic mean lifetime, which agreed with the time that theory predicted they should live if they paired with electrons to form a neutral atom. The same considerations have made it possible to study some of the chemical properties of this atom despite the fact that it annihilates itself less than a microsecond after it is formed.

This is a truly remarkable achievement if one considers how extremely small are the quantities available for study. Suppose that the radioactive source used is emitting one million positrons per second; even if all these positrons produce atoms of the longer-lived variety of positronium, their lifetime is so short that 90 per cent of the time there is not a single atom present.

The two varieties of the atom have been named para-positronium (two photons) and ortho-positronium (three photons). To analyze the difference between them we must go back about 30 years to the time when it became apparent that one could say something about electrons beyond the fact that they were small balls of a certain weight and a certain electric charge. It was learned that an electron not only revolves around the nucleus of an atom but also spins on its own axis, like the earth, with a constant angular momentum. Now the same can be said for the positron, which is identical with the electron in all respects except the sign of its charge. This intrinsic spin of the electron and the positron is always one half as large as the unit of angular momentum used in atomic physics. When an electron and a positron pair to form positronium, their spins can be either parallel or antiparallel. If parallel, they will add up to one unit; if antiparallel, they will cancel out to zero.

This explains the two types of positronium. In an atom of ortho-positronium the electron and positron spins are parallel, while in para-positronium the spins are opposed to each other. (To remember which is which, think of the word paradox.)

Now photons also may spin. Their angular momentum is usually one full atomic unit, either plus or minus—that is, in one particular direction or the reverse. Since angular momentum, like energy and ordinary momentum, obeys the law of conservation, we can see that ortho-positronium, with a total spin of one unit, cannot break up into two photons, for the spins of two photons add up either to zero or to two, according to whether they are opposite or parallel. Ortho-positronium therefore undergoes the next most probable process: it breaks up into three photons. On the other hand, para-positronium, with total spin zero, easily converts into two photons.

The life of positronium, though almost too short to be measured with our most refined instruments, is still long from the point of view of time on the atomic scale. According to the Bohr theory of the atom, the electron and positron must make a circuit around each other in about a millionth of a billionth of a second. Thus even in para-positronium there is time for this to happen something like a million times before the atom breaks up. So we have plenty of margin for studying the motions of the particles around each other.

In addition to possessing spin, the electron and the positron, like the earth, possess magnetic moments, *i.e.*, they behave like small magnets, with the axes of the magnets more or less pointing along the axes about which the particles are spinning. In ortho-positronium the north and south poles of the two magnets point in opposite directions, because the opposing charges of the electron and positron have this effect when the particles are spinning the same way [*see drawing at left on page* 89]. The small

Advances in Applied Radiation

DEVELOPMENTS in the FIELD OF APPLIED RADIATION ENERGY, its APPLICATIONS and the APPARATUS USED TO PRODUCE IT

Research in Radiation Crosslinking of Plastics

The past 18 months has seen a remarkable rise in the attention given by industrial scientists to the possible commercial applications of radiation energy. This work was greatly intensified after publication of the work of Charlesby* in changing the characteristics of polyethylene by radiation bombardment. Normally a thermoplastic, polyethylene becomes thermosetting after exposure to high doses of ionizing radiation. Not only is its resistance to many solvents increased, but also its plastic memory and its resistance to stress-cracking. Most dramatic, however, is the ability of irradiated polyethylene to hold its shape at higher than normal temperatures. These changes in physical properties are a consequence of the crosslinking produced by radiation energy, and it is this phenomenon that has created so much interest.

*"*Crosslinking of Polythene in the Atomic Pile,*" *BRITISH PLASTICS, March 1953*

Many other high polymers have been investigated in recent months. Some, such as polyvinyl chloride and methyl methacrylate, degrade in the presence of ionizing energy. Others, such as polystyrene and certain rubbers, appear to crosslink. The silicones in particular look promising because cures can be effected at relatively low dosages and in a very short space of time.

Although some of the work now going on in this field looks toward more immediate applications of radiation-crosslinked polymers, much is of a fundamental nature, directed to learning more about the mechanisms of interaction and to creating polymers and copolymers to take advantage of the unique characteristics of this interaction. Considerable attention is also being given to the use of radiation as a catalyst in the polymerization reaction itself.

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One of the regular users of High Voltage's electron radiation facilities is the U. S. Army Quartermaster Corps. High Voltage is one of the contractors under the QM Food and Container Institute's Radiation Sterilization project. Both Food and Container Institute and the QM's Pioneering Research Laboratories, Natick, Mass. are conducting work in this long-range program of fundamental research into the use of radiation energy as a means of food preservation. High Voltage is proud to be associated with this project, which may prove to be of far-reaching consequences to the military services and to the food industry.

High Voltage's *2-MeV Van de Graaff Model AK research accelerator is well adapted for use in laboratories engaged in diversified studies in physics, chemistry, and metallurgy. This unit produces the following radiations: electrons — 250 microamperes, positive ions — 75 microamperes, x-rays—5000 roentgens/minute at 10 cm., neutrons — up to 5 x 10^8 n/sec-cm^2. Write for Bulletin AK.*

Pondville State Hospital

The newest installation of a two-million-volt Van de Graaff x-ray generator for supervoltage therapy has recently been completed at the Pondville State Hospital, Norfolk, Massachusetts. This is the fourth Van de Graaff for the treatment of cancer to be installed in the New England area. One of these is in use at the Massachusetts General Hospital in Boston, and two are located at the Massachusetts Institute of Technology (Lahey Clinic), Cambridge. A fifth unit will be installed in a few months at the Hospital for Chronic Diseases in Boston.

Complete information on the Van de Graaff for supervoltage therapy is offered in our new 12-page Bulletin M, written to aid the radiologist in evaluating a number of interrelated technical factors involved in the choice of supervoltage equipment—including x-ray quality and output, field size and definition, and equipment and installation costs.

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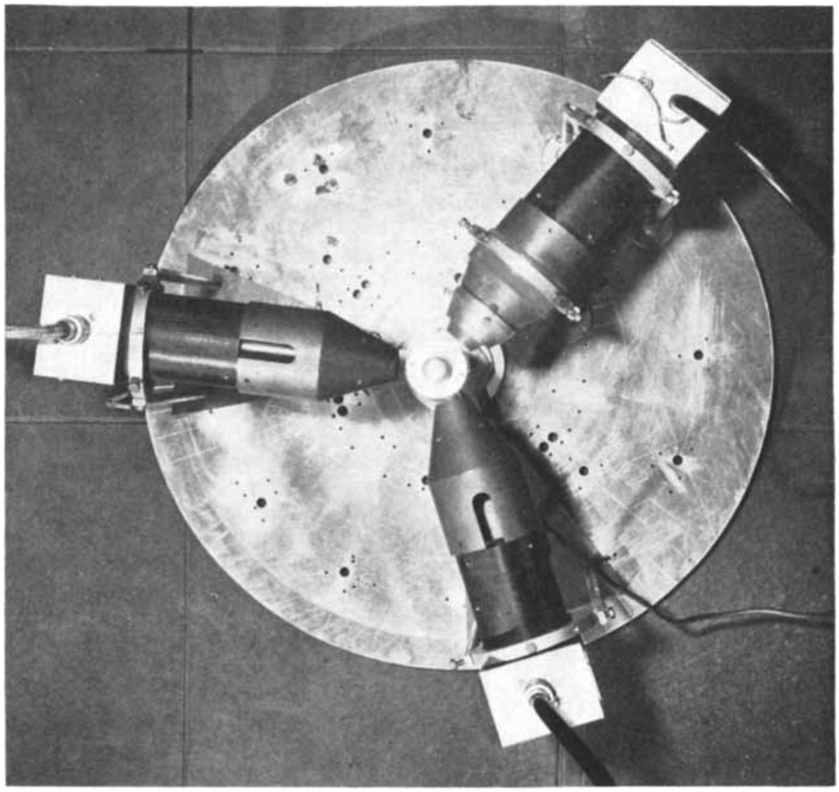

ORTHO-POSITRONIUM is detected in this apparatus. Here three scintillation counters are arranged so that an event is registered only when photons pass through all of them at once.

repulsion between the like poles facing each other makes the system slightly less cohesive than para-positronium, where magnetic attraction reinforces the electrical attraction [*drawing at right*]. The effect of course depends on how the particles are oriented toward each other, but it is found to average out so that the energy of ortho-positronium is slightly greater than that of para-positronium.

In order to compute the energy levels as accurately as possible, we should take into account the fact that the atom has an urge to disintegrate. It is as if every now and then the atom made an abortive attempt to blow up. This is particularly true of ortho-positronium. Its angular momentum of one unit would permit it to be converted into one photon, though that, as we have seen, is forbidden by the recoil requirement. But it seems that the atom tries anyhow, and finding that it does not work, goes back to its original state. Thus about 1 per cent of the time the electric charges in ortho-positronium are not effective—they have been annihilated while the atom tried to become a photon. This effect, which is called the "annihilation force," makes ortho-positronium slightly less bound than it would have been otherwise. On the other hand, para-positronium does not even try to become one photon because its angular momentum is not right. When it tries to become two photons, there is nothing to stop it from succeeding. This is another reason why ortho-positronium is bound less tightly than para-positronium.

Combining these effects, it is possible to show theoretically that the difference between the energies of the two atoms is about a thousandth of a volt. Taking account of certain other minor effects as well, Robert Karplus and Abraham Klein at Harvard University calculated the difference more precisely to be, in terms of frequency, 203,370 megacycles per second. The amazing thing is that Deutsch and his associates at M.I.T., in recent measurements, found the actual difference to be 203,350 ± 50 megacycles per second.

One cannot help but feel that quantum electrodynamics is a very sound theory if it is capable of predicting so accurately this small difference in energy of the two types of positronium. The very theory that does this so well, however, also suggests some completely meaningless conclusions. In particular, it leads to the result that the mass and charge of an electron are infinite! No one has yet figured out how to modify the theory to avoid these infinite answers. When someone learns how to do this, he (or she) may gain at the same time a better understanding of the nature of other "elementary" particles.

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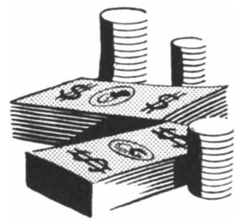

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Robert Hooke

This 17th-century Englishman was a prodigious scientist and inventor. To mention a few of his achievements, he made basic contributions to physics, chemistry, meteorology, geology, biology and astronomy

by E. N. da C. Andrade

The name of Robert Hooke is known to every student of physics and engineering by Hooke's law (mechanical strain is proportional to the stress). This law, with the consequences Hooke deduced from it, certainly is an achievement of the first importance—sufficient to entitle its originator to a sure place in the history of science. But the law that bears his name constitutes only a small part of Hooke's claim to greatness. He made contributions of fundamental value to every branch of science known in his day. Scientists who have studied his work, or aspects of it, have expressed astonished admiration for his versatile genius and the range of his discoveries. However, for a variety of reasons, prominent among which is the fact that no book devoted to his life and doings has ever appeared, his achievements are not as widely known as they should be.

Robert Hooke was born on July 18, 1635, in the village of Freshwater on the Isle of Wight, just off the south coast of England. His father was curate there and lived in a little house which was still standing at the beginning of the present century. Robert was a weakly boy from birth, and all through his life his health varied from indifferent to miserable. Even as a youngster he suffered from severe headaches, almost certainly due to chronic inflammation of his frontal sinuses. From the diaries he kept in his middle age we know that he was plagued with catarrh, with indigestion so troublesome that he gratefully noted any meal that happened to agree with him, with giddiness, with insomnia and with fearful dreams when he slept. In considering the irritability with which he is sometimes reproached, it is well to remember this background of chronic suffering.

Nor was Hooke well favored in looks for making his way in the world. No portrait of him exists, but we know from contemporary descriptions that he was lean, bent and meanly ugly, with a wide, thin mouth and a sharp chin. Samuel Pepys referred to Hooke's unpromising appearance in his diary. After a visit to the Royal Society on February 15, 1665, Pepys wrote: "Above all, Mr Boyle to-day was at the meeting, and above him Mr Hooke, who is the most, and promises the least, of any man in the world that ever I saw."

When Hooke was 13, his father died. Somehow the boy managed to become an apprentice to the famous painter Sir Peter Lely in London. But the odor of the oil paints made his headaches worse, and he soon left to go to school at Westminster, where he won the regard of the famous headmaster, Dr. Busby, who remained his friend for life. Hooke's father had left him 100 pounds, which went far in those days. At the age of 18 he entered Oxford University with a decent knowledge of Latin and Greek and of the elements of geometry. He had acquired considerable ability as a craftsman in wood and metal, skill as a draftsman (judging by drawings which he made a little later) and sufficient musical ability to win a position as a chorister in Christ Church, one of the Oxford colleges. With the chorister's stipend and work as a servant to a certain Mr. Goodman, he supported himself.

At Oxford there was a small band of brilliant young men keenly interested in experimental science, then a new study. Among these were Christopher Wren and Robert Boyle, both of whom were to have decisive influences on Hooke's career. Boyle, eight years older than Hooke, was a man of means and position—the seventh son and 14th child of the "great" Earl of Cork. It was later said of Boyle that he was "the father of chemistry and brother of the Earl of Cork." About 1655, while Hooke was still a student at Oxford, Boyle engaged him as assistant in his experimental work. The air pump described in Boyle's earliest scientific book was designed and made by Hooke, and there are good grounds for believing that "Boyle's law" was really due to Hooke.

Hooke's first publication, in 1661, was a little book dealing mainly with surface-tension phenomena, especially the rise of liquids in capillary tubes. He did not go

SNOWFLAKES observed through the microscope by Hooke appear in his book *Micrographia*. Hooke made these and all the other drawings. The copy from which the illustrations in this article were taken is in the Burndy Library in Norwalk, Conn.

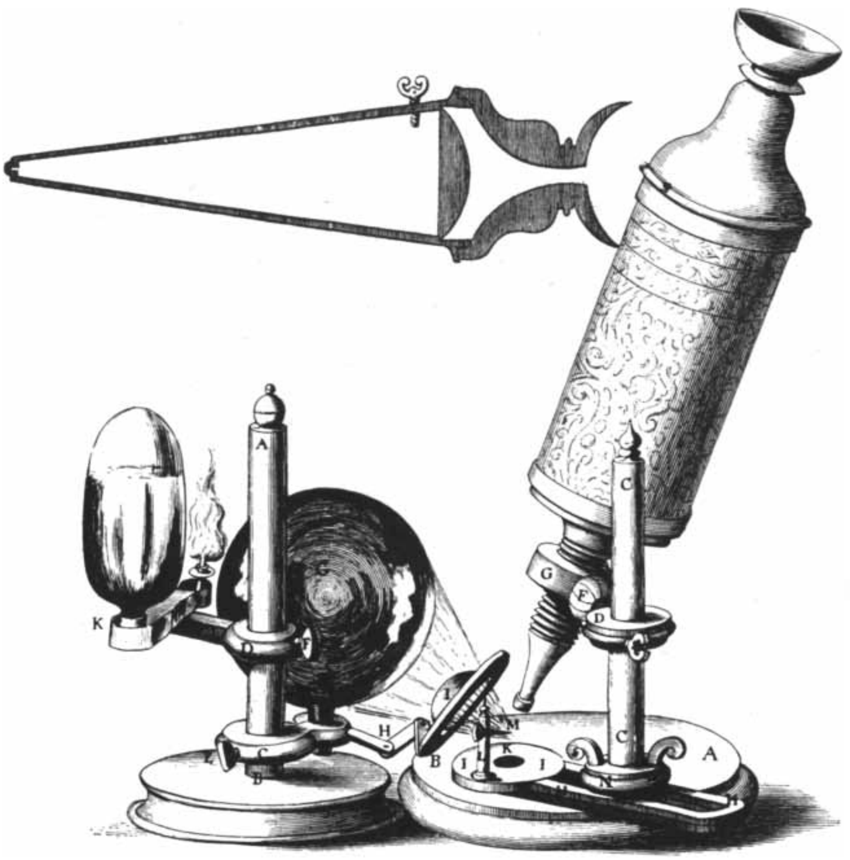
far toward explaining these phenomena, but his book is full of acute observation and the experimental spirit. For instance, he recognized that the floating of small bodies on a liquid surface and the rise of oil in a lampwick and of the sap in a tree were due to the same agency that caused the liquid to rise in the fine tubes.

Hooke's first major invention, concerned with the balance wheel for watches, occasioned the first of the acrimonious disputes that were to embitter much of his working life and his relations with some of his contemporaries. The history of the watch episode is involved and obscure. Before Hooke's day, watches kept time by means of a swinging bar which bounced to and fro under the impulses of the teeth of the escape wheel. They were notoriously inaccurate; in fact, Shakespeare had used watches of his day, known as "Nuremberg eggs," to exemplify unreliability.

A woman, that is like a German clock,
Still a repairing, ever out of frame,
And never going aright; being a watch . . .

There seems no doubt that Hooke conceived the fundamental idea of a spring to control the oscillations of a balance wheel in a watch, and that he drafted a patent for this device before 1660. It appears probable that a few years later he invented the spiral spring, which was introduced later (in 1675) by Christiaan Huygens. Hooke failed, however, to publish an account of this discovery, explaining afterward that he had put off doing so on account of a dispute with the backers of his patent. After the news of Huygens' invention, Hooke submitted his claim for priority to the Royal Society. The Society did not support him. Its secretary at the time was one Oldenburg, a great intriguer, to whom Huygens had consigned the English patent rights for his invention. Oldenburg, an enemy of Hooke, admitted that the latter had "made some watches of this kind" before 1675, but contended that they did not work—a matter about which he can scarcely have had personal knowledge.

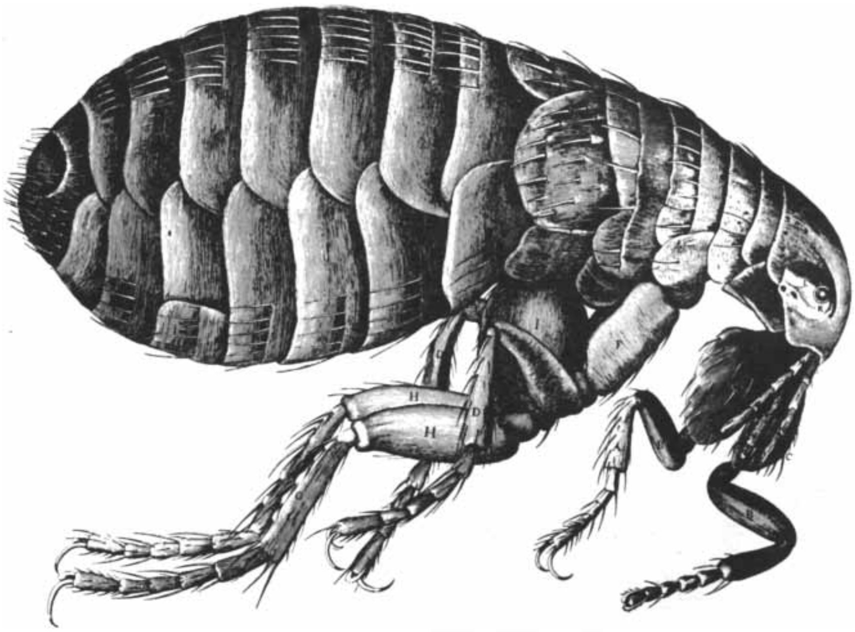
The English authority A. R. Hall, who has investigated the question, recently summarized Hooke's inventions in chronometry as follows: "We can only admire the penetration with which he went to the heart of the difficulties: the remontoir, the independent balance, the detent escapement were all features of the first successful chronometers, and they are all suggested in Hooke's contrivances, crudely, but clearly and originally. If he had included a means of temperature compensation, he would have grasped all the essential principles of the chronometer." The anchor escapement of pendulum clocks also is generally attributed to Hooke, but here the evidence in his favor seems insufficient. The whole story of Hooke's performance in this episode of the watch—his comprehensive and clear-sighted solution of fundamental difficulties, his haste, his incomplete records—is typical of much of his work.



HOOKE'S MICROSCOPE is depicted in the first illustration of the *Micrographia*. He used a flask of water as a condensing lens. A cross section of the instrument is at upper left.

When the Royal Society received its Charter in 1662, it decided to appoint Hooke as its curator. His duty was to provide "three or four considerable experiments" every time the Society met, which was once a week! He did, in fact, produce an extraordinary diversity of experiments, mostly original, for the Society. Hooke received no pay as curator for two years, and he had to make a living somehow in the meantime. He must have been prodigiously busy. In 1665 he published his great work *Micrographia*, which alone would have sufficed to put his name among the very great in science. Pepys, no scientist but a man of sound judgment and wide interests, records that he sat up until two o'clock in the morning reading the volume—"the most ingenious book that ever I read in my life." In scientific circles, both in England and on the Continent, the book made a great impression and established Hooke's name.

The *Micrographia* places Hooke among the great founders of microscopic study in biology—in the company of Anton van Leeuwenhoek, Marcello Malpighi and Nehemiah Grew. In this work Hooke described the first practical compound microscope. It consisted of a hemispherical objective lens and a large plano-convex eyepiece, of which only the center was used. A third lens could be inserted at the top of the cylindrical tube to act as a field lens, but this Hooke used only occasionally when he wanted to see much of the object at once. The focusing was effected by means of a screw cut on the eyepiece extension. Hooke discussed the defects of the instrument in quite a modern manner and later proposed the use of an immersion objective. The illustration above, reproduced from the *Micrographia*, shows both the microscope and his arrange-



FLEA was drawn in remarkable detail for the *Micrographia*. In the original plate the drawing is 16 inches long. The *Micrographia* contains drawings of some 60 microscopic objects.

ment for illuminating the object by lamplight—the first proper disposition for artificial illumination.

Proof of the excellence of the instrument and of the genius and perspicacity of the observer is given by the plates of some 60 microscopic objects, all of which he drew by his own hand. They record a number of fundamental discoveries in the world of living things: for example, he described the compound eye of the fly, observed the metamorphosis of the gnat larva and gave a description of the structure of feathers which remained the standard delineation for some 200 years. His figures of the louse, the silverfish insect and the flea (magnified to a length of 16 inches) are extraordinary in their accurate detail. Fungi and the sting of the nettle and of the bee are other subjects on which he made pioneering observations. In describing the structure of cork he used the word "cell" for the first time in its biological sense. Hooke turned the microscope not only on the living world but on the inanimate. He was the first to use it to examine metals—the point of a needle, the edge of a razor, the tiny spheres of steel struck off by a flint. He observed and depicted the beautiful crystals of snow.

Hooke was, then, a great pioneer in microscopy, distinguished alike as a designer of the instrument and its adjuncts, as an observer and as an interpreter of what he saw. But the *Micrographia*, in spite of its title, was by no means confined to microscopy. It records fundamental work in many branches of science. In it Hooke described the first refractometer for liquids, the first wheel barometer, a sealed alcohol thermometer and an indicating hygrometer which measured the moisture of the atmosphere by means of the beard of a wild oat, whose natural twist varies with the dampness of the air. Hooke was the first to propose as zero the freezing point of water—"common distilled water, that is so cold that it just begins to freeze and shoot into flakes." He devised the first examples of almost all the other common meteorological instruments used today—a wind gauge, a self-measuring rain gauge and a "weather clock" which registered automatically, by punches in a paper strip, the readings of the various meteorological instruments. Members of the Royal Society saw the latter instrument work, but it was frequently out of order, which is scarcely surprising.

Hooke was indeed the founder of scientific meteorology. He was the first to point out clearly that a rapid fall in the barometer presaged storms, to explain the polar circulation of the atmosphere and to ascribe the weather to physical forces governed primarily by the sun's radiation and the rotation of the earth. He put forward a scheme for making systematic meteorological records.

The *Micrographia* does not include Hooke's meteorological theories, but it contains a host of other significant discoveries and theoretical suggestions, most of which were never followed up. He proved by ingenious experiments that thermal expansion was a general property of liquids and solids. He put forward clearly the mechanical theory of heat, saying that it was "nothing else but a very *brisk* and *vehement agitation* of the parts of the body." In support of this idea he showed that mechanical friction gives rise to heat, and that the sparks struck from steel are spherical particles of the metal—evidence that they have been molten. He demonstrated that wood heated in a sealed vessel would not burn in the absence of air, and then put forward the theory (later adopted by the English chemist John Mayow without acknowledgement) that combustible bodies burned because air contained a "dissolving" substance, "like, if not the very same, with that which is fixed in *Salt-peter*" (that is, oxygen): The substance was used up in the combustion, so that fresh supplies of air were continually necessary. His remarks on respiration show a like grasp of the essentials. To realize Hooke's genius it is only necessary to read other contemporary speculations on these subjects.

Starting with an examination of quartz crystals in flint, he was led to consider crystal structure as a general property exhibited by various substances, among which he specified salts and metals. He then proceeded to build with spherical bullets some models of crystals which look remarkably modern. In particular he stated that rock salt "is compos'd of a texture of *Globules*, placed in a *cubical* form. . . ."

Considering the colors of thin plates—flakes of mica, films of air between glass sheets, soap films—Hooke shrewdly concluded that these colors were produced by the cooperation of light reflected from the front and the back of the film. His theory of light was that it was produced by a very rapid vibration in the luminous body, the waves being carried by an all-pervading ether. Many features of his theory of light and color are obscure, but much correct perception lies in these speculations, which occupy only a few pages. We know that Isaac Newton read them carefully.

The work concludes with some pages on astronomical matters—unexpected, perhaps, in a book on the microscope. Hooke for the first time pointed out the refracting effect of the atmosphere on light reaching us from heavenly bodies. He also reported two experiments he had made to see how the craters on the moon might have been formed. In one he let bullets fall into a mixture of pipe clay and water. In the other he noted how the last bubbles broke the surface in a pot of wet powdered alabaster as it ceased to boil. In both cases he obtained pits like the craters of the moon. These two experiments precisely illustrate the two leading theories today: that the craters were made either by falling meteorites or by volcanic eruptions.

This remarkable book by a young man of 29 gives a picture of a mind bursting with new and astonishingly correct ideas on all aspects of science, and of a superb experimenter. Its publication happened to coincide with a major change in England and in Hooke's life. The Great Plague of 1665 and the Great Fire of 1666 destroyed much of London and its life. Hooke helped his friend Christopher Wren in the rebuilding of the city. Hooke was made City Surveyor, which relieved him, probably for the first time, of financial anxiety. Within a week after the Fire ended, Hooke laid before the Royal Society a model for rebuilding the city on a rectangular pattern, as adopted later in New York! He was, incidentally, quite a good architect and designed several well-known London buildings.

Hooke's scientific activity never ceased. In 1674 he published an account of a systematic attempt to observe the parallaxes of stars. To measure angular distances in the heavens he devised a new quadrant which was the first instrument with telescopic sights and a screw adjustment ever made. It was an immense advance over the open-sight instruments of his contemporary, Hevelius of Danzig. It is to be particularly noted that Hooke not only designed the improved instrument but was perfectly clear as to what its advantages were. He found out by measurement that the resolving power of the naked eye was only about a minute of arc and realized that the telescope greatly increased this resolving power.

Hooke was the supreme instrument-maker of his time. In the same publication he described, with detailed illustrations, a clock-driven equatorial telescope to follow the stars. An incidental feature of his astronomical instruments was the universal, or "Hooke's," joint so widely used today. Apparently Hooke never actually built a clock-driven telescope; the first one was constructed in France some 70 years later.

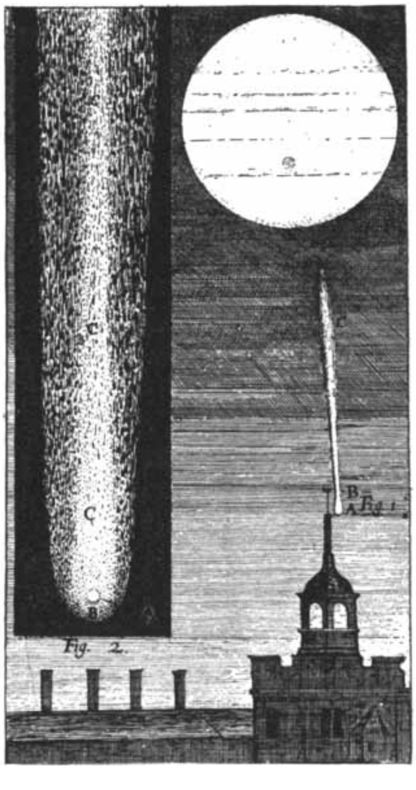
In writing of Hooke it is hard to avoid piling up a catalogue of discoveries. We cannot list them all here. But a word must be said about his work entitled *Lectures de Potentia Restitutiva, or Of Spring*, which appeared in 1678. Hooke's law and its implications were here expounded. He showed that the vibrations of any body in which the restoring force was proportional to the displacement, that is, of any elastic body, must have the same period whatever the amplitude —a capital discovery. From vibrations he proceeded to form a general, if necessarily crude, kinetic theory of matter, conceiving that motion of its particles accounted for many phenomena.

In 1677, Oldenburg having died, Hooke was appointed secretary to the Royal Society. In that capacity he soon wrote to Newton asking him to contribute a paper. The two men had previously been involved in controversy, exacerbated by Oldenburg, over the nature of light, but Hooke's letter now was courteous and led to a correspondence. However, it ended in hostility. Hooke had published in 1674 these principles: firstly, that all celestial bodies had a gravitational attraction toward their centers; secondly, that all bodies continued to move in a straight line except insofar as they were pulled aside by some force; thirdly, that the gravitational attraction fell off with the distance according to some law which he did not then know. Newton had already reached these conclusions himself, but he had not published a word or spoken of them to anyone, and Hooke's proposals were entirely independent. In 1680 Hooke wrote a letter to Newton asking what form the orbits of the planets would have if it was assumed that gravitational attraction was in inverse proportion to the square of the distance. If Hooke himself had been able to deduce mathematically the consequences of his principles where planetary orbits were concerned, he would have solved the great problem of the solar system which it was Newton's glory to settle. How near he came, with his instinctive sense of scientific truth!

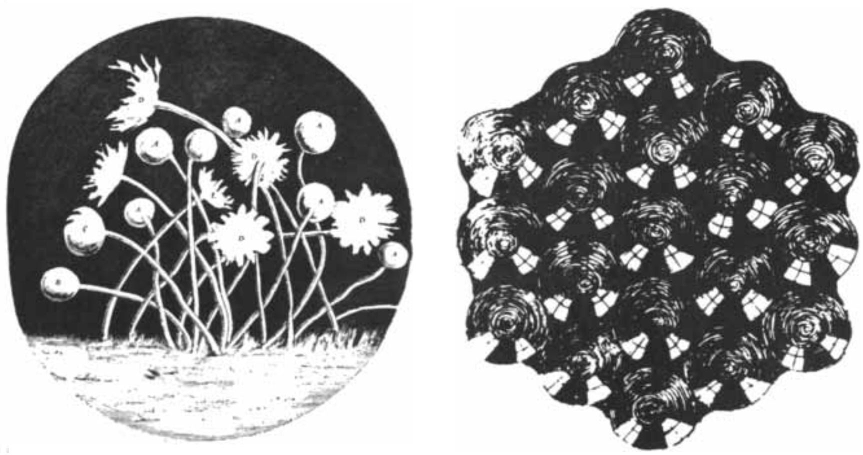
When Hooke learned, just before publication of Newton's *Principia* six years later, that the book contained a demonstration of the solar system based on the principles he had put forward, without any acknowledgement to him, he was much irritated. It appears that all he wanted was a mention in the preface or some such civility. But Newton, an equally irritable man, was highly incensed by Hooke's protest. He omitted any mention of Hooke, not only from the *Principia* but also from the *Opticks*, published after Hooke's death. Hooke, who lacked not generosity but only tact, deserves all sympathy.

He gave up the secretaryship in 1682 but continued to deliver papers to the Royal Society on everything from the nature of memory to comets. In 1687 the death of his niece, who had lived with him for several years, came as a great shock. A few years later his wretched health finally broke down entirely. He lingered on, however, until 1703. He had a decent funeral, attended by all the Fellows of the Royal Society then in town. But it seems a symbolic commentary on this unhappy man that the site of his grave is unknown.

Two years after his death the *Posthumous Works of Robert Hooke* appeared as a volume of some 400,000 words. The collection was prepared from manuscripts, mostly of lectures, that he had left unpublished. These extraordinary papers establish Hooke as a great geologist and a pioneer evolutionist, among other things. He recognized fossils as a record of the past life of the globe. After pointing out that coins, medals or documents can be forged, he said of fossil shells: "These Characters are not to be counterfeited by all the Craft in the World, nor can they be



ASTRONOMY also interested Hooke. These are his drawings of Halley's comet (*left and right*) and the planet Jupiter (*upper right*).



TWO MICROSCOPIC OBJECTS observed by Hooke were the mycelium of a fungus (*left*) and the compound eye of a fly (*right*). The latter was one of his biological discoveries.

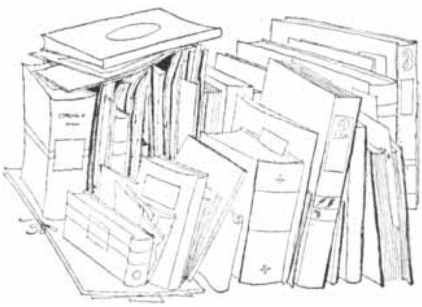
doubted to be, what they appear, by any one that will impartially examine the true appearance of them: And tho' it must be granted, that it is very difficult to read them, and to raise a Chronology out of them, and to state the intervalls of the Times, wherein such, or such Catastrophies and Mutations have happened, yet 'tis not impossible. . . ." Compare this with the fairy tales written by his contemporaries on the subject.

One could go on for pages noting discoveries by Hooke, any one of which should have made his name remembered, and many of which have been credited to later men. Let us take a single day in the Royal Society. At the meeting of July 27, 1681, it is recorded: "Mr Hooke showed his new-contrived aperture for long telescopes, which would open and close just like the pupil of a man's eye, leaving a round hole in the middle of the glass of any size desired; which was well approved of. He shewed an experiment of making musical and other sounds by the help of teeth of brass-wheels; which teeth were made of equal bigness for musical sounds, but of unequal for vocal sounds." Here are, firstly, the iris diaphragm, usually supposed to be a 19th-century invention, and, secondly, a superior version of the acoustical instrument known as Savart's wheel, after a Frenchman who is credited with inventing it in 1820. Hooke also showed a third trifle, his helioscope, on the same day.

I have deliberately avoided a systematic classification of Hooke's work, for the chronological story tells more faithfully and more vividly how one discovery, invention and prediction after another tumbled out of this extraordinary man. As John Ward very truly observed in 1740: "Had he been more steady in his pursuits, and perfected one discovery before he entered upon another, he might perhaps in some cases have done greater service to the public, and prevented what often gave him uneasiness, the fear of losing credit of them by others, who built upon his foundation."

Hooke, sick, overworked, often cheated, the object of envy and attack by lesser men, made many enemies, but note that some of the great figures of the period were his firm friends—his headmaster Busby, John Evelyn, Thomas Sydenham and Christopher Wren, for example. For Wren and for Boyle he always expressed the greatest admiration. He was, if irritable, also fearless, upright, quick to thank for any kindness shown and quick to forgive injuries by great men whose work he admired. L. T. More, in his biography of Newton, expressed the wish that Newton, "in the full plenitude of his fame, could have shown more tolerance and a greater sympathy" for Hooke, "that brave mind and spirit, housed in a suffering body."

Hooke was hasty, impatient with fools and intolerant of obliquity, which it is perhaps safe to resent in the small but unwise to take amiss in the influential. "He had," his friend and editor R. Waller wrote, "a piercing Judgment into the Disposition of others, and would sometimes give shrewd Guesses and smart Characters," which is a dangerous diversion. He lacked the smooth approach, the adroitness, the discrimination of motives and the concealment of antipathy that are so essential to worldly success. He was also, alas, sensitive—a grave fault. No doubt everyone believes that in our times Hooke would have been better treated. Perhaps.



CHILDREN'S BOOKS

A fifth Christmas review of books about science for younger readers

by James R. Newman

Reviewing the annual output of children's science books this year has been a much more gratifying experience than usual. The list includes several uncommonly good books—books which will give as much satisfaction to grownups as to children. I can speak warmly of at least 12 items: Roy Chapman Andrews' absorbing volume on whales; a primer of anatomy by Anthony Ravielli; the story of storks by Margaret Wise Brown and Tibor Gergely; a fine introduction to chemistry by Ira Freeman; a superb book on snow by Thelma Bell; an unusually clear introduction to biochemistry by Isaac Asimov; James Kendall's excellent reworking of his richly informative Christmas lectures on young chemists; an engrossing survey of language by Mario Pei; a beautifully illustrated book by the Yashimas on a Japanese village; a good story and a distinguished example of bookmaking in Pantheon's edition of Baumann's *The Caves of the Great Hunters*; a helpful, original and interesting little book by Julius Schwartz on using a magnifying glass; a first-class account of earth physics by Wyler and Ames. These books deserve consideration for any library, and there are a number of others that do much better than merely trudge along. The harvest is as unprecedented as this year's weather—an *annus mirabilis* however you look at it.

Biography

MICHAEL FARADAY, by Harry Sootin. Julian Messner, Inc. ($2.75). Faraday was perhaps the last great scientist to believe that man could find out everything about the physical world if only he asked the right questions, made the right experiments and persevered. He himself was the best example of the merits of this recipe—a remarkably skillful experimenter, wonderfully imaginative, imbued with a granite determination not to let go of an idea until he had exhausted its possibilities. Though self-educated and without mathematical capacity, he made discoveries in the most difficult regions of physics because he knew both how to interrogate nature and how to interpret her replies. He was a good man and happy in his married life. He was not, however, a simple man, as his biographers like to assert: one has only to recall his long periods of mental illness to realize the falsity of this sentimental notion. Sootin's fictionalized biography of Faraday (for youngsters of 12 and older) is undistinguished, filled with implausible dialogue and accounts of reflections which almost certainly were never reflected, but he gets his facts pretty straight and his descriptions of Faraday's experiments are, if not incandescent, at least comprehensible. This is no small feat in view of the publisher's courageous refusal to mar the book by even a single illustration.

THE STORY OF JOHN J. AUDUBON, by Joan Howard. Grosset & Dunlap ($1.50). JOHN JAMES AUDUBON, by Margaret and John Kieran. Random House ($1.50). Jean Jacques Audubon, the illegitimate son of a French navy captain, was born in Santo Domingo in 1785, reared in France, and sent to his father's estate near Philadelphia in 1803 to enter business. His commercial ventures, undertaken in Kentucky where he migrated with his wife, were unsuccessful; he neglected his business for the pursuit of ornithology, was imprisoned for debt, traveled down the Mississippi in a flatboat to draw birds in crayon and water color, and supported himself and his family in New Orleans as a sidewalk portraitist and teacher of dancing, fencing and violin. In a trip abroad he finally rounded up enough subscribers to publish in four elephant-folio volumes 435 magnificent hand-colored copperplate engravings of the birds of America, the finest ornithological illustrations ever made. These two new biographies of this most interesting and attractive man are addressed to children of 9 to 12. The Kierans' version is quieter and better written, but I find it puzzling that neither book gives any space to Audubon's longest and most difficult excursion: his 1843 journey with his friend Edward Harris and others up the Missouri River to the headwaters of the Yellowstone.

> **EDITOR'S NOTE**
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> The illustrations that accompany this article are not from the books reviewed here. Drawn by Marian Parry, they reflect the content of some of the books.

GREAT DISCOVERIES BY YOUNG CHEMISTS, by James Kendall. Thomas Y. Crowell Company ($3.00). Professor Kendall's excellent book is based on his Christmas Lectures to the Royal Institution first published in 1939. They have now been recast from lecture into narrative style, brought up to date on current topics and further enlarged to incorporate additional historical material. Young chemists have played a remarkably influential part in the development of their science, and these stories describe the life and youthful work of no fewer than 16 pre-eminent figures, among them Faraday, Pasteur, Moseley, the Curies, Davy, Mendeleyev, Arrhenius, van't Hoff. A pleasingly written, attractively designed book, warmly recommended for readers 12 years of age and up. Fine illustrations.

LAUGHING GAS AND SAFETY LAMP, by Amabel Williams-Ellis and Euan Cooper Willis. Abelard-Schuman, Inc. ($2.50). A biography of Sir Humphry Davy which carries the story of the apothecary's apprentice through his most fruitful years. Davy was as vain and self-seeking as he was gifted, and it is sometimes said of him that his greatest gift to science was Faraday, whom he took on as an assistant and gave the chance to abandon bookbinding for research. But this is scarcely just. Despite his social climbing and other foibles, Davy found time for brilliant work: the first isolation of sodium, potassium, boron and other elements by electrolysis; the demonstration that diamonds are made of carbon; the invention of the miner's safety lamp; the discovery of the physiological effects of inhaling nitrous oxide; the proof that chlorine and iodine are simple substances. This is an accurate and a thoughtful book, happily free of imaginary conversations but with much too much quoted material from other biographers. The book has no index—an unfortunate omission.

Maria Mitchell: Girl Astronomer, by Grace Hathaway Melin. The Bobbs-Merrill Company, Inc. ($1.75). "Goody, goody, the rain is over!" is the first line of this story of the life of the noted U. S. astronomer Maria Mitchell. She was five, we are told, when she made this observation; 65 years later her last line, as quoted in this book, was: "When you leave Vassar [she was speaking to her lady students] to be scientists, teachers, artists and workers in other fields you must prove your ability again." For about 190 pages the girl astronomer is made to say what most of the subjects of the well-known "Childhood of Famous Americans" series are usually made to say. Lamentable.

Physical Sciences

Snow, by Thelma Harrington Bell with drawings by Corydon Bell. The Viking Press ($2.50). It would be difficult to praise too highly this fascinating book. The Bells explain the mechanics of a snowfall, the help and the harm snow does, how an igloo keeps its tenants warm against temperatures of 50 below zero, the work of snow surveyors and the use of "Santa-Claus chimneys," the structure of snow crystals and how they are formed, the various types of snowflakes, the origin of snowflake cousins such as frost, windowpane frost, rime, glaze, sleet and hail. The book also describes the delicate and wonderfully ingenious methods devised by Ukichiro Nakaya in Japan for producing artificial snowflakes, and by Vincent Schaefer at the General Electric Research Laboratory in Schenectady for fossilizing snowflakes. The flakes are caught on black velvet, transferred to glass slides, coated with a clear, quick-drying solution of polyvinyl formal resin and then permitted slowly to get warm, whereupon the water composing the snow crystal evaporates through the thin plastic shell, leaving a perfect replica of the ice pattern of the original flake. The text and pictures make what is in my opinion the year's most distinguished science book for children.

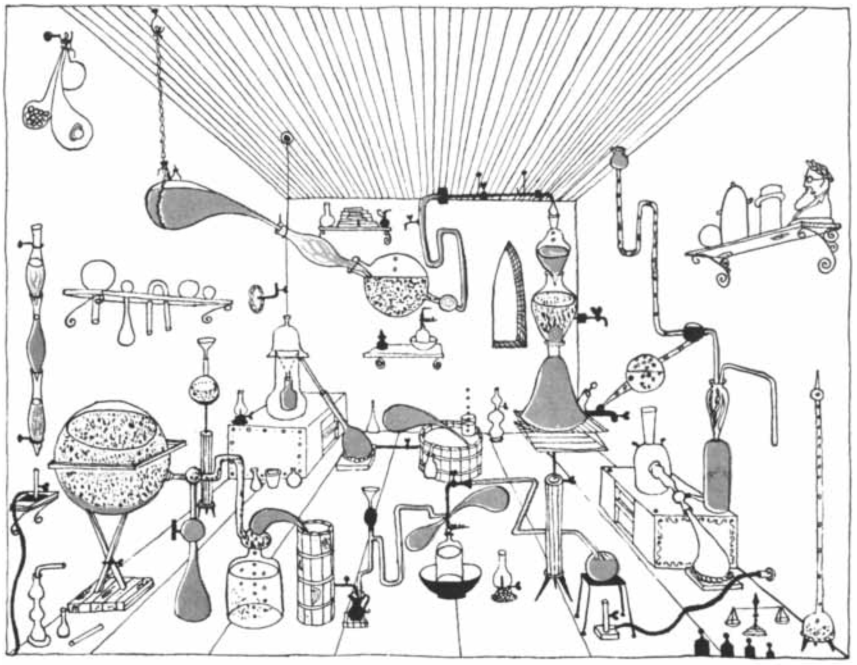
All about the Wonders of Chemistry, by Ira M. Freeman. Random House ($1.95). This is one more excellent book by Professor Freeman who, though a physicist by profession, has written for children on chemistry and astronomy, besides serving as consultant to UNESCO in developing methods for teaching and popularizing science. He explains how chemistry began and how the theories of molecular combination and atomic structure evolved, and he goes on to describe the applications of chemical knowledge in metallurgy, oil refining, agriculture, the manufacture of fibers and plastics, the synthesis of rubber, the development of antibiotics. His style is congenial and clear and is enriched by many felicitous analogies and examples.

The Wonderful World: The Adventure of the Earth We Live On, by James Fisher. Hanover House ($2.50). This book bears a resemblance to Mrs. Murphy's chowder. It contains many good things, but also an extraordinary assortment of odds and ends tossed in as blithely as the famous overalls. In less than 70 pages the volume covers "how the world began," "the face of the world" (land, sea, vegetation, climate and so on) and "man's world" (how he has adapted himself to nature and exploited its resources). Mainly it is a picture book, and the illustrations, edited by F. H. K. Henrion, are of several different kinds. There are full-page, multi-colored panoramic paintings, absurdly crowded, some charming and gay, some deliberately lurid and horrifying, some informative, some merely stupefying. There are Neurath "isotypes" of mixed merit. There are "shadow relief maps" which, it is claimed, show you the relative heights of mountains on a flat page, but which, as far as I can see, only make the earth look bilious. Among other things the book depicts Dr. Livingstone at Victoria Falls, a tyrannosaur chewing up a stegosaur, an Oxford boat race, Amundsen at the South Pole, prehistoric cave paintings, Hillary and Tensing on Everest, a tornado descending on a herd of buffalo, the main street of Innsbruck, a great mammal called the gray baluchithere, now, alas, extinct. For all its disorganization, I cannot imagine a child or an adult who would not find at least parts of this hodgepodge fascinating.

Great Discoveries by Young Chemists

Icebergs and Jungles, by Shirley Carpenter and Marie Neurath. Hanover House ($1.00). Designed along the same lines as *The Wonderful World* (see above), this book on world weather and climate has many of the same merits and defects. The illustrations, printed in colorgravure in London, are gay, charming, moderately instructive and not infrequently irrelevant; the text is gummy; the page layout is a mixture of drawings, isotypes, shadow-maps, captions and two-column text—all having a tendency at times to run into each other and make the reader feel he is losing his mind. Perhaps the book has had this effect on me, for I like it very much in spite of what I have said, and other children, I am sure, will feel the same.

Restless Earth, by Rose Wyler and Gerald Ames. Abelard-Schuman, Inc. ($2.50). This is a first-rate introduction to the study of earth physics. A gifted husband-and-wife team explains the nature of volcanoes and earthquakes, how mountains are formed, the behavior of earthquake waves and the operation of a seismograph, the evolution of rocks,



All about the Wonders of Chemistry

the constant transformation of the earth's skin by internal forces of heat, pressure, radioactivity and surface processes of erosion and sedimentation. The writing is interesting and the explanations are crisp and admirably clear. Highly recommended for anyone over 13.

THE EPICS OF EVEREST, by Leonard Wibberley. Farrar, Straus & Young, Inc. ($3.25). A gripping short history of the attempts to climb Mount Everest. It begins with the Howard-Bury reconnaissance of 1921 and ends with the triumph over the "Goddess Mother of the World" by the Hunt party in 1953. The book will engross any reader 12 or older.

THE REAL BOOK ABOUT THE SEA, by Samuel Epstein and Beryl Williams. Garden City Books ($1.50). The Epsteins are a skilled writing team and this book serves their reputation. They describe how the seas were created, the submarine landscape, tides and ocean currents, marine life, the sea as a highway of commerce and conquest, its effects on the weather, its mineral and food resources. The illustrations are tepid, but the story is well told and this is an attractive volume at the price. For adolescents.

ALL ABOUT THE STARS, by Anne Terry White. Random House ($1.95). Mrs. White has written children's books on subjects ranging from Shakespeare to archaeology and George Washington Carver, but don't let this prolificacy put you off. She has a firm grasp of the essentials of astronomy, and this primer will gladden and instruct boys and girls in the vicinity of 12—plus or minus one or two years.

THROUGH THE MAGNIFYING GLASS, by Julius Schwartz. Whittlesey House ($2.50). This happy book for children of nine and older is based on a simple and fruitful idea: namely, that an inexpensive magnifying glass is an endlessly useful piece of scientific apparatus. With a glass costing no more than half a dozen comic books a child can explore a fascinating world. Among the things to be seen are the exploding atoms on a watch dial, skin cells, sparkling salt and snow crystals, the faces of insects, the many-colored dots in magazine pictures, the eggs of spiders, the whorls of finger prints, the grooves of a phonograph record, the nodules and hairs on plant roots, the fine structure of flowers, the tiny letters on coins. Schwartz tells how to make a viewing stand for the lens, what to look for and what the various objects mean. Jeanne Bendick's illustrations fit the text very well.

EXPERIMENTS WITH ATOMICS, by Nelson F. Beeler and Franklyn M. Branley. Thomas Y. Crowell Company ($2.50). A clearly written, attractively illustrated primer of atomic energy for children of 12 to 14. It gives instructions for performing experiments and building with common materials a remarkable assortment of nuclear but nonlethal apparatus. An electroscope can be made of newspaper strips; experiments in radioactivity can be performed with a luminous-dial watch, a sheet of photographic paper and a paper clip; a cloud chamber can be built of a jam jar, some black velvet, dry ice and rubbing alcohol; a model Geiger counter can be put together from an ice-cream carton, a mailing carton and a knitting needle.

THE BOYS' FIRST BOOK OF RADIO AND ELECTRONICS, by Alfred Morgan. Charles Scribner's Sons ($2.75). The author, an electrical engineer and an experienced writer of science primers, has turned out another sound, straightforward book in which emphasis is placed on equipment the reader can build for himself. Morgan explains the basic facts of electricity, radio waves, electronics, radio tubes; he then gives detailed plans and instructions for making simple radio receivers, amplifiers and other apparatus. With its many lucid diagrams this is a good introductory volume for a youngster who is handy and persevering.

Biological Sciences

THE CHEMICALS OF LIFE, by Isaac Asimov. Abelard-Schuman, Inc. ($2.50). An introduction to biochemistry which gives particular attention to the enzymes, vitamins and hormones. The author, who teaches biochemistry at Boston University School of Medicine and has written many science fiction books as well as student texts, has a tendency to be cute (*e.g.*, "the carbon atom is dissatisfied"), but he more than makes up for these lapses by his clear presentation of a difficult subject and his numerous effective analogies. I recommend his book to teen-agers.

ALL ABOUT THE INSECT WORLD, by Ferdinand C. Lane. Random House ($1.95). A 1948 entomological census indicated that 686,000 species of insects had already been described and 6,000 or 7,000 new ones are added each year. Lane does not tell all about all of them, but he gives an account of some important and familiar ones, including butterflies, moths, beetles, water bugs, the praying mantis, bees, wasps, termites, mosquitoes, flies and ladybugs. His story moves along briskly, offering a full complement of strange facts: the cockchafer has 40,000 organs of smell, the dragonfly's eye has 25,000 lenses, some insects have 4,000 muscles (man has about 500). A good book for children of 10 and up.

Dinosaurs, by Herbert S. Zim. William Morrow & Company ($2.00). A competent book on a subject not too difficult to write about, especially for a veteran. Zim describes the great race of extinct reptiles from the allosaur through the tyrannosaur. Their company included species weighing 50 tons and others no bigger than a Pekingese, flesh eaters and vegetarians, long-necked brachiosaurs and armored stegosaurs, clumsy ankylosaurs and fleet ornitholestes. The dinosaurs laid eggs with a hard covering and gave not much mind to their young. Indeed, they had not much mind to give, for their brains represented only one 50,000th of their body weight. Of course the little they had was precious, and in one species it was protected by a skull a foot thick. The dinosaurs ruled the continents for about 100 million years. Climate, geologic changes and natural enemies gradually closed in on them. They had difficulty adapting. "Can man's brain," asks Zim, "help him to change and adapt so that the human race can last longer than the dinosaurs?"

Insects and the Homes They Build, by Dorothy Sterling. Doubleday & Company, Inc. ($2.50). Mrs. Sterling tours the silk tents of caterpillars, the cocoons of silkworms, moths and bagworms, the webs of spiders, the bubble houses of the potbellied froghopper and the praying mantis, the mud houses of wasps, the multi-room paper domiciles of hornets, the tree cavities of wild bees and the hives of their domesticated cousins, the wood houses of ants and beetles, the plant residences of galls. Myron Ehrenberg's photographs are adequate, but the halftone reproduction of them is as moldy a job as you are apt to see.

Here Come the Bears, by Alice E. Goudey. Charles Scribner's Sons ($2.25). A pleasant account for small children. It describes the habits of grizzlies, polar bears, black and brown bears, and tells a story about a family of each kind. The illustrations by Garry MacKenzie are only so-so.

Paws, Hoofs, and Flippers, by Olive L. Earle. William Morrow & Company ($3.50). Miss Earle's soleful work classes mammals in a new way: by the kind of feet they have. The varieties of appendages are claws (hedgehog, kangaroo, lion, beaver), hoofs (horse, elephant, hippopotamus), flippers (whale, sea cow) and nails (you know who).

The Wonder World of the Seashore, by Marie Neurath. Lothrop, Lee & Shepard ($1.75). A mildly beguiling assortment of stories about small seashore creatures. They include starfish, fiddler crabs, cockles, parchment worms, goose barnacles, Portuguese men-of-war, Australian sea dragons, small crabs that carry tiny stinging sea anemones as weapons in their claws, cotton spinners that manage to befuddle predatory lobsters with their sticky threads, and teredos, which are sea-going termites. For children as young as 8.

All about Whales, by Roy Chapman Andrews. Random House ($1.95). Some years ago the whale forsook the land and went to sea. It was a sensible move; in the oceans the mammal grew great. Whales are the biggest animals that ever lived. There are two main classes: baleens (whalebones) and toothed whales. The baleens, which get

The Epics of Everest

their name from the huge food-strainers suspended like hairy mats from the upper jaw, include several species. There is the stubby, 50-foot humpback, with an enormous mouth, a humplike dorsal fin and barnacles hanging from its chin. The majestic gray sulfur-bottom reaches more than 110 feet in length, weighs almost 200 tons and has a great flabby tongue weighing more than 6,000 pounds and a 1,000-pound heart. But its brown eyes are "not more than twice as large as those of a cow," and its ears are tiny holes. It has exactly 32 whiskers on its chin and a few blades on top of its head. Small chunks of bone buried deep in its flesh are left as remnants of the hind legs of its ancestors. The sulfur-bottom emits a "terrific whistling roar" when spouting. The female gives birth to 8-ton, 25-foot babies, which it nurses tenderly until they can do for themselves. Also in the baleen group are the "right" whales, a name they owe to the Basques, who discovered a thousand years ago that this species yielded more oil than any other and therefore was the "right whale to kill." The class of toothed whales includes sperm whales and porpoises. Among the latter are the killer whales, which attack other whales in packs, tearing out their tongues and ripping them to pieces. These are among the details to be found in Andrews' fascinating book, addressed to adolescents but obviously of interest to all ages. One of Andrews' first jobs at the American Museum of Natural History was to help build a life-sized model of a sulfur-bottom. Thereafter he traveled over the world for many years studying whales, taking part in many whale hunts. His knowledge of the subject, his exciting experiences, his love of the species itself, combine to make this one of the most enjoyable natural-history primers of recent years.

Horses and Their Ancestors, by William A. Burns, Whittlesey House ($2.75). The Horse and Pony Book, Margaret and Stuart Otto. William Morrow & Company ($2.50). These two books have much in common. Burns skims over the evolution of the horse, gives examples of its part in man's history, tells how it has been celebrated in story and art and discusses briefly the various types of horses and what uses are made of them. Paula Hutchison's illustrations are more decorative than informative. The Ottos' volume has a little less history, but the account of the several breeds of horses and the jobs they do is pleasant and uncluttered and the photographs are excellent. Both volumes are for 9- to 12-year-olds.

Wonders of the Human Body, by Anthony Ravielli. The Viking Press ($2.50). This book explains for children of 10 to 13 how the neckbone is connected to the shoulderbone, the hipbone is connected to the thighbone, the thighbone is connected to the kneebone, the kneebone is connected to the legbone, and so on up and down. It also tells what the muscles look like and how they work, the construction of the nervous system, the functioning of the internal organs. The author is a free-lance artist skilled in anatomical drawings; he writes competently and many of his pictures are very good. Recommended.

Zoo Expeditions, by William Bridges. William Morrow & Company ($3.50). The expeditions are those of the Bronx Zoo to various parts of the world to capture exhibits. The quarry included blind fish in a Mexican cave pool, elephants and peacocks in the Belgian Congo, paradox frogs in Trinidad. One of the most interesting trips was to Rhode Island to get background information on a box turtle which had the date 1844 carved on its belly. It turned out, in fact, to be at least 129 years old and is still trundling around. An agreeable book by the author of last year's delightful *Zoo Babies*. Photographs.

Wheel on the Chimney, by Margaret Wise Brown and Tibor Gergely. J. B. Lippincott Company ($3.00). In Hungary, and perhaps elsewhere, it is thought to be a sign of good luck when storks build their nest on the chimney. Farmers tie a wheel to the chimney to make the nest-building easier. In this gently poetic story, with many vivid and a few really lovely illustrations, young readers are told about storks.

The World through Your Senses, by Sarah R. Riedman. Abelard-Schuman, Inc. ($3.00). This competent book for adolescents tells about the structure of the nervous system: how impulses travel along nerve circuits; how we feel, see, hear, smell, taste; and many more facts about the communication and control machinery of organisms.

Introducing Animals, by William and Helena Bullough. Thomas Y. Crowell Company ($2.50). A lucid, charming primer for youngsters 10 and up. It gives a great deal of information about animals without backbones, from amoebae, which are so small it would take about 15 of them to cover a period on this page, to 12-foot Australian earthworms and 50-foot squids. This is one of the best books on animals in a long time. It is made doubly attractive by excellent drawings.

Prehistoric Animals, by William E. Scheele. The World Publishing Company ($4.95). The author, director of the Cleveland Museum of Natural History, presents in pictures and text some of the principal fish, insects, reptiles, birds and other creatures that dwelled on earth during the first few hundred million years after life appeared. He tells how fossil bones are assembled to show what the animals looked like. The book is authoritative but leans a little to the lurid side, especially in the illustrations.

Technology

The First Book of Cotton, by Matilda Rogers. Franklin Watts, Inc. ($1.75). An uncommonly clear and interesting volume for youngsters over 9. It relates how cotton is raised, how the crop is harvested, the operation of the cotton gin, the many uses of cotton seeds, the manufacture of yarn and fabrics, the machines, the processes, the people who enter into this major industry. The book has pleasant illustrations, a useful glossary and an index.

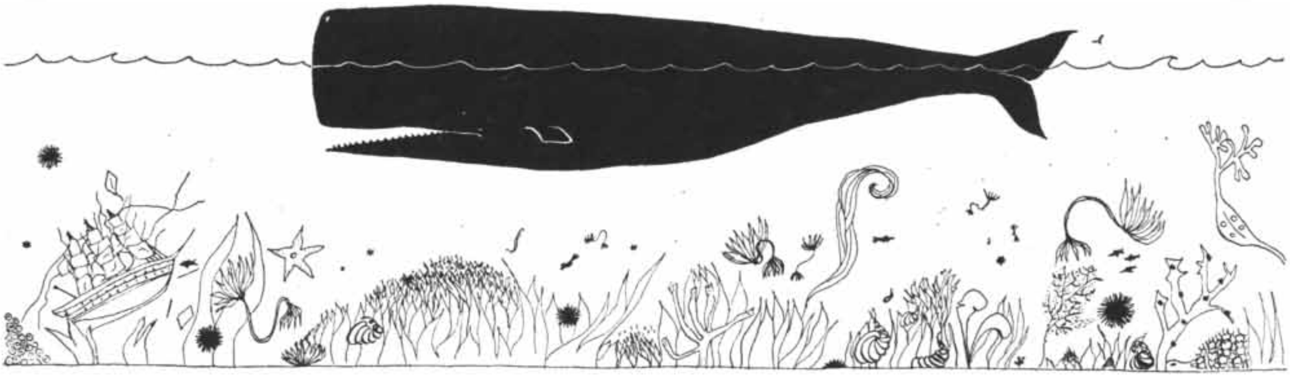
Things around the House, by Herbert S. Zim. William Morrow & Co., Inc. ($1.75). This is a new addition to Zim's series of books in two sizes of type for two reading levels. He explains what is inside the walls and floors of a house and how the doorbell, the electric light, the gas stove, the refrigerator, the oil furnace, the toilet and the water faucet work. Colored pictures by Raymond Perlman.

Tunnels, by Marie Halum Bloch. Coward-McCann, Inc. ($2.75). The book by Edward and Muriel White called *Famous Subways and Tunnels of the World*, reviewed here last year, might be thought to have covered the subject pretty well for youngsters, but here is another volume which makes its own place. For one thing, Mrs. Bloch's story is on a somewhat simpler level, so that 8- or 9-year-olds can enjoy it. Moreover, while her account is less dramatic than the Whites', her explanation of tunnel construction is exemplary in its clarity. Ten full-page photographs and 25 drawings by Nelson Sears.

Let's Look under the City, by Herman and Nina Schneider. William R. Scott, Inc. ($2.00). This was a good book in the earlier edition (1950), and the revision is even better. It explains the essential underground mains and utilities of a city—water, gas, electricity, telephone, sewage. An admirable little volume for ages 8 to 11, with charming and helpful illustrations by Bill Ballantine.

Freighters and Tankers of the U.S. Merchant Marine, by Gordon A. Growden. G. P. Putnam's Sons ($2.00). Here is an attractive album of merchant vessels. It has 26 full-color drawings by Lemuel B. Line and accompanying captions describing the principal cargo of each type of ship, its speed, hoisting machinery, propulsion engines and kindred features. Boys will like the book even if it doesn't tell them much.

Freight Train, by William Bunce. G. P. Putnam's Sons ($2.00). A companion to the volume above, this book presents 29 colored illustrations by the



All about Whales

The Complete Book of Helicopters

same artist of the carriers and Diesel units that compose a typical freight train. The text explains the purpose of each car, what the mysterious markings on their sides mean, how coupling devices and other equipment work, how the railroad lines keep track of the travels of their rolling stock.

THE COMPLETE BOOK OF HELICOPTERS, by D. N. Ahnstrom. The World Publishing Company ($4.95). The managing editor of *Skyways* presents a comprehensive, readable, illustrated survey of helicopters. He explains how the "egg beater" or "whirlybird" species of flying machine evolved and describes the extraordinary range of its uses: for forest-fire control, seed-sowing, whale hunting, scouting for tuna, ice-pack reconnaissance, rescue and ambulance service, spraying against pests and insects, transporting cowboys on huge ranches, patrolling power lines, carrying mail and passengers, bringing supplies to lighthouses, surveying archaeological sites, trailing horse races on the lookout for fouls—in short, all kinds of useful and silly jobs which formerly could not be done at all or can now be done more easily with the help of a flying carpet. For adolescents or grownups.

RADAR AND OTHER ELECTRONIC INVENTIONS, by Frank Ross, Jr. Lothrop, Lee & Shepard Co., Inc. ($2.75). Adolescents and adults will find in this book a great deal of clearly presented information about the working and uses of radar and the application of electronic instruments to an astonishing variety of activities, from appraisals of the ripeness of tomatoes and the determination of the crystalline structure of aluminum sheets to the remote control and monitoring of auto assembly line operations and the checking of customers' signatures in banking. You will also be happy to learn that in the U. S. most walnuts are now cracked electronically.

GOING INTO SPACE, by Arthur C. Clarke. Harper & Brothers ($2.50). If your child of 12 or older is still ravenous for information on how to get to the moon and on when he can look forward to sharing a space station with Wernher von Braun, and you can find no way of deflecting these lunar drives, you will do him a minimum of harm in giving him this book. It says nothing that has not been said before, and the explanations are not always luminous, but Clarke is a knowledgeable man on this subject.

THE ATOMIC SUBMARINE, by John Lewellen. Thomas Y. Crowell Company ($2.50). A smoothly written account for adolescents of the Navy's new nuclear nautilus. The author explains clearly the machinery and operation of the sub and what daily life will be like for the crew. Amenities for the 70 or more crewmen include moving pictures, electric phonographs and a large record collection, a snack bar open 24 hours a day, "walls painted in pleasing colors to give a sense of spaciousness and to help calm tense nerves," and an abundant supply of cottage cheese—because in underwater-living tests this was "the food crewmen missed most." The reason: Breathing air with a high carbon-dioxide content, the men need the calcium that cottage cheese gives.

SCIENCE THE SUPER SLEUTH, by Lynn Poole, Whittlesey House ($2.75). A policeman's lot is becoming happier all the time. If he can't catch and cosh the criminal on the scene, the following refinements will help track the fellow down: equipment for identifying small bits of material by suspending them in liquids, the lie detector, the spectrograph, the electron microscope, ultraviolet light, X-rays, Geiger counters and what-all. The book will be embraced by all students of Dragnet, and who among us is entirely free from this tendency?

Social Sciences

A WORLD FULL OF HOMES, by William H. Burns. McGraw-Hill Book Company, Inc. ($2.50). A house may not be a home, as a contemporary social critic has observed, but in different parts of the world and at different times anything has been made to serve as a home that protects from heat, cold, rain, snow, wind and sun. The author of this book, assistant to the director of the American Museum of Natural History, reports on a remarkable range of ancient and modern dwellings: Chinese river boats, lighthouses, Eskimo igloos, Italian beehive houses (made of loosely piled stone), Japanese paper and wood houses, trailers, Quonset huts, log cabins, caves, tents, Philippine tree houses, New Guinea grass houses, glass houses, Borneo stilt houses, Swazi straw huts, Pueblo adobe and Egyptian mud houses, double-roofed Sumatran houses built on volcanic slopes, Assyrian and American brick houses, Cape Cod shingle cottages, Roman marble houses, Iroquois bark houses, modern steel-frame apartments. An unpretentious, interesting survey for youngsters over 9.

FOOD FOR PEOPLE, by Sarah R. Riedman. Abelard-Schuman, Inc. ($2.50). This book covers the chemistry of food, the processes of digestion and metabolism, the importance of vitamins, the amount of food we need, the rational planning of diets, fads and facts concerning food, the problems of world food supply. Dr. Riedman is not a sparkling writer, but she knows the subject thoroughly, explains it well and has added to the interest of her account by giving historical and biographical details about the men whose work underlies the science of nutrition, among them Sanctorius, Antoine Lavoisier, Count Rumford, Sir Frederick Gowland Hopkins and Dr. Joseph Goldberger. A sound book which you can recommend to children of 12 and older.

THE FIRST BOOK OF CONSERVATION, by F. C. Smith. Franklin Watts, Inc. ($1.75). Here is an intelligent, well-written primer explaining the balance of nature, its disruption by man, the resulting damage to plant and animal life and to the soil, the methods of mending this damage by various conservation measures. Instructive illustrations. For children of 10 or so.

ALL ABOUT LANGUAGES, by Mario Pei. J. B. Lippincott Company ($2.75). The human race today, according to Professor Pei, speaks 2,796 different languages. In this excellent book he explains what a language is and how it works, the special languages of various occupations (did you know that bellboys refer to a tip as a "Higgins," and railroad men to passengers as fish?), the origins of place names and people's names (20 million persons in the U. S. are named John or Mary), the natural history of polite expressions, the geography and development of English, the sources of slang, jargon and abbreviations, the logic and illogic of usage and grammar. A readable and valuable account for anyone older than 12.

THE SEMINOLE INDIANS, by Sonia Bleeker. William Morrow & Company ($2.00). This is a new item in the author's series of unpretentious, informative accounts of American Indian tribes. The Seminoles—the name means "people who go to another country"—migrated to Florida two centuries ago from Alabama and Georgia, where their once populous tribes had been thinned by the wars and diseases brought in by white men. Mrs. Bleeker, using an unobtrusive fictional device, describes the migration, the character and habits of the people, how they saved themselves from extinction. A good book for 9-to-12-year-old children. Illustrations by Althea Karr.

Careers and Opportunities in Science

A HISTORY OF EVERYDAY THINGS IN ENGLAND, by Marjorie and C. H. B. Quennell. B. T. Batsford, Ltd. ($13.00). This four-volume work, long a favorite in Britain and many times revised and enlarged since the first edition appeared in 1918, is now readily available to U. S. readers through the British Book Centre in New York. The Quennells, addressing themselves to boys and girls upwards of 10 or 11 years of age, give a rich, fascinating account of how the English people worked and lived from the Norman Conquest to the beginning of the First World War. One learns about the breakfast of a 12th-century monk, the effects of the Black Death, siege operations with a trebuchet, the changes in furniture and kitchen utensils between the 13th and 20th centuries, the games children played in Chaucer's time and Disraeli's, the shoes and underclothing ladies wore in Elizabeth's reign, naval life in the 17th century, how a yeoman made his will, how children were bathed in 1400 and where one bought a bird cage, how families survived Sunday afternoons in Victoria's period, what led to the rise of plumbing and women's bustles. There are hundreds of illustrations, including color plates, photographs, paintings, prints and the author's own line drawings. A delightful, higgledy-piggledy set of volumes, appealing to adults as well as children.

PLENTY TO WATCH, by Mitsu and Taro Yashima. The Viking Press ($2.50). This is one of the most enchanting children's books published in years. It describes life in a peaceful Japanese village where Taro Yashima lived long ago when he was a little boy. There were the village school, the barrel-maker (Mr. Tanko) who made washtubs and pickle barrels, the dye house run by an old man whom people called Mr. Blue "because his arms were blue even when he wasn't working," the sweetshop where they made sweet-potato taffy and turtle-shaped cakes stuffed with bean jam, the mattress and lantern and umbrella shops, the studio of the sign painter who the children thought "must be the best painter in the whole country because he was alive, and all the great ones we read about in books were not living." When the children took the mountain road home, they saw the camphor factory where the raw camphor logs were chopped and steamed to draw out their juice, the mill where huge machines that shook the ground made fertilizer from animal bones, the blacksmith's shop, the barbershop where one sat for a haircut "before holidays," the farmers' yards busy with tool sharpening, straw-sandal making, rice pounding, rope making, persimmon drying. The text is simple; the crayon drawings are unsentimental and beautiful.

THE YOUNG TRAVELER IN SCOTLAND, by Ian Finlay. THE YOUNG TRAVELER IN NEW ZEALAND, by Hilda M. Harrop. THE YOUNG TRAVELER IN AUSTRALIA, by Kathleen Monypenny. E. P. Dutton & Company, Inc. ($3.00). These three volumes are the most recent additions to a bright, cheerful travel series for children of 12 and older. Each book describes a tour as seen through the eyes of a pair of visiting American youngsters. Up-to-date, helpful and dangerously stimulating for those with wanderlust. Good photographs.

THE CAVES OF THE GREAT HUNTERS, by Hans Baumann. Pantheon Books, Inc. ($3.00). Because they are both inquisitive and small enough to wriggle into holes in the ground, children have played key roles in the discovery of the marvelous ice-age cave paintings of southern France and northern Spain. A five-year-old girl in Spain was the first to find cave paintings, in Altamira; the caves at Trois Frères were first explored by Count Louis Begouën when he was a boy; four little boys and a dog in 1940 uncovered the famous cave at Lascaux in France. The Lascaux story, presented in a fictional setting, is the main theme of this book, which attempts to explain the origins of primitive art. The writing is somewhat murky and the translation from the original German has certainly not improved matters, but the story is so good as to be almost impervious to the teller's clumsiness. The illustrations are unbelievably beautiful. Altogether the handsomest children's book of the year.

RAINBOW ROUND THE WORLD, by Elizabeth Yates. The Bobbs-Merrill Company, Inc. ($2.50). An 11-year-old boy makes a trip around the world with a U. N. official to observe the work of the United Nations Children's Fund. A heartening report of man's humanity to man.

CAREERS AND OPPORTUNITIES IN SCIENCE, by Philip Pollack. E. P. Dutton & Co., Inc. ($3.75). The chemical industry needs from 5,000 to 10,000 chemists every year, but no more than 5,000 degrees will be granted in 1955; the median income of U. S. physicists is $6,100, but for Ph.D.'s, $7,100; astronomers don't earn as much as meteorologists; it's more profitable to be in wildlife research than in geological research; there are 62 schools and colleges offering courses in aeronautical engineering but only 48 offering four-year courses in agriculture. The author has assembled information of this kind on the science business: the fields of greatest current interest, the study and training needed to get into each, how much you can expect to earn, what scientific careers are open to women, what leading scientists have to say on scientific education, and so on. This is a rambling book, a mixture of anecdotes, statistics and homilies, but it is not dull and is worth leafing through for youngsters with ambitions in science.

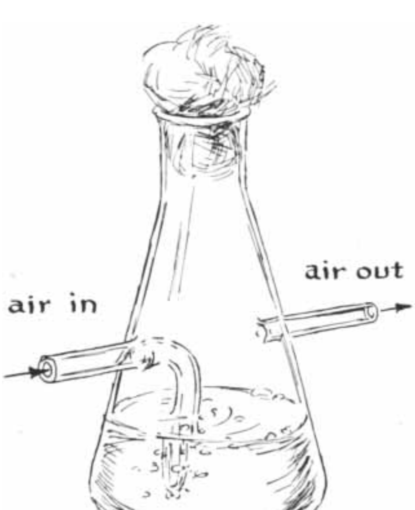
THE AMATEUR SCIENTIST

About cultivating algae from the soil and making steady telescope mountings

Conducted by Albert G. Ingalls

A retired naval architect of New York City, I. C. G. Cooper, has developed an avocation which combines half a dozen sciences—chemistry, optics, taxonomy, histology, genetics and hydroponics. All of these activities converge on one project: growing algae.

Algae have become a popular subject with science writers, engineers and even bankers, who see these aquatic plants as a promising source of food, fuel and process chemicals. When Cooper took up his hobby 20 years ago, however, algae were just scum on ponds and a subject in botany books; few laymen thought of them as objects of beauty or commercial opportunity. It is only since World War II that laboratories and pilot plants have sprung up in various countries to explore their possibilities. As Harold W. Milner reported in his article in the October, 1953, issue of SCIENTIFIC AMERICAN ("Algae as Food"), the results so far are spectacular.



Aeration flask for algal culture

On the basis of the preliminary work it is estimated that we can grow 40 tons of algae per year on every acre given over to algal culture equipment. That would be the equivalent of 20 tons of scarce and valuable protein and three tons of equally scarce fat per acre—astronomical figures compared with production rates in agriculture.

But it will be a long time before algal products appear at your corner grocery store. There are big problems to solve, and of the 10,000 species of algae that are candidates for culture, fewer than 30 have been studied in detail.

The algae range in size from microscopic single cells to kelps nearly as tall as an oak tree. Some algal species live in boiling natural springs; others thrive in the polar wastes. The algae have adopted almost every method of reproduction known to biologists. If variety is what you want in a hobby, the algae should satisfy you.

Cooper has a considerable collection of algae, but his interest is not in collecting but in culturing these organisms. He writes:

"The algae have given me an excuse for playing with a whole basement full of scientific gadgetry, which includes everything from microbalances and microscopes to geologists' picks. I have had a lot of fun with these plants, and you can imagine how stimulating it has been to see them come in for major recognition during the past few years. I must confess that when I got into this thing I had no intention of taking up a hobby, much less of tangling with a group of sciences in which I had no background. I merely started out one afternoon for a pleasant walk in the woods.

"William T. Davis, an amateur naturalist and one of the founders of the Staten Island Institute of Arts and Sciences, had volunteered to teach me how to identify some of our local wildflowers. His enthusiasm was contagious, and before the afternoon was over the bug had bitten me.

"During the next few months I gathered and mounted a lot of flowers and weeds. Before long it became evident that I was a little late with my discoveries; the specimens I collected were already represented in the Institute's display cases. It seemed pointless to go on duplicating work already well done. Then one evening at the end of a field trip I took a short-cut home by way of the beach and noticed a strange clump of seaweed waving back and forth in the low tide. I took off my shoes and waded in. After I had pulled up a specimen of the plant, I had an idea: Why not make a study of Staten Island's marine flora?

"Although that first specimen turned out to be only a common variety of rockweed, it occupies a special place in my collection because it introduced me to the thallophytes, the grand division of the plant kingdom occupied by the algae.

"You don't need a scientist's background to get fun out of collecting algae, especially the big ones. You simply float them in whole or in part onto a sheet of paper and let them dry. The leaflike parts of many consist of only two layers of cells coated with a clear pectinous substance. They dry on the paper without apparent thickness, like ink, and few artists paint more colorful or exotic abstractions.

"Things went along nicely for a couple of years, and my original rockweed grew into quite a substantial collection. Then the job became rough. As I worked my way down the scale of algal sizes, the number of species increased all out of proportion. Identification became difficult. The reference texts, which fully describe the giant kelps and often carry colored illustrations of them, become sketchy when you get down to the species that make a pocket magnifier handy.

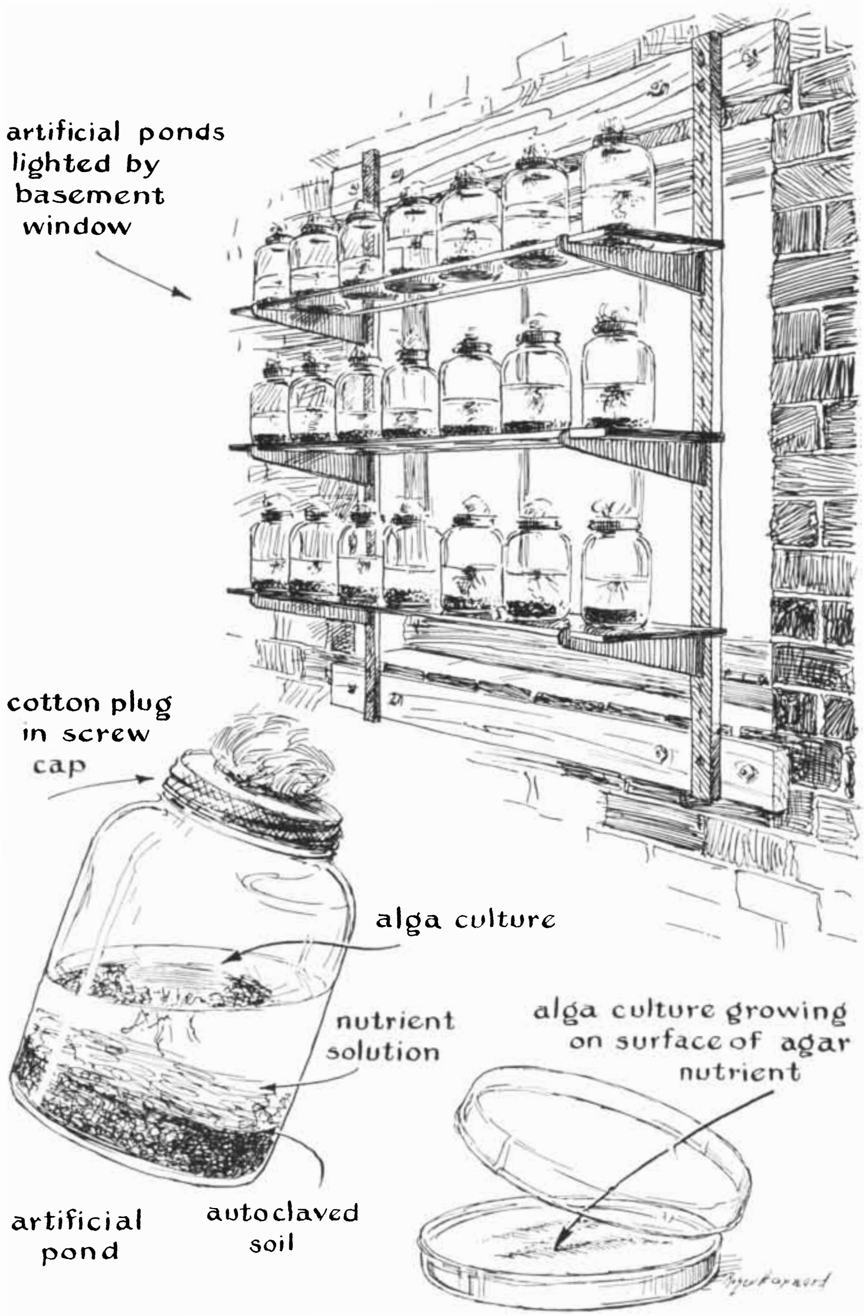
"Without knowing it would make matters worse, I bought a microscope. The first look through it almost ended my new hobby. Here was no man's land. I could not even distinguish between plants and animals, much less identify the plants. A single drop of fluid scraped from a stalk of marsh grass would hold scores of organisms, including animals that grow in branching patterns like plants and plants that swim by means of whiplike tails and eat like animals! At this point I want to put in a good word for the patience of our museum's curators and that of my fellow members in the New York Microscopical Society. They finally succeeded in teaching me how to recognize a chloroplast when I saw one, and also to identify the cellulose walls which aid in distinguishing one biological kingdom from the other.

"But learning how to tell plants from animals was only a beginning. Each drop of liquid that appears under the microscope's objective contains a unique population. Before I could complete a census, the drop would evaporate and destroy the individuals. How do you introduce order into a scramble like this, and where do you begin?

"It is a good idea, the curators advised, to commence by narrowing your field. Staten Island is not large as islands go, but in terms of its algal population it is vast. In naively undertaking the collection of all our local 'seaweed' I had staked out too much territory. After years of sampling the immensely various populations of algae in the island's waters, I decided I would have to limit myself to the less abundant algae of the soil.

"As a rule, algae are not too difficult to find in the soil once you have picked up a bit of experience in handling cultures and the microscope. But separating them into individual species and exploring their structure and behavior can get you embroiled in all sorts of puzzles and complications. Fortunately the phycologists and bacteriologists have solved the hard problems of method, and it is not difficult to adapt their techniques to an amateur's studies.

"I use the so-called 'soil-water' culture method advocated by E. G. Pringsheim of Cambridge University. In effect the algae grow in a miniature artificial pond —a glass jar of nutrient solution covering a bottom of mud [*see drawings at upper right*]. The pond is prepared by partly filling a wide-mouthed glass container—such as a peanut-butter jar—with nutrient solution, adding a tablespoonful of soil and then sterilizing the whole in an autoclave. The pond is then inoculated with the specimen of soil to be investigated. A pinch does the job. The pond is kept at room temperature and exposed to light during incubation; a window having a northern exposure is a good light source.

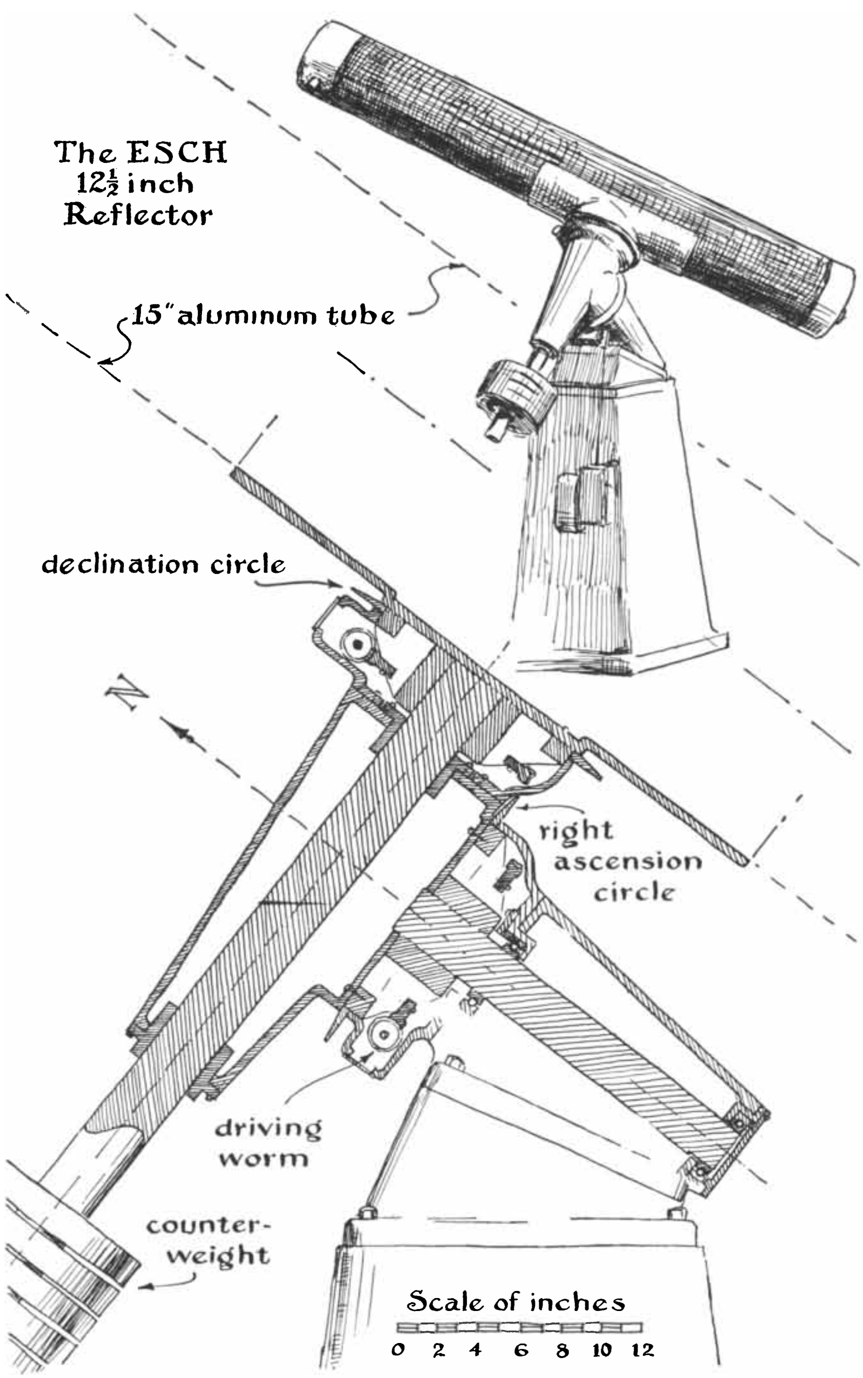


Cooper's setup for the cultivation of algae from the soil

"After incubation is completed—when the characteristic green 'scum' appears in quantity—a smear of the culture is transferred to an agar plate where it continues to grow. If the smear has been made carefully, distinct colonies of the various organisms will appear here and there on the plate. You then pick out one of these with a glass needle or a micropipette and inoculate a second sterile pond with it. What you thought was a colony of identical organisms will likely prove to be a mixture—but the second pond will be less motley than the first. You continue this cycle of operations until your species appear in splendid isolation—or your patience gives out. Sometimes I wonder if it is possible to develop a perfectly pure culture of anything.

"Single-celled algae are enveloped by the same pectinous substance that causes the giant kelps to dry on paper so beautifully. This sheath is usually alive with bacteria. Just try to kill them without killing the algae! Irradiation by X-ray or ultraviolet light in measured doses tends to kill the bacteria without destroying all the algae. But even if you succeed in knocking out the bacteria without damaging the plant, you still face the job of separating the alga from the culture without contaminating it and of inducing it to grow in a fresh pond. I have not tackled that experiment so far. Problems like this can tempt you into getting mixed up with X-ray machines and lots of other costly gadgetry.

"Keeping things simple and resisting the urge to follow every byway that opens is the most difficult part of my hobby. This year my resistance broke down again, and I am now constructing a reflecting spectroscope, as described in *Amateur Telescope Making—Book III.* It requires time which should perhaps be devoted to the cultures. But I reconcile this cost by telling myself that I have learned a little about replica gratings and that a mighty useful gadget will soon be on hand. You come up against a lot of chemical problems in the course of growing algae, such as the analysis of nutrient solutions for their content of minor elements. My limited chemical facilities were not up to such exacting work and so I sold myself on the necessity of taking time out for constructing the spectroscope and learning how to use it for chemical analysis.



An amateur's telescope re-equipped with adequate axes

"The artificial-pond technique always leaves you with a number of chemical unknowns. I hope the spectroscope will eliminate some of them. The growing culture takes part of its nourishment from elements added to the solution and part from sterilized soil. The first are under your control. If we could grow cultures by pure hydroponic methods, a lot of question marks that come with the soil would vanish. But that would necessitate a comprehensive knowledge of the organism's nutrient requirements in advance of growing a culture of it. Hence we combine the major elements—nitrogen, potassium, magnesium and others common to all plants—in the nutrient solution and rely on the 'mud phase' to supply the minor ones plus other unknown factors such as vitamins. The mud also serves as a reservoir and a place of reduction and synthesis for keeping the heavy metals in solution. Incidentally, the proper soil for the pond's bottom must be found by trial. After a lot of sampling, I located one that works unusually well. A large quantity of it was sterilized at one time by autoclaving and stored in sealed containers for future use.

"Friends sometimes ask what I do with an alga when it has been isolated and added to the collection of cultures. In a way that is like asking a philatelist what he does with his stamps. If he is a good philatelist, he preserves them carefully and tries to learn something from them. Preserving live algae is no less satisfying nor more difficult than caring for any other plant. If you give them light, water and food, and maintain the temperature they prefer, they glow with health. In turn they challenge you to discover how they react to such things as subtle changes in diet; how, when and by means of what mechanism they reproduce; what products their metabolism yields—and the countless related secrets of their life processes. In accepting this challenge you can, as they say, dive in as deeply and stay down as long as you wish. I have been at it now for some years without getting more than my feet wet.

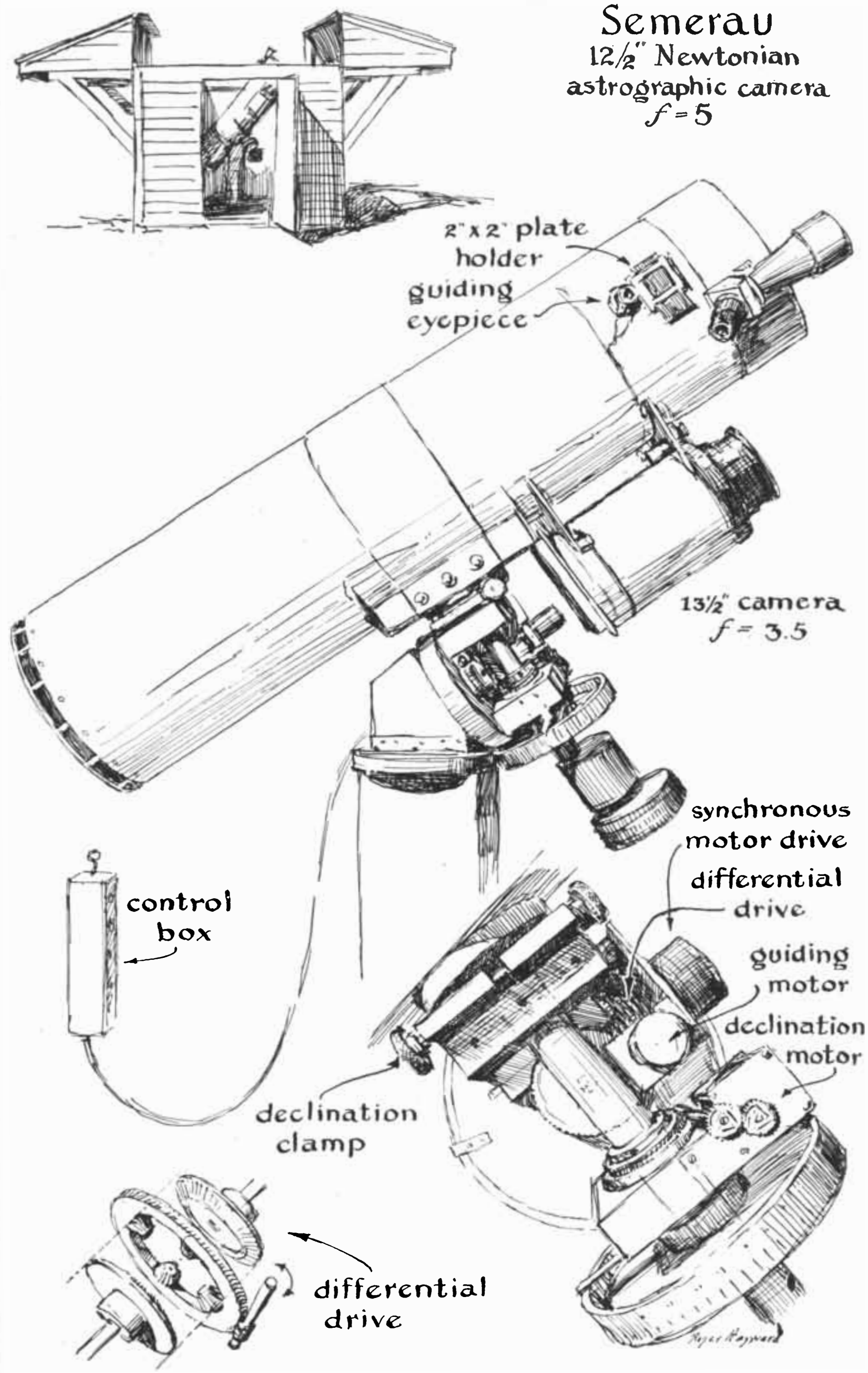
"Those who enjoy hydroponics like to develop nutrients, and I have had some success in this work. One series of experiments ended in a solution which seems to work better for me than those listed in the reference texts. You lay out a set of slightly differing ponds in a rectangular grid, with a single element in the nutrient progressively diluted more and more in each vertical row. The entire grid is inoculated and kept under observation. A detailed record of the culture's reaction in each pond is made. The experiment can be continued by simultaneously altering the strength of two elements in each vertical row, then three elements and so on. An analysis of the accumulated record discloses the ideal concentration of each element in the nutrient for the species under study. Incidentally, a culture subjected to this study becomes a tool of great power and subtlety for investigating unknown nutrients. The alga's reactions when transferred to the unknown nutrient provide an indication of the ingredients present and, in some cases, a quantitative measure of their concentrations.

"Once a culture has been standardized, that is to say, brought to a reasonable state of purity and provided with the preferred nutrient, it suggests endless other experiments. If the alga employs sexual reproduction, for example, you can attempt to mate it with a near relative and create a hybrid. It is interesting to modify a plant's diet and observe the result. A heavy concentration of nitrogen can cause *Chlorella*, an alga which may become commercially important, to increase its production of protein from about half its weight to almost 90 per cent. In contrast, putting Chlorella on a starvation diet of nitrogen boosts fat production from something under 10 per cent to more than 70 per cent. The commercial implications are obvious.

"It is easy to see how such metabolic gymnastics can fascinate the amateur. Learning to observe such changes, to take the plants apart and measure the substances of their bodies, or those that appear as by-products, will bring you into contact with as many fields of science as you have time and talent to enjoy."

An ideal approach to becoming an advanced amateur astronomer is to begin by building a 6-inch reflector, use it a season, and then progress to 8-inch, to 10-inch and (if that does not satisfy) to 12½-inch telescopes—the sizes are based upon available Pyrex mirror disks. This sounds like a long lot of hard work. But to start with the ultimate size robs the builder of the fun of designing and making the series of mirrors and becoming an expert in the process. After building several telescopes an amateur has a right to regard himself as advanced and seasoned.

This account is about two amateurs who began with a 12½-inch telescope be-



An "amateur-professional-amateur's" fine instruments

cause they had inherited a 12½-inch mirror completed by a friend who had died. Robert and Karl Esch of Cherryvale, Kan., and their neighbors put "uncounted hours" on the project (see this department for May, 1952), but when they put the big telescope to use, the stars danced in the eyepiece. They had used solid steel axis shafts 1⅞ inches in diameter, but evidently these were not massive enough. After inspecting a professionally built instrument at the University of Kansas and noting its massive solidity, Robert went home and wholly redesigned and rebuilt the mounting. Roger Hayward's drawing on page 110 shows its new proportions. Karl says: "This one really has rigidity. I had little to do with the mounting, which was designed and built by my brother Bob, though I made a new 12½-inch mirror for it and was responsible for the rest of the optical parts."

What the brothers had overlooked in their first mounting was the fact that a telescope magnifies tiny vibrations in proportion to its own magnification and must therefore be much more rugged than other machines.

Robert's new design was inspired by illustrations in the *Amateur Telescope Making* books of Russell W. Porter's stocky mountings for a 12-inch reflector and for the 18-inch Schmidt at the Palomar Observatory. Robert says: "The result of all our efforts in fattening the axes was more than fruitful."

It has sometimes been urged that the data of engineering stress analysis be furnished for guidance in the design of telescope mountings. Such instructions were published in this department in April, 1951, but they have had no observable effect beyond the fact that a number of readers quarreled with them because they called for mountings that seemed unnecessarily rugged. Axes 6 7/16 inches in diameter for a 12½-inch telescope were "big beyond reason." One who quarreled with them was Karl Esch, then an engineering student. Nevertheless, older brother Bob made the new housings eight inches in diameter.

I have an inch-thick file of round-robin correspondence on this matter with advanced amateurs. Some of the readers quarreled with each other. From the protracted argument the main facts that emerge are that the sizes of telescope parts are highly dependent upon the assumptions made at the beginning, and that these assumptions vary, are arbitrary and have only an uncertain basis in optics. A dozen readers were to contribute instructions for making a stress analysis of a telescope, and the best was to be chosen for use in *Amateur Telescope Making—Book One.* But nothing fruitful resulted. Thus after going full circle we return to an original hunch that the successful builders, such as Russell Porter and Robert Esch, usually arrive at a sufficiently rugged mounting by intuition and judgment, while those who feel they need instructions would probably reject the stress-analysis answers anyway.

The Esches found that their neat one-legged support for the diagonal mirror resonated in vibration when the Kansas "zephyrs" whistled down the telescope tube, blurring the image. They substituted a more conventional three-legged support spider.

Robert writes: "We are most proud of the simplicity of the driving controls, now that we have added a drive. The drive uses a synchronous ball-bearing motor of 1/20 horsepower and 1,800 revolutions per minute, geared through a 96-3-3-30-100 gear combination to give a ratio of 2,592,000 to 1. While this does not give perfect sidereal time, it would be wasteful to buy special gears for a closer approximation." Karl adds: "I set the telescope on Sirius and went indoors for an hour to blot up heat and on returning I found Sirius still in the field."

Walter J. Semerau, whose astrographic camera and still larger guiding telescope are shown on page 112, is a professional scientific instrument maker for whom telescope making is a hobby. Before he built these instruments he had made some simpler telescopes. He writes:

"For photographic work a telescope must be as rigid as a rock throughout. The mirror is mounted on a nine-point support system in a cast-aluminum cell attached to a 60-inch length of 14-inch aluminum tubing with walls one eighth of an inch thick. One half of a rebuilt 10-power binocular with illuminated cross-hairs is attached to the side of the main tube and is used for wide-angle photography. If photographs are to be made simultaneously with it and the reflector, the guiding is done with a special guiding eyepiece on the telescope. This eyepiece receives light from a single star near the edge of the field, lengthens its own focus with a tiny negative lens, and reflects it into the eye with two tiny diagonal prisms. This guiding eyepiece has a 1¼-inch focal length and is equipped with illuminated cross-hairs. These must be parallel to the motion of the star and at right angles to the declination."

Roger Hayward comments on this telescope: "Semerau has a very professional instrument. The only weak spot is the guiding eyepiece, which is fixed. There are lots of things one would like to photograph for which there is no convenient star at just the right distance and spacing to fit his instrument. Therefore guiding eyepieces should be arranged to be fixed at any orientation around the plate holder. When I built my photographic attachment, I arranged things so that the plate holder and eyepiece could be rotated around the line of sight. The professionals use two guiding eyepieces which are clamped to the plate holder. They are adjusted to fit two stars so that the plate holder can be set aside with the eyepieces still attached and the exposure continued at some future time. The two eyepieces insure replacing the plate holder in both the same orientation and direction. It is also more convenient if, as Semerau states, the cross-hairs are parallel to the motion of the star and at right angles to the declination, but I have guided the 100-inch telescope at the coudé focus with the angle between the cross-hairs and the right ascension and declination motions changing over a period of two hours. It can be done."

INDEX OF ADVERTISERS

DECEMBER, 1954

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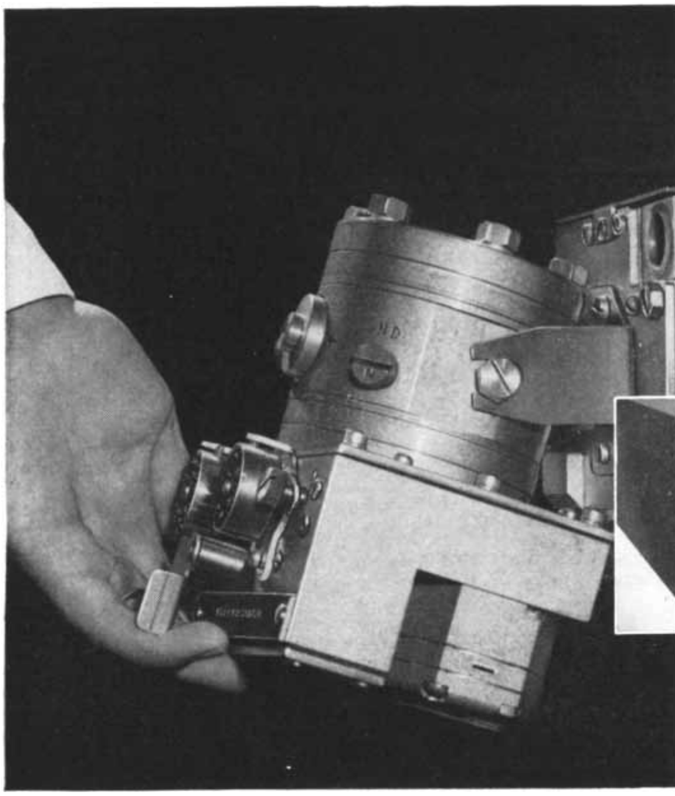

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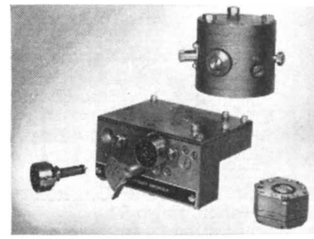

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