SCIENTIFIC AMERICAN

CRYSTAL GROWTH

FIFTY CENTS

March 1955

University of Virginia: Thomas Jefferson, Architect.

Leaders . . . for tomorrow

"What greater or better gift can we offer the republic than to teach and instruct our youth?"*

"SHOULD I GO TO COLLEGE?" That all-important question is in the minds of many high school students. That they find the right answer is equally important to every one of us . . . and to the future of America.

GREAT GAINS TO YOUTH have been accomplished through education. Still, four out of five of our young people do not go to college. Some of these may have a spark of genius, or leadership talent, that will be wasted through lack of educational opportunity.

400 UNION CARBIDE SCHOLARSHIPS have been provided for through The Union Carbide Educational Fund to encourage able and deserving students toward successful careers in business. Scholarships are now open without special restrictions—through 45 selected liberal arts colleges and technological institutes—to all students of high schools and preparatory schools.

THE PEOPLE OF UNION CARBIDE hope you, too—as you think of the future for your children and other deserving American youth—will do everything you can to encourage their ambitions for adequate education. Also, that you will join in giving co-operation and encouragement to those who guide and teach them.

TO LEARN MORE about the Union Carbide scholarships, their purposes, and the colleges, institutes, and universities in which they have been established, write for booklet Q.

*Cicero

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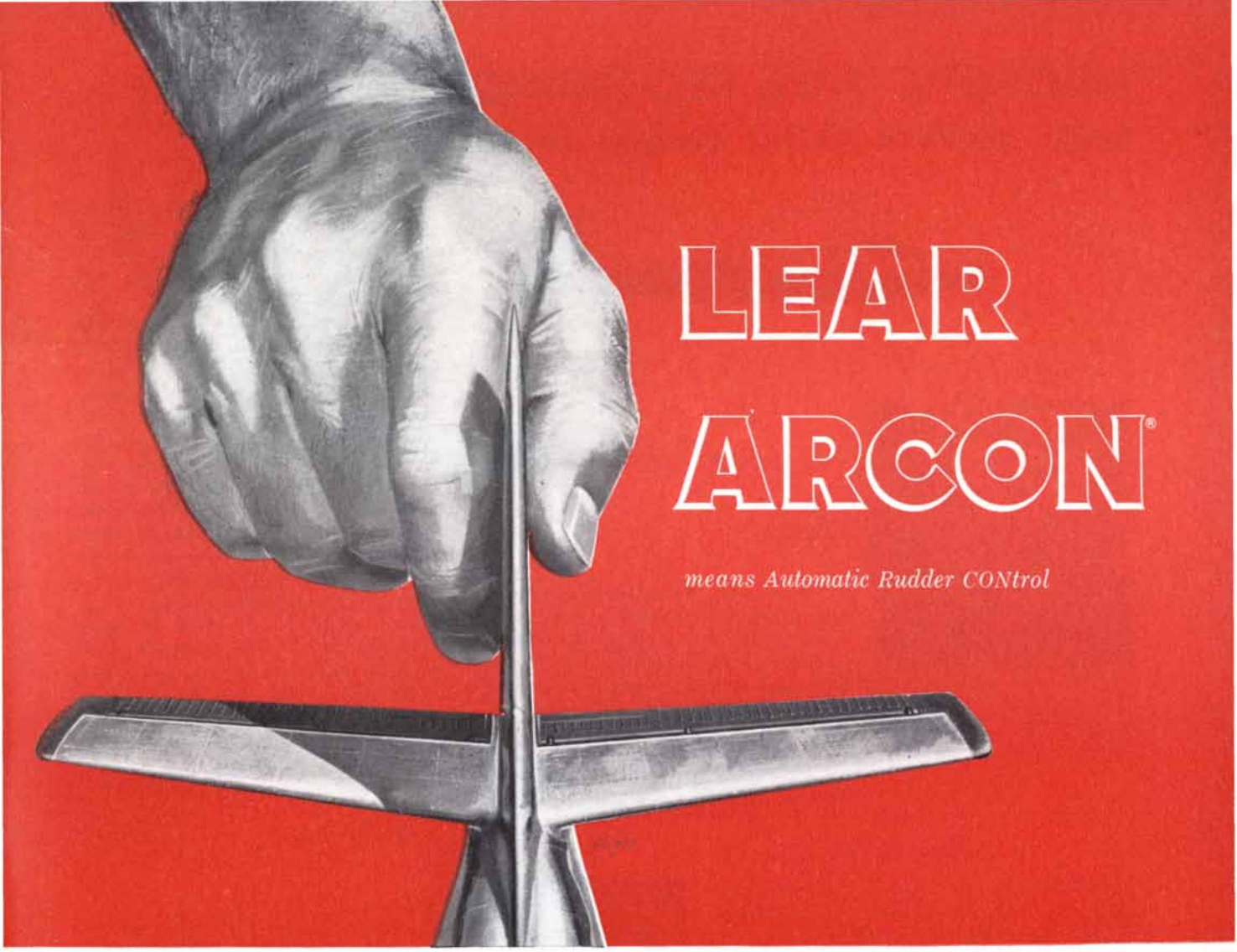

"Marks the beginning of a new era of both utility and safety"

... says Leighton Collins, Editor Air Facts Magazine

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IS THE ARCON AN AUTOPILOT? No, but it is the *next best thing* to an autopilot, especially when you are under pressure to do something else, such as navigate, communicate, or just plain relax.

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IS IT PILOT APPROVED? Ask any pilot who has had an opportunity to fly it. You will soon find very few pilots who will fly without it, because it makes an airplane fly the way it should – automatically. The Arcon is here *now*. See it. Fly it. Discover how it "marks a new era of safety and utility" for *you!*

* * *

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LETTERS

Sirs:

The writer has immensely enjoyed David B. Steinman's fine article on bridges [SCIENTIFIC AMERICAN, November, 1954], and the accompanying illustrations are certainly thrilling.

The impression may be gained that the Florianopolis Bridge was the first span using rocker towers. Here in the U. S. in the Muskingum River crossing near Trinway, Ohio—designed by Professor Clyde T. Morris in 1913 and 1914—this feature was incorporated. The towers are pin-connected to the eye-bar chains at the top and rest on pins at the piers, so that as the shape of the chain curve changes under a moving load, the towers may rock slightly without being subjected to transverse loading of any kind; much as if one stands his pencil upright and, placing his finger firmly on the upper end, rocks the pencil back and forth. . . . The pier ends of the trusses at Trinway also rest on posts pin-connected at both ends.

T. S. NEEDELS

Houston, Texas

Sirs:

The letter from T. S. Needels and his interest in my article are appreciated.

I did not intend to imply that the

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Florianopolis Bridge (1922-26) was the first suspension bridge using rocker towers. I am glad to be reminded that my friend Clyde T. Morris built one in 1913-14. I believe, however, that the rocker towers at Florianopolis were the first application to a bridge of that magnitude and thereby served to direct attention to that feature. Moreover, instead of resting on pins on the piers the Florianopolis towers were true rockers (like a rocking chair). The bottom on each tower leg had its bearing on a flat steel casting on the pier. Steel dowels (cycloidal) prevented any creeping of the rocker. Pins introduce secondary stresses through friction; true rockers avoid this defect.

D. B. STEINMAN

New York, N. Y.

Sirs:

In explanation of the case of a woman possessing erythrocytes of groups A and O, Sir Macfarlane Burnet ["How Antibodies Are Made"; SCIENTIFIC AMERICAN, November, 1954] postulates a common placental circulation with a fraternal twin and the exchange of "blood cells."

If we accept the theory of Burnet and Frank Fenner regarding a "critical point in formation of recognition units," we may readily explain a continued tolerance in such a host individual to transfusions of this alien type of erythrocyte. Since erythrocytes, however, have a life span measured in weeks, it is clear that the acquisition of alien red blood cells in the assumed manner could not explain the continued presence of such cells over a 25-year period. We must assume, instead, (1) the transfer of a mass of erythropoietic cells from one embryo to the other and (2) either (a) the continued proliferation in an adult site of this donor tissue or (b) some influence of this "graft" on the differentiation of the erythropoietic tissue of the host. The final result in either case must be the existence in the adult host of discrete functional masses of erythropoietic tissue of two genetic types.

DAVID FROST

College of Pharmacy
Rutgers University
Newark, N. J.

Sirs:

I think the point made by Dr. Frost is quite a good one and one which I

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would have elaborated in any fuller account. He is quite correct that for the continuance of the "foreign" red cells in the circulation after birth one must postulate functional haemopoietic tissues also of the foreign genetic type. The erythropoietic cells, however, are just as alien as the erythrocytes they produce, and the same principles hold. The point probably should have been made in the article but I was anxious to keep the presentation as simple as possible.

F. M. BURNET

The Walter and Eliza Hall Institute of Medical Research
The Royal Melbourne Hospital
Melbourne, Australia

Sirs:

I am writing this in regard to an article which appeared in your November issue. In this article, which was entitled "Trade in the Ancient World," Lionel Casson stated that ships of that period had no rudders by which to steer them. I am of the opinion that this is not true and, as proof, I state the following quoted from *The Odyssey* of Homer, Chapter 9.

"He made a mast too, and a rudder by which to steer the raft, also he made a bulwark of skin which was to keep out waves."

I am a student of Bryant High School and I find your magazine very helpful in my school work.

JUDITH GOLD

Jackson Heights
Long Island, N. Y.

Sirs:

Miss Gold has put her finger on a key passage—Homer's description of how Odysseus built a raft, the earliest account we have of boatbuilding.

Ancient ships had steering oars, not rudders. It is the translator, not the poet, who set Miss Gold off the course. Homer's word (*Odyssey*, Book 5, line 255) is *pēdalion* which, although it can be loosely translated "rudder," really means "steering oar." A good example of one can be seen in the illustration on page 99 of my article.

LIONEL CASSON

Department of Classics
New York University
New York, N. Y.

Never Clean, Dress, or File the Contacts

Here is a magnetic motor starter that is "the industrial engineer's delight." You can install the Bulletin 709 solenoid starter . . . and forget it.

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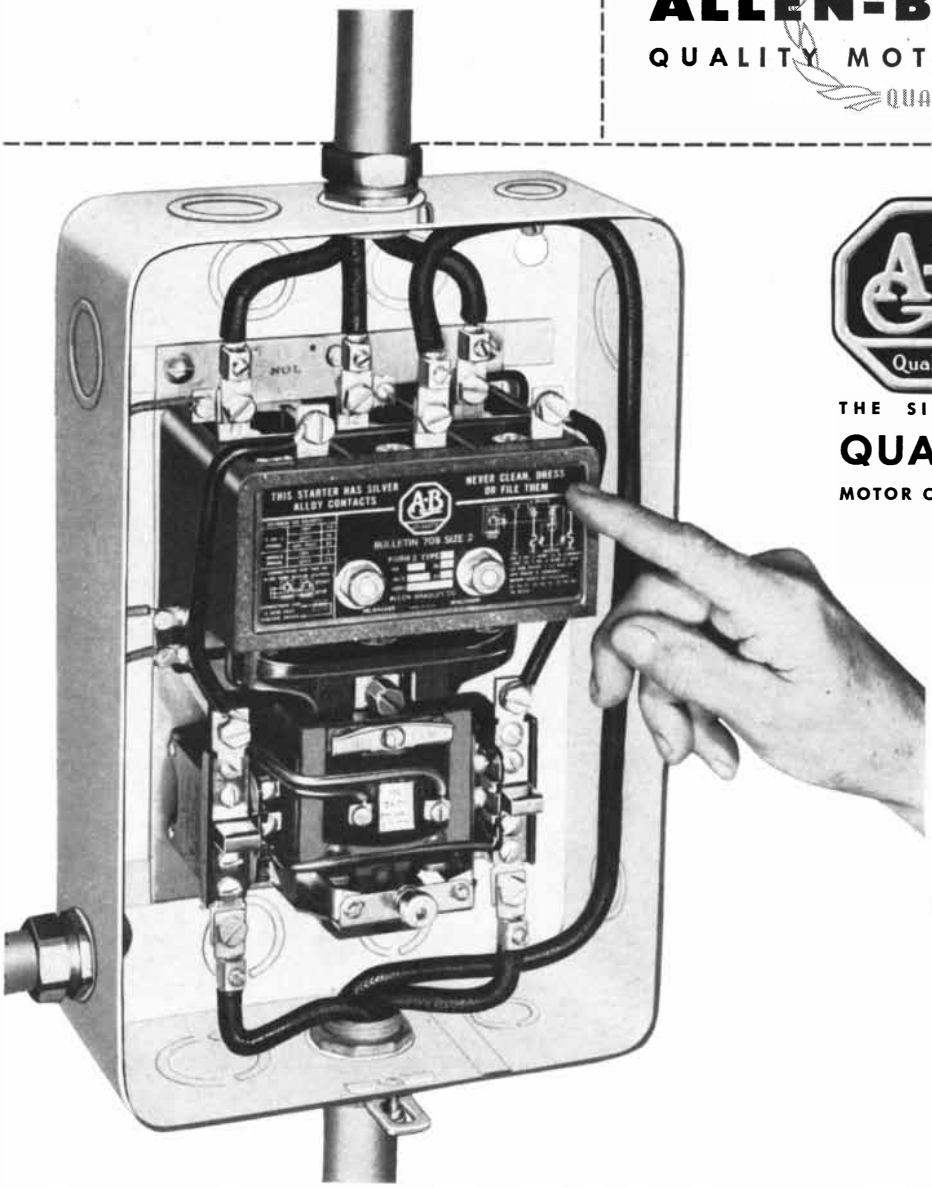

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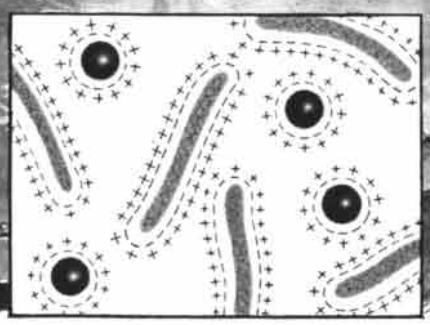
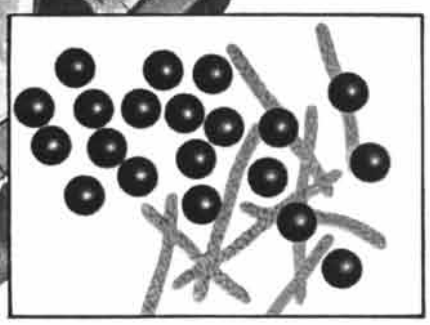
Bulletin 709 solenoid starters are made in 8 sizes up to 300 hp, 220 v; 600 hp, 440-550 v. Note the white interior which makes wiring and inspection easier in dark locations.

In a large mixing tank, new procedures for precise control of ions permit rubber particles to form an even coat on paper fibers, producing impregnated paper products with a multitude of new industrial applications.



Paper fibers and tiny rubber particles will not combine when merely suspended in water. One theory explains that ions, or electrically charged atoms from the water, collect in double layers on both rubber and paper. These layers act like protective envelopes that keep the two materials apart.



It's easy to remove the double layers from both materials . . . by adding an electrolyte, such as salt, to the water. But the rubber still will not deposit on the paper fibers. Instead, the rubber particles cluster together in stringy masses that research workers were quick to nickname "rhubarb."

How a new method of "ion control" is opening up amazing industrial uses for paper

For years it was believed that a material made of rubber-coated paper fibers would have almost unlimited possibilities—as a base for artificial leathers, as a filtering medium, for use in low-cost gaskets, and in many other industrial applications.

To make such a material, and make it inexpensively, Armstrong research workers felt that the individual fibers had to be coated with large amounts of rubber while they were suspended in a liquid . . . in the watery pulp stage of paper manufacture. But they also knew that suspended paper fibers and rubber normally wouldn't combine uniformly in the right proportions.

The reason for this situation was well known. In fact, the 19th Century writings of a German physicist named Helmholtz describe the phenomenon that occurs when particles of any material are suspended in water. Double layers of tiny electric charges — called ions — form protective envelopes around the particles and keep them apart.

A few years ago, a group of Armstrong research chemists set out to make practical use of the Helmholtz Double Layers. After working through a year-long maze of experiments, they hit upon a process which precisely controlled the layers of ions. With it, rubber could be made to coat paper fibers evenly and thoroughly and in amounts as large as 100 per cent of the fiber weight.

Most important, this new process was adaptable to mass production with virtually no sacrifice of laboratory accuracy. Completely uniform compositions could be made combining rubber and fiber in almost any useful proportion. Saturated papers with wider and more interesting industrial applications thus became possible.

A low-cost gasket material of unusual dependability is one of the many applications of the new Armstrong process. This material, called Accopac®, also contains finely ground cork. It is resilient, dimensionally stable, and impervious to most common fluids, even at bolting pressures as low as 800 pounds per square inch. Accopac already is widely used in automotive equipment, aircraft devices, appliances, and many other consumer and industrial products.

For more information about Accopac, write for the 24-page manual, "Armstrong's Gasket Materials." It's free to industrial users. Write Armstrong Cork Co., Industrial Division, 8203 Inland Road, Lancaster, Penna.

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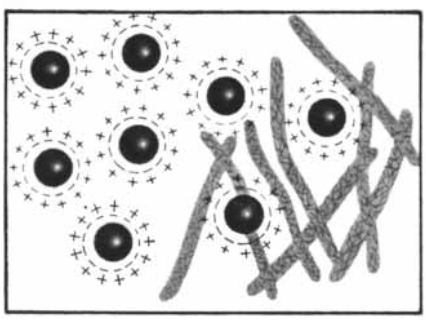
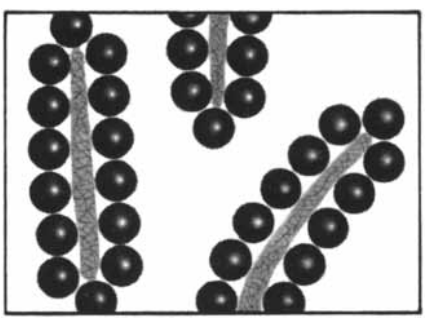
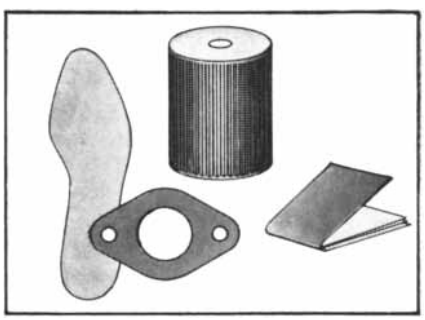


If you remove the charges from the paper fibers only, the double layers of ions on the rubber particles keep the rubber particles from sticking to each other. But these layers also keep the rubber from sticking to the paper fibers except in a random, haphazard manner. This obviously is not the answer.



The trick, then, is to remove the double layers from the fibers only, while those on the rubber are merely made thinner. This is managed so the layers on the rubber particles remain thick enough to keep the rubber from bunching, but not thick enough to keep it from coating the fibers uniformly.



A practical and precise method of ion control is what Armstrong research chemists developed. Commercial applications include new and far better saturated papers for artificial leathers, gasket materials, oil filter cartridges, notebook covers, shoe insoles, and many other important industrial uses.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

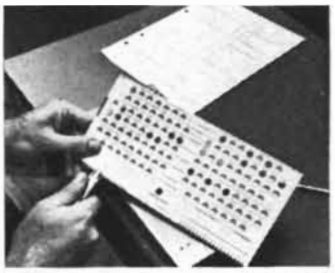
MARCH, 1904. "News comes from Buenos Aires that the Charcot Antarctic expedition has arrived at Puerto Madryn, Argentina. A telegram received from Dr. Charcot is as follows: 'We wintered at Wandel Island and carried out all our scientific work under favorable conditions. The question of Bismarck Strait was solved, our party passing through it. We reached Alexander I Land, though ice prevented our landing. We explored several unknown points on Graham Land. Notwithstanding the fact that our vessel grounded, sustaining a serious leak, we were able to continue the voyage and determine the contour of the external coast line of the Palmer Archipelago.'"

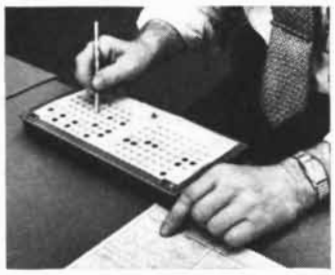
"The boring of the Simplon tunnel between Italy and Switzerland has at last been completed, the thin diaphragm of rock that separated the two headings having been finally burst through on February 24, 1905. The tunnel is 19.729 kilometers, or 12¼ miles, in length, constructed with twin passages, each 16½ feet wide, and separated by a distance of 55.7 feet between their axes; it is straight except for a short curve at each of its ends. The success of an enterprise of such magnitude marks this as the greatest event in civil engineering for several years past."

"Dr. Perrine of the Lick Observatory has discovered a seventh satellite of Jupiter. The discovery of the seventh moon was made on January 6, the day following the announcement of the discovery of the sixth satellite, when Mr. Perrine resumed his comparative examination of the negatives secured and was rewarded by discovering the image of a very faint body which changed its position from night to night."

"M. Berthelot, in a paper read before the *Académie des Sciences*, gives an account of an examination he recently made of some samples of metal from ancient Egypt. Some of these were sent to Paris by Prof. Maspero, and came from

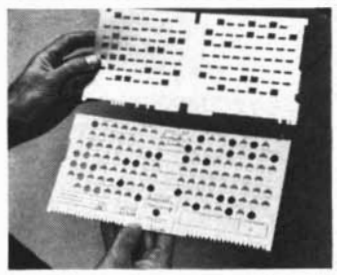
How your telephone call asks directions... and gets quick answers





Perforated steel cards, which give directions to the Long Distance dial telephone system, are easy to keep up to date. New information is clipped (1) and punched (2) by hand on a cardboard template. This guides the punch-press that perforates a steel card (3), and the two are checked (4). The new card is put into service in the card translator (5).

↓3



When the Bell System's latest dial equipment receives orders to connect your telephone with another in a distant city, it must find—quickly and automatically—the best route.

Route information is supplied in code—as holes punched on steel cards. When a call comes in, the dial system selects the appropriate card, then reads it by means of light beams and phototransistors. Should the preferred route be in use the system looks up an alternate route.

It is a simple matter to keep thousands of cards up to date when new switching points are added or routing patterns are changed to improve service. New cards are quickly and easily punched with the latest information to replace out-of-date cards.

This efficient, flexible way of keeping your dial system up to the minute was devised by switching engineers of Bell Telephone Laboratories, who are continually searching for ways to improve service and to lower costs. Right now most of the Long Distance dialing is done by operators, but research is hastening the day when you will be able to dial directly to other telephones all over the nation.

BELL TELEPHONE LABORATORIES

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

a tomb which he opened not long ago. The tomb is probably of the end of the second dynasty or the beginning of the third. An analysis made upon small quantities of the matter gave 56.7 per cent copper and 2 per cent tin. There were also traces of zinc, and in the coating was found a considerable proportion of chlorine, carbonic acid, oxygen and lime, but no arsenic, lead, silver or iron, at least in any great measure. This specimen is of interest from its great antiquity, as it goes back to the most remote epochs of the ancient empire. The presence of small quantities of tin at this epoch is remarkable. This metal no doubt comes from the voluntary addition of a tin-bearing mineral to the copper ore."

SCIENTIFIC AMERICAN

MARCH, 1855. "Prof. Vierordt has been exhibiting a machine at Frankfort to record on paper the beatings of the pulses. The arm of the patient is placed in a longitudinal cradle, and screwed down sufficiently to keep it steady. A small erection on one side holds a sort of lever worked on a hinge, at the end of which a pencil is inserted, the point of which has been dipped in Indian ink. The lever rests upon the pulse, and at every moment records the action. A more accurate and more ingenious machine has been developed in this country. The invention of this instrument, called the sphygmograph, was occasioned by the wish of Dr. C. Hering of Philadelphia to have a machine for such a purpose. It was invented by Mr. E. F. Hilgard of the U. S. Coast Survey, and made in Washington about a year ago. It is an electro-magnetic machine, recording on the same strip of paper the time and the number of beats of the pulse; it is, in fact, a Morse recording telegraph instrument, with two magnets, two batteries, and a clock. The current of one battery is broken by the stroke of the pendulum of a clock, each stroke making a dot. The current of the other battery is broken by the pulse; each beat of the pulse breaks the circuit and makes a dot."

"A very important patent trial relating to an improved process of photography lately took place in London between Fox Talbot, plaintiff, and M. Laroche, defendant, for infringement of the plaintiff's patent, he being the author of the art which has been named "Talbotype,"

Boeing offers a real creative challenge to engineers

This Boeing engineer is determining antenna properties that will influence the design of supersonic airplanes which still are in their preliminary study stage. This illustrates the variety and challenge Boeing offers in many fields: civil, electrical, mechanical and aeronautical engineering, mathematics and applied physics.

Emphasis at Boeing is on engineering excellence. Boeing engineers develop airplanes and guided missiles for jobs never done before, at altitudes and speeds never reached before. They work to closest tolerances of weight and space, using new materials like titanium and magnesium alloys, acrylics and plastics. If this challenge interests you, there is a place for you on a Boeing design, research or production team.

Recent Boeing developments like the B-47 and B-52 jet bombers, the F-99 guided missile, and America's first jet tanker-transport are evidences of solid growth and engineering skill. New projects are already under way in widely diversified engineering fields: rocket, ram jet and nuclear propulsion, supersonic flight, guided missiles, research in new materials, and much more.

Boeing now employs nearly twice as many engineers as at the peak of World War II. And more engineers are needed. As a Boeing engineer, you will work with the most advanced equipment, like electronic computers, the world's fastest and most versatile privately owned wind tunnel, superb laboratories, and the huge new Flight Test Center.

You can be sure of individual recognition at Boeing as a member of a tightly knit "team." Promotions come from within the organization, after regular merit reviews. You will be encouraged to take graduate studies while working, and will be reimbursed for all tuition expenses.

JOHN C. SANDERS, Staff Engineer — Personnel
Boeing Airplane Co., Dept. 16-B, Seattle 14, Wash.

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in honor of the discoverer. He secured an American patent in 1847, nine years after his first English one was granted. M. Laroche set up the defence of non-infringement,—that his process was entirely different; also that Fox Talbot was not the first discoverer of photography. The new process of M. Laroche was discovered in 1851 by a Mr. Archer, and was stated to consist in the use of collodion (gun cotton dissolved in ether) in the treatment of the plate before it is placed in the camera. When withdrawn, the latent image is developed by pyrogallic acid, or protosulphate of iron, and is fixed with hyposulphate of soda. Some eminent chemists gave testimony that this was merely the Talbotype under a modified form. On the other hand, Robert Hunt (perhaps the best authority of all) gave evidence that collodion possessed unknown photographic powers, and that pyrogallic acid was more sensitive than the gallic acid of Mr. Talbot. The Chief Justice, in summing up the case, stated, it was very evident that Fox Talbot was the first to discover the latent image, but as this was a philosophical discovery, from its nature, it could not be the subject of a patent which only embraced the means of producing the result. The verdict of the jury was that the plaintiff was the first inventor, but that there was no infringement of his patent by the defendant."

"*La Crónica*, a Spanish journal in New York City, says that Dr. W. L. Humboldt has discovered means to prevent yellow fever by inoculation. The government of Cuba, as *La Crónica* is informed, has directed the inoculation of the major part, amounting to one thousand, of the newly arrived troops, which has resulted in the greatest success, since none has been attacked by this terrible disease, which generally decimates the foreign population shortly after their arrival. The operation is similar to vaccination, in that the virus discovered by Dr. Humboldt is inserted, generally in both arms. A few hours later the symptoms of a miniature yellow fever commence, and all the pathological consequences follow rapidly and slightly, rarely exceeding 48 hours in duration, and with nothing more than a slight feverish action."

"In some sections of the State of Mississippi the people, it is reported, have pulled down a number of miles of telegraph wires, because some learned ignoramus had demonstrated to them that the long drouth in these regions was caused by these wires carrying off the lightning, which used to bring rains."

For America's first jet tanker-transport fleet...

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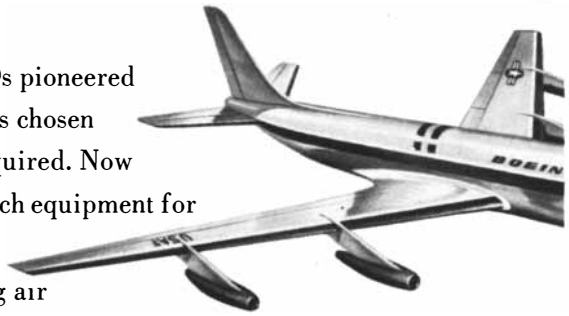

History repeats. When Boeing B-29s pioneered heavy bomber flying at high altitudes, AiResearch was chosen to supply the cabin-conditioning equipment required. Now Boeing has again selected AiResearch equipment for its sleek new KC135s.

AiResearch has unmatched experience in developing air conditioning equipment for the majority of present day commercial and military aircraft. It has produced more complete air-conditioning and pressurization systems and components than all other manufacturers put together.

Once more a leading manufacturer confirms that where proved designs, reliability and high performance are required, AiResearch is the choice in its field.

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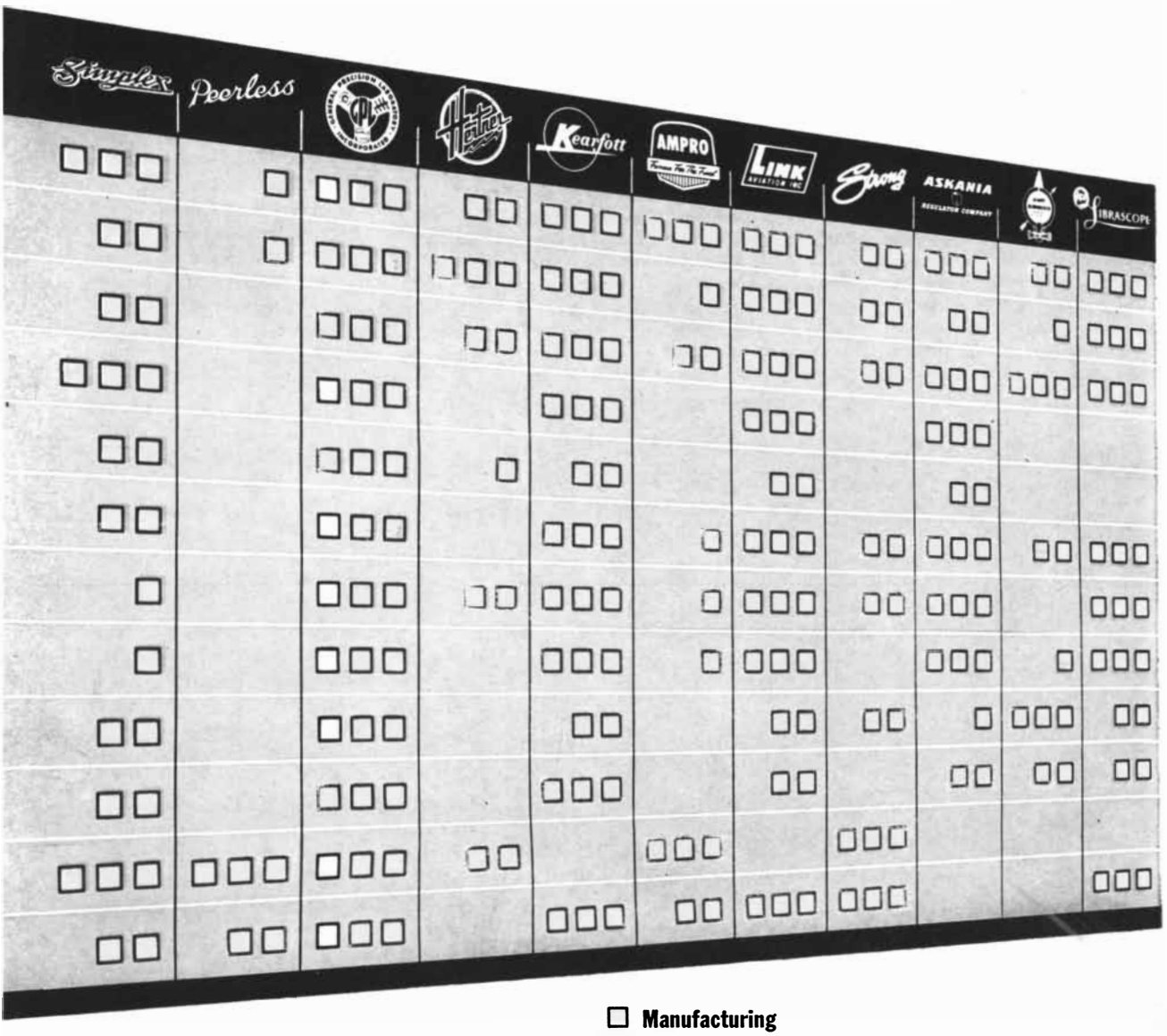

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THE AUTHORS

ROBERT F. BALES ("How People Interact in Conferences") is a lecturer in sociology and a research associate in the Laboratory of Social Relations at Harvard University. He grew up in a small town in Oregon, where he spent most of his spare time in amateur radio, model plane building and other shop hobbies. He writes: "I really became interested in social interaction as a result of skepticism about its importance. In a graduate seminar at the University of Oregon I maintained there was something nonsensical about my professor's question: 'How can we measure social interaction?' I have been busy reversing my position ever since." Bales's interest in the psychological mechanisms controlling behavior led him to a study of Alcoholics Anonymous and later to an attempt to solve "the classic riddle as to why rates of alcohol addiction are so low among Jews." After receiving his degree in sociology at Harvard in 1945 he spent a brief period of research with the Section on Alcohol Studies at Yale. Then he went to Harvard in 1946 to develop laboratory methods for the study of small groups. Bales's spare-time interests are landscape painting and music. His wife is a violinist and he plays the guitar.

JOHN D. KRAUS ("Radio Telescopes") is professor of electrical engineering at the Ohio State University. He did his graduate and undergraduate work at the University of Michigan, where his father taught mineralogy and was later a dean. In 1936 Kraus helped James M. Cork set up the 100-ton cyclotron at the University of Michigan, then the largest cyclotron going. He first turned to directional antennas in the early 1930s when, as a radio amateur, he was trying to improve communication with U. S. missionaries in the Belgian Congo. During World War II he worked on protection of ships against magnetic mines and on antennas for military use. Several Kraus-designed short-wave and television antennas are now a familiar part of the world's landscape—notably his corner reflector antenna and the helical beam antenna. Kraus was present at the 1935 meeting of the Institute of Radio Engineers in Detroit, Mich., where Karl Jansky reported the first discovery of radio waves from outer space. Five years later Kraus met Grote Reber, then the only active

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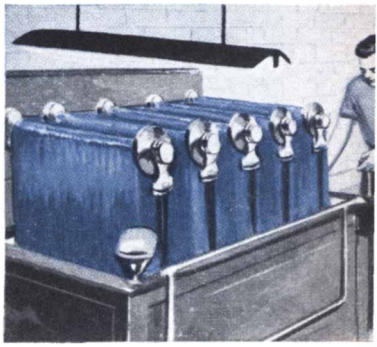

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radio astronomer in the world, and realized that in radio astronomy high-gain antennas had come into their own.

JAMES MARSTON FITCH ("The Curtain Wall") is associate professor of architecture at Columbia University. He studied at Southern universities during the 1920s and after a spell as low-cost housing analyst for the Federal Housing Administration entered the field of architectural publishing. He was successively associate editor of the *Architectural Record*, technical editor of the *Architectural Forum* and architectural editor of *House Beautiful*. As an editor Fitch directed some pioneering studies of architectural climatology. In 1950 he returned to school, studying for three years at Columbia University and last year at the University of Florence. His Italian excursion was part of his research on the life of Horatio Greenough, whom he calls the "first functionalist in American architectural criticism."

GEORGE W. GRAY ("Unknown Viruses"), a member of the staff of the Rockefeller Foundation, contributes frequently to SCIENTIFIC AMERICAN; his article "The Yerkes Laboratory" appeared in the February issue.

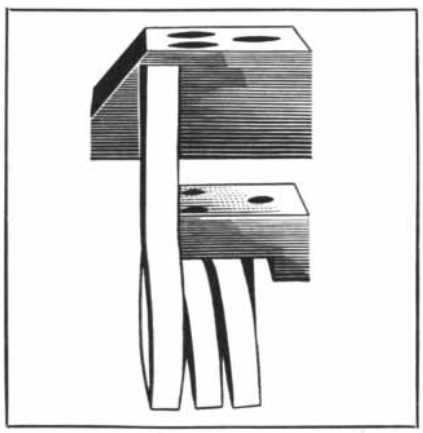
ROBERT L. FULLMAN ("The Growth of Crystals") is a research associate at the General Electric Research Laboratory, where he has been since 1948. Born in 1922 in Sewickley, Pa., a suburb of Pittsburgh, he went to Yale University to study metallurgy and became interested in the structure of crystals. He was the codiscoverer, with Arno Gatti, of the method for producing perfect iron crystals described in the article "Pure Metals" in SCIENTIFIC AMERICAN of July, 1954. During World War II Fullman served in the U. S. Navy for three years and did duty on a destroyer in the Pacific.

HENRY C. STETSON ("The Continental Shelf") is submarine geologist for the Woods Hole Oceanographic Institution and research oceanographer at Harvard University. After graduating from Harvard in 1923 he went first into paleontology, working on primitive fish-like vertebrates, and then gradually became absorbed in studies of marine sediments. He has worked at Woods Hole ever since the Oceanographic Institution was founded in 1930. Stetson notes that the U. S. Navy has kept up its World War II interest in oceanography, and he feels that this is all to the good—"research in this field has become so expensive that

BUSINESS IN MOTION

To our Colleagues in American Business . . .

The assembly shown here is the actuating mechanism of an overload device, used to interrupt the current of electricity when it exceeds a certain value. Thus, it protects the apparatus connected to the lines with which it is associated. Naturally, the contacts are of copper, since copper has the highest electrical conductivity of any commercial metal. You will note the special forms of the two contact blocks. These are supplied to the manufacturer as extruded copper shapes, so that to make the contacts it is necessary only to cut pieces of the right length from the extrusion delivered by Revere, and drill the holes.



This method of slicing parts off a pre-formed shape can provide important economies by greatly reducing machining time. Take the bottom angular contact, for example. During development work this piece was milled from solid copper bar, dimensions 1 x 2 inches. The bar weighed 7.75 pounds per foot, and in machining it to the required form, 1.8 pounds of scrap per foot were generated. Copper scrap is readily salable at good prices, of course, but the chief expense in this operation was machining.

Once the design had proved itself under severe tests, Revere suggested copper shapes instead of plain bar. In the case of the angular contact, use of an extruded shape saved 1.75 pounds per foot, a reduction in weight sufficient to save almost 44 cents per foot over the plain bar. Larger savings were made by the reduction in machining time, and in the labor involved in handling scrap. Production also was speeded up. Though the shape cost more per pound than the bar, it made possible economies that much more than absorbed this.

• Another example, not illustrated here, has to do with an electronic device. The base plate must be non-magnetic, and brass was chosen. The design was rather simple, and one would not usually suppose that a special extruded shape would save money. However, to produce the part from solid bar, which weighed 1.61 pounds per foot, required three separate operations. The extruded shape weighs 1.22 pounds per foot, and its use reduces machining to a single operation. Result: a saving of 15 cents per part.

• These two examples are taken from the Revere files, which contain remarkable evidence of the economies that can be realized through extruded shapes. If your plant is doing any extensive machining of plain bar in copper and copper-base alloys, or aluminum alloys, look into extruded shapes. They can be furnished in much more complicated shapes than those illustrated, and can save important sums.

If you do not work with any of the Revere Metals, but with other materials, we suggest you get in touch with your suppliers and see if they may not be able to find ways to save you money. In buying, please remember that it is not the cost per pound or ton or gallon that is important, but the cost of the finished item. Sometimes paying a little more for materials may make the end product cost less.

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it is far beyond the means of any private institution."

CARL WELTY ("Birds as Flying Machines") is professor of zoology and chairman of the department of biology at Beloit College in Wisconsin. He was brought up in Fort Wayne, Ind., except for summers spent on a run-down fruit farm in Michigan, which his mother, a widow, had bought to "turn her four boys out to pasture" each summer. These summers left him with a taste for nature, and when he later went to Earlham College, a Quaker school in Indiana, he majored in biology. He took a master's degree at Haverford College in 1925 and spent the following winter in a logging camp in northern Ontario. He remembers spending "11 hours per day logging in the bush and two hours teaching arithmetic and reading to French-Canadians under the auspices of the Frontier College of Toronto. Pay: board, bunk and $25 a month! Hardest work I ever did." From there he went to Parsons College, Iowa, where he taught biology and met his wife, a fellow teacher. She is a free-lance writer. Welty has been at Beloit College since 1934. In 1946 he took a year's leave to head a team of American Quakers engaged in postwar relief work in Coblenz, Germany.

LOUIS M. STUMER ("History of a Dig") is an archaeologist affiliated with the Museum of the American Indian in New York and a professor of Peruvian archaeology at the Universidad Nacional Mayor de San Marcos of Lima, Peru. Born in New York City, he attended Yale University, where studies in the history of art led him into archaeology "through the back door." Stumer took his Ph.D. in anthropology and archaeology at Lima. He began field work in Peru in 1951 with the help of a grant from the Wenner-Gren Foundation for Anthropological Research. In 1953 he was a visiting fellow at Columbia University. Stumer's interest in Peru does not stop at archaeology: he likes to watch bullfights and to fish for trout in the Andes. He is a widower with an 11-year-old son who lives with him in Peru and wants to be an archaeologist too.

MORRIS KLINE, who reviews George Polya's *Mathematics and Plausible Reasoning* in this issue, is professor of mathematics and director of electromagnetic research at the Institute of Mathematical Sciences at New York University. He was the author of the article "Projective Geometry" in the January issue.

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THE COVER

The photomicrograph on the cover shows a single crystal of cadmium iodide growing in a water solution. The spiral pattern of the crystal is due to a basic feature of crystal growth (*see page 74*). The colors, due to the interference of light passing through the crystal, indicate which parts have the same thickness.

THE ILLUSTRATIONS

Cover photograph by J. B. Newkirk

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31-32	Jerome Snyder
32-34	Sara Love
36-37	Bunji Tagawa
38	National Bureau of Standards
39	Naval Research Laboratory
39	Commonwealth Scientific and Industrial Research Organization
40	Ohio State University (*top*), National Research Council of Canada (*bottom*)
44	Brown Brothers
45	Ewing Galloway
46	Culver Service (*top*), Ewing Galloway (*bottom*)
47	Brown Brothers
48	Bunji Tagawa
63	Joel Warren (*right center*), J. C. Bugher (*all others*)
64-72	John Langley Howard
74	James Egleson
75	F. Hubbard Horn
76	James Egleson (*top*), I. M. Dawson and V. Vand (*bottom*)
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92-99	Courtesy of the author
100	John Tremblay
101-104	Courtesy of the author
116-123	Roger Hayward
122	E. Leinad

DESIGNING WITH ALUMINUM

This is one of a series of information 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. 10

ALUMINUM SOLDERING

ALUMINUM has been considered to be a difficult metal to solder, but this is not true today. Aluminum can be readily soldered by using the commercially available materials and any of the soldering procedures commonly used with other metals.

Soldering Aluminum

Aluminum can be satisfactorily soldered for many applications by using a soldering iron, torch or furnace, or by employing dip or resistance soldering procedures. The surface oxide film can be readily removed by abrasion, ultrasonics or by using either a reaction or organic flux. The solder usually is an alloy of zinc containing one or more of the elements aluminum, cadmium, copper, silver, tin or lead. Aluminum soldered joints exhibit excellent mechanical properties and their corrosion resistance is determined by the composition of the solder. In general, the high zinc content solders develop the best corrosion resistance; soldered aluminum systems made with these solder alloys are still very serviceable after 7 years' outdoor exposure to an industrial atmosphere.

Parent Alloy

The solderability of aluminum alloys varies considerably with the amount of alloying constituents present. All aluminum alloys can be soldered by the employment of either abrasion or ultrasonic soldering techniques. However, if a flux is employed to remove the oxide film, the choice of aluminum alloys is restricted to those containing less than 4% silicon or 3% magnesium. For this reason, the alloys most commonly soldered are EC, 1100 (2S), 3003 (3S), 5005 (K155), 5050 (50S), 6061 (61S) and Kaiser Aluminum Utility Sheet.

Soldering Fluxes

There are two general types of aluminum soldering fluxes commercially available. The first type, called a reaction flux, relies on the reaction of a metal halide, such as zinc chloride or tin chloride, to remove the oxide film. This type of flux is generally preferred for soldering alloys containing magnesium or for soldering at temperatures of 650°F or higher. Reaction type fluxes are readily used in most soldering operations. However, the flux residue is capable of accelerating corrosion and it should be removed by thorough washing after the soldering operation is complete.

The second type of flux widely marketed is a chloride-free organic flux. This flux is normally useful only for low temperature soldering operations. The flux residue does not materially accelerate corrosion. Hence, organic fluxes have been used successfully in some commercial applications where the removal of flux residue is impracticable.

Fig. 1. This photograph shows an aluminum cable being soldered by immersion in a bath of molten solder. Using fluxes developed by Kaiser Aluminum, it is as easily dip soldered as the most soluble metals.

TABLE I Typical Compositions of Solders Commonly Used to Solder Aluminum

Alloy	Solder	% Sn	% Zn	% Pb	% Cd	% Al	% Cu	Melting Temperature*	Corrosion Resistance
1	Zinc Base		96.2			3.8		750	Best obtainable
2			94			4	2	740	Best obtainable
3			81.6	3	.4	10	5	750	Good
4	Tin Containing	28.2	70.9	.6			.3	710	Suitable for most indoor and some outdoor applications
5		64.9	35.1					615	"
6		50	15	.5	31.5	3		570	"
7	Lead Containing	40.6	21	37.7			.7	680	Must be protected outdoors but suitable for many indoor applications
8		31.7	9	51	8		.3	485	"
9		50	21.5	28.5				640	"

*Temperature at which the solder is completely liquid.

Alloys 1, 2 and 3 are widely used as abrasion type solders and are best applied using a gas torch. In addition, they can be used with reaction type fluxes and the commonly used sources of heat.

Alloys 4, 5 and 6 are general purpose alloys and are usually used with reaction type fluxes although they can be used with the organic types of fluxes if care is taken to avoid overheating. Torch, furnace and dip soldering procedures are generally used with these alloys.

Alloys 7, 8 and 9 are frequently used with the organic type of flux in low temperature soldering operations. These solders can be used with any of the common sources of heat, including the soldering iron.

Solders

The commercial solders can be classified into three general groups. The first group consists of alloys of zinc containing 3 to 10% aluminum and small amounts of other metals such as copper, silver and iron. This group of solders form the most corrosion resistant soldered assemblies, but they require soldering temperatures of 750°F to 800°F. The mechanical strength of joints made with the high zinc solder is excellent.

The second group of solders contain zinc and tin with small additions of copper, lead, cadmium or silver. They require soldering temperatures of 650°F to 750°F. These solders are general purpose materials and are extensively used by industry for those applications requiring a fairly simple soldering operation but where some sacrifice in corrosion resistance is permissible. The mechanical strength of

PLEASE TURN TO NEXT PAGE ➡

joints made with these solders is satisfactory for most applications; the shear strength will range from approximately 8,000 to 15,000 psi (pounds per square inch) of soldered area.

The third group of solders contain tin and zinc with major additions of lead and/or cadmium. These solders are characterized by low melting temperatures, which in turn permit low soldering temperatures of 450°F to 650°F. The shear strength of the soldered joints approaches that of soft soldered joints made in copper, i.e. about 7,000 psi. These solders produce joints having the lowest corrosion resistance but they are the easiest to use in a soldering operation.

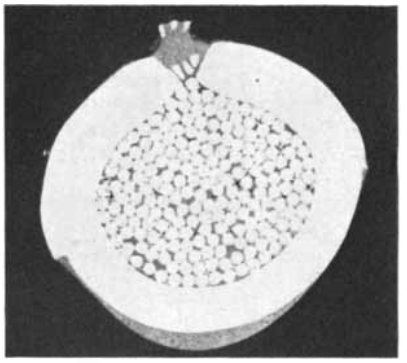

Fig. 2. Photomicrograph showing a cross section of an aluminum cable soldered by immersing it in a molten bath of 70% Zn 30% Sn solder using a liquid flux developed by Kaiser Aluminum. 5X.

Soldering Procedure

The fundamental operations involved in soldering are simple. The surface oxide film is removed and molten solder flowed over the clean surface to form a bond with the parent metal.

The first step in a soldering operation is the removal of the extraneous dirt and grease present on the surface. The commonly soldered aluminum alloys can be easily cleaned with organic solvents such as alcohol, carbon tetrachloride, etc. If the surface is badly weathered it should be wire brushed. The clean metal can then be soldered using either manual or mechanized soldering procedures commonly used for soldering other metals. The actual choice of solder, fluxes and soldering procedure will depend upon the specific joining problem at hand.

For manual soldering operations, gas torches, resistance tongs, or a molten bath of solder are commonly used as heat sources. Gas or electrically heated soldering irons find limited use for soldering thin aluminum assemblies or relatively small articles. A flux is generally used to remove the oxide film when using any of the heat sources mentioned. The solder can be either manually fed into the joint by using a rod of solder or it can be preplaced in the joint in the form of shims, rings, washers, etc. Ultrasonic vibrations have recently been introduced as a means of removing the oxide film on aluminum. Such vibrations currently have some limited use when dip soldering in a bath of solder. Furthermore, specially constructed ultrasonic soldering irons are being used fairly successfully. When soldering with a torch or ordinary soldering iron, it is also possible to use abrasion to remove the oxide film. This can be done by heating the aluminum with a torch or iron to the soldering temperature, melting a small amount of solder on the surface, and then removing the oxide film by abrading it with steel wool or a wire brush. Alternatively, a specially alloyed solder marketed as abrasion or friction solder may be rubbed directly on the surfaces to be soldered. If this is done, the oxide film is removed and the aluminum is coated with solder in one operation.

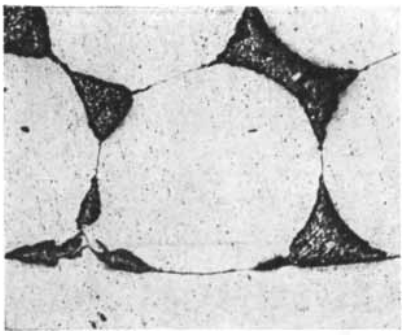

Fig. 3. This photomicrograph at 100X shows an enlarged section of the cable shown in Fig. 2. The solder has filled the interstices of the cable and joined the individual strands to each other to provide an electrical joint of minimum resistance.

In mechanized soldering operations the heat sources are usually multiburner torches, resistance tongs, a molten solder bath, electric resistance furnaces or electrical induction. A flux is usually used to remove the oxide in mechanized operations. The solder is preplaced in the joint using the common forms of preplaceable material, such as shims, washers, etc. Another effective method is to "pre-tin" at least one of the surfaces to be soldered to produce a coating of solder on its surface. This solder coating will melt when heated and it furnishes the solder necessary to fill the joint. Recently, some use has been made of ultrasonic vibrations applied directly to the dip soldering bath for removing the oxide film. In general, mechanized soldering operations should be completed in the shortest time possible to minimize warpage. The maximum speed attainable is determined by equipment limitations, although soldered aluminum joints have been made at speeds of over 200 feet per minute.

Corrosion Resistance

Soldered aluminum assemblies corrode because of the galvanic cell which results from the difference in electrode potential between the aluminum and the solder. These galvanic cells can be likened to small batteries in which the aluminum is the anode, the solder is the cathode, and the corrosive medium is the electrolyte. The current flowing in such a simple cell will be determined by the potential difference between the anode and cathode and the electrical resistance of the cell. If this analogy is correct, those metals having electrode potentials close to that of aluminum would make the most corrosion resistant soldered assemblies. On the other hand, those having the greatest potential difference would make the least corrosion resistant assemblies. In addition, we would expect the corrosion rate to be greatest in electrolytes or corrosion media which are good conductors of electric current. Conversely, corrosion would be the slowest in those which are poor conductors of electricity. In general we find this is true. The electrode potential of zinc is close to that of aluminum, and solders containing high percentages of zinc provide the most corrosion resistant soldered joints. Conversely, both lead and tin have potentials that are more widely separated from aluminum; hence, they provide a system having poor corrosion resistance. Therefore, the tin-lead solders commonly used with other metals are not suitable for soldering aluminum unless the assembly is protected from corrosive environments. In addition, we find that the corrosion rate is greatest in good electrolytes, such as salt solution, and is least in a poor conductor, such as pure water. Corrosion stops entirely when the assembly is exposed to dry air, under which condition no electrolyte is present.

More detailed assistance with design, alloy selection and fabrication procedures are obtainable through the Kaiser Aluminum sales office listed in your telephone directory, or through one of our many distributors. Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office:* Palmolive Bldg., Chicago 11, Ill.; *Executive Office:* Kaiser Bldg., Oakland 12, California.

SCIENTIFIC AMERICAN

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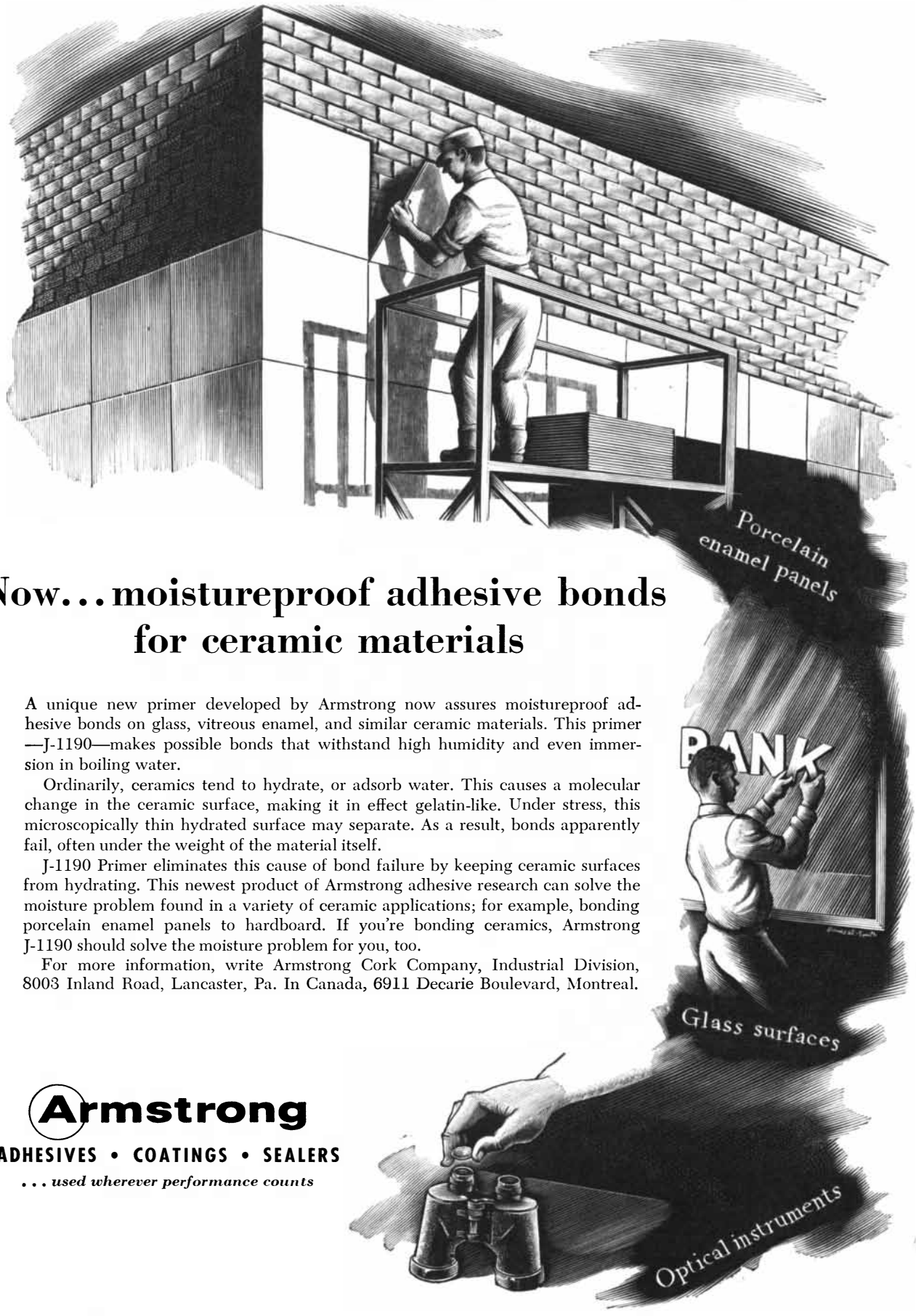
ARTICLES

DEPARTMENTS



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How People Interact in Conferences

In which talk is subjected to formal observation and analysis. A sample finding of the investigation: The average conference group has dual leaders, an "idea man" and a "best-liked man"

by Robert F. Bales

Social interaction is made up largely of the talking that people do when they get together. Talk is an elusive object of study, in spite of the fact that a good deal of it exists. It is also a rather sensitive subject. Even a friend might find it hard to put up with a dissection of the following kind: "I was just noticing how much you talk. In the last 10 minutes I noticed that you made a total of 114 remarks, while I made a total of 86. According to my count you gave about twice as many opinions as facts. Although I agreed with you 15 times and didn't disagree at all, I noticed that you stammered once and blushed twice."

I first began to develop a systematic procedure for analyzing social interaction when I became interested in trying to account for the success of Alcoholics Anonymous in helping apparently hopeless drinkers to stop drinking. Although I attended meetings and talked with many members, I did not feel free to ask all the questions I wished. Consequently I fell back on observation and began to develop crude methods for recording who did what, who spoke to whom, and how. Eventually even this quiet occupation began to appear sinister and the effort was abandoned. But by this time my fascination with the process of social interaction had developed to the point of no return. I decided that I must pursue my studies in the more favorable conditions of a laboratory.

A number of laboratories for the study of social interaction within small groups and organizations have been started in the last 10 years—in hospitals, clinics, special research centers and military installations. The studies and experiments I shall describe were conducted in one of the earliest of these laboratories, established in 1947 at Harvard University.

The laboratory consists of a large, well-lighted room for the group under study and an adjoining room for observers, who listen and watch from behind windows with one-way vision. The subjects are told at the beginning that the room has been constructed for the special purpose of studying group discussion, that a complete sound recording will be made and that there are observers behind the one-way mirrors. The

purpose of the separation is not to deceive the subjects but to minimize interaction between them and the observing team.

After much research we developed a standardized task from which significant generalizations could be drawn. A group of persons (ranging from two to seven in number) is asked to discuss a complex human relations problem of the sort typically faced by an administrator. Each member of the group first reads a five-page presentation of facts about the case to be discussed, but each is left uncertain as to whether he has been given exactly the same range of facts as the others in the group. The members are not introduced to one another or coached in any way; they must develop their own organization and procedure. They are to consider the facts and report to an administrator, as if they were his staff, their joint conclusions concerning the problem and what should be done about it. They are allowed 40 minutes for the discussion. The group is observed for four such sessions.

On the other side of the one-way screen the observers systematically record every step of the interaction, not omitting such items as nods and frowns. Each observer has a small machine with a moving paper tape on which he writes in code a description of every act—an act being defined essentially as a single statement, question or gesture. Acts ordinarily occur at the rate of 15 to 20 per minute. The recorded information on each includes identification of the person speaking and the person spoken to and classification of the act according to predetermined categories. There are 12 categories, covering positive and negative reactions, questions and attempts to solve the problem by the offering of information, opinion or suggestions [*see table on opposite page*].

As this table shows, on the average about half (56 per cent) of the acts during a group session fall into the categories of problem-solving attempts; the remaining 44 per cent are distributed among positive reactions, negative reactions and questions. In other words, the process tends to be two-sided, with the reactions acting as a more or less constant feedback on the acceptability of the problem-solving attempts. The following is a typical example of the pattern of interchange:

Member 1: "I wonder if we have the same facts about the problem? [Asks for opinion.] Perhaps we should take some time in the beginning to find out." [Gives suggestion.]

Member 2: "Yes. [Agrees.] We may be able to fill in some gaps in our information. [Gives opinion.] Let's go around the table and each tell what the report said in his case." [Gives suggestion.]

This example illustrates that a speaker's first remark is likely to be a reaction, and if he continues speaking, the probability is very high that his second act will be a problem-solving attempt. The lower chart on the opposite page sums up this finding statistically: about 50 per cent of the time a member's first remark in a series is a reaction; if he continues, about 80 per cent of the succeeding comments are opinions or other offerings classed as attempts to solve the problem.

When we examine the reactions, we find that positive reactions commonly outnumber negative ones about two to one during a session. It is as if after every negative reaction, the members of the group feel they must make another problem-solving attempt which meets with a positive reaction "just to catch up," and net forward progress is felt to be sufficiently secure only when a repetition of the problem-solving attempt meets unopposed acceptance. It may be that members employ repetition, or near repetition, as an error-checking device to determine whether the others "really agree." Social interaction, in common with many other goal-seeking control mechanisms, seems to depend upon error and correction of error for guidance.

The process of attempting to arrive at a group decision through discussion is in many ways very like the operation of a large-scale communication and control system such as an air-defense network. I recently compared the two processes in collaboration with John Kennedy of the Systems Research Laboratory at the Rand Corporation.

In the military case there are three functions to be performed: surveillance of the air by radar, identification of planes as friendly or unknown and direction of fighters sent out to intercept unknown planes. These are something like the three problems confronting our groups in the standard interaction task: assembling the given information on the case, evaluating it and proceeding toward a solution as the goal. Now the stepwise operations involved in the air-defense system may be tolerably well described as an interlocking series of seven types of information-processing operations [*see chart on page 34*]. Here

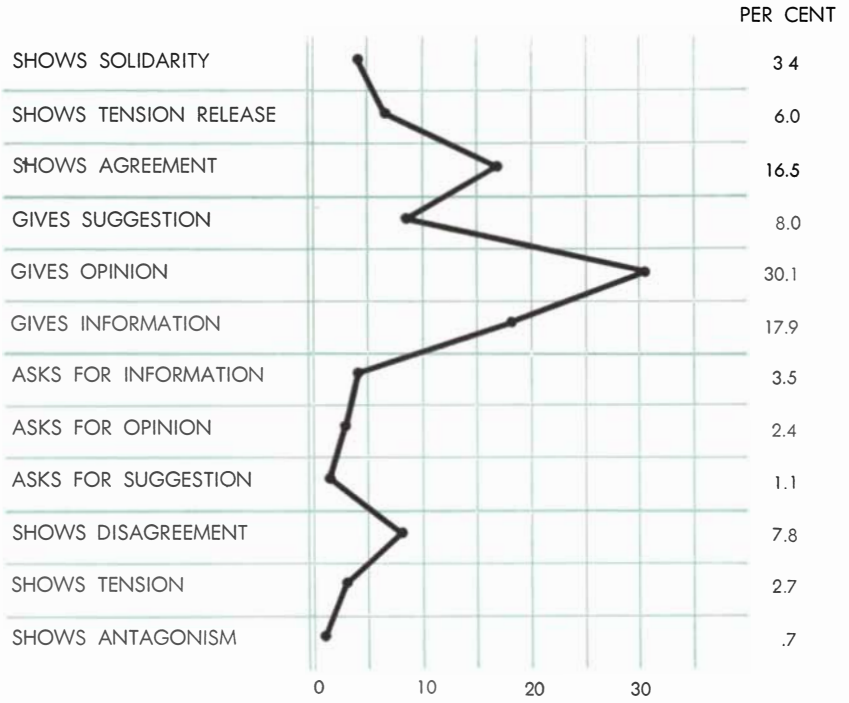
x stands for the path of a plane tracked by radar, and O represents the class of objects unknown. If no known flight plan of a friendly plane coincides with x—a fact represented by the symbol y—then x must belong to the class O. Since there is a general rule, W, that all unknown planes are to be intercepted, the conclusion is that a specific order, w, should be given to intercept x.

Such a decision, involving many groups and interlocking processes, is obviously a very complicated affair, socially as well as technically. The job of the decision-making organization is essentially to build and maintain through means of communication and evaluation a sufficiently complex and commonly accepted symbolic structure to guide or control the stages of behavior of all the operating units. Effective decision making is basically a continuous process of building and maintaining a structure of cultural objects which in their totality constitute the common culture of the organization affected.

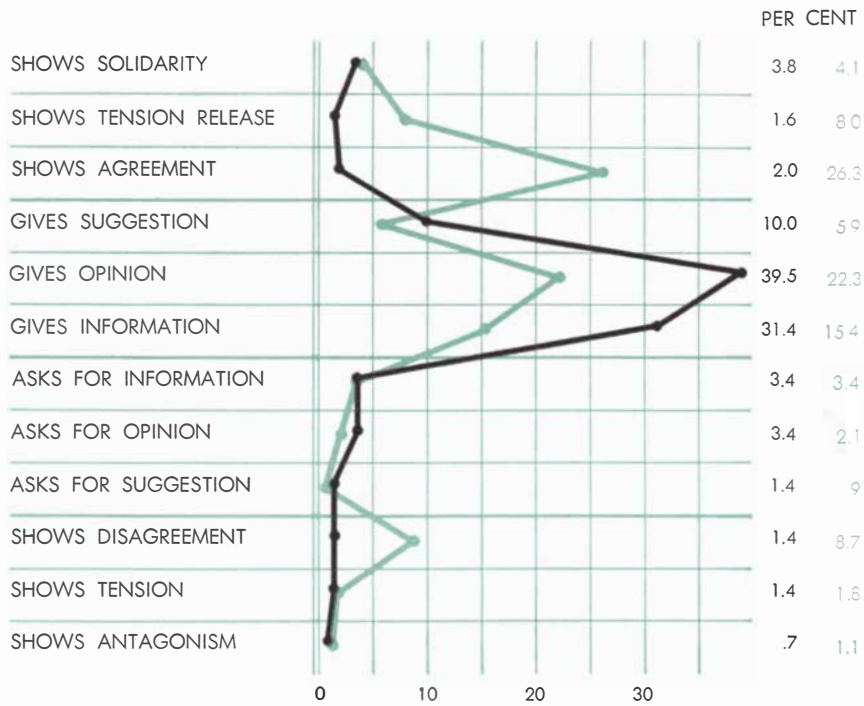
The seven types of acts, or stages, just described are very general: they apply quite as well to the interaction of five experimental subjects in the laboratory group, trying to decide in 40 minutes what the administrator in their case should do about his problem, as to the large-scale operations of an air-defense network. Not all of the elements in the process are primarily logical in character. They involve elements of perception, memory, association and perhaps inductive insight. All sorts of motivational and evaluative pressures affect the process. The steps make sense not as a formally perfect chain of logic, but rather as a set of symbol transformations which help to guide, although in an imperfect way, a process of decision-making behavior. Error checking is an integral part of this fallible process.

The reason for calling attention to the seven-step structure of the process is that it may help to explain the unequal ratios of suggestions, opinions and information offered in the problem-solving attempts of the groups in our tests. As the first table shows, of every seven problem-solving attempts, on the average four are opinions, two are offers of information and one is a suggestion. It seems significant that in the idealized seven-step outline of the air-defense operation two steps have the interaction form of giving information, four intermediate steps have the interaction form of giving opinion and only one step, the final one, has the form of giving a suggestion.

From the transcription of a group discussion it is often possible to reconstruct



TYPES OF ACTS in social interaction may be classed in four main categories: positive reactions, problem-solving attempts, questions and negative reactions. The averages for 96 group sessions show that 56 per cent of the acts fall into the problem-solving category.

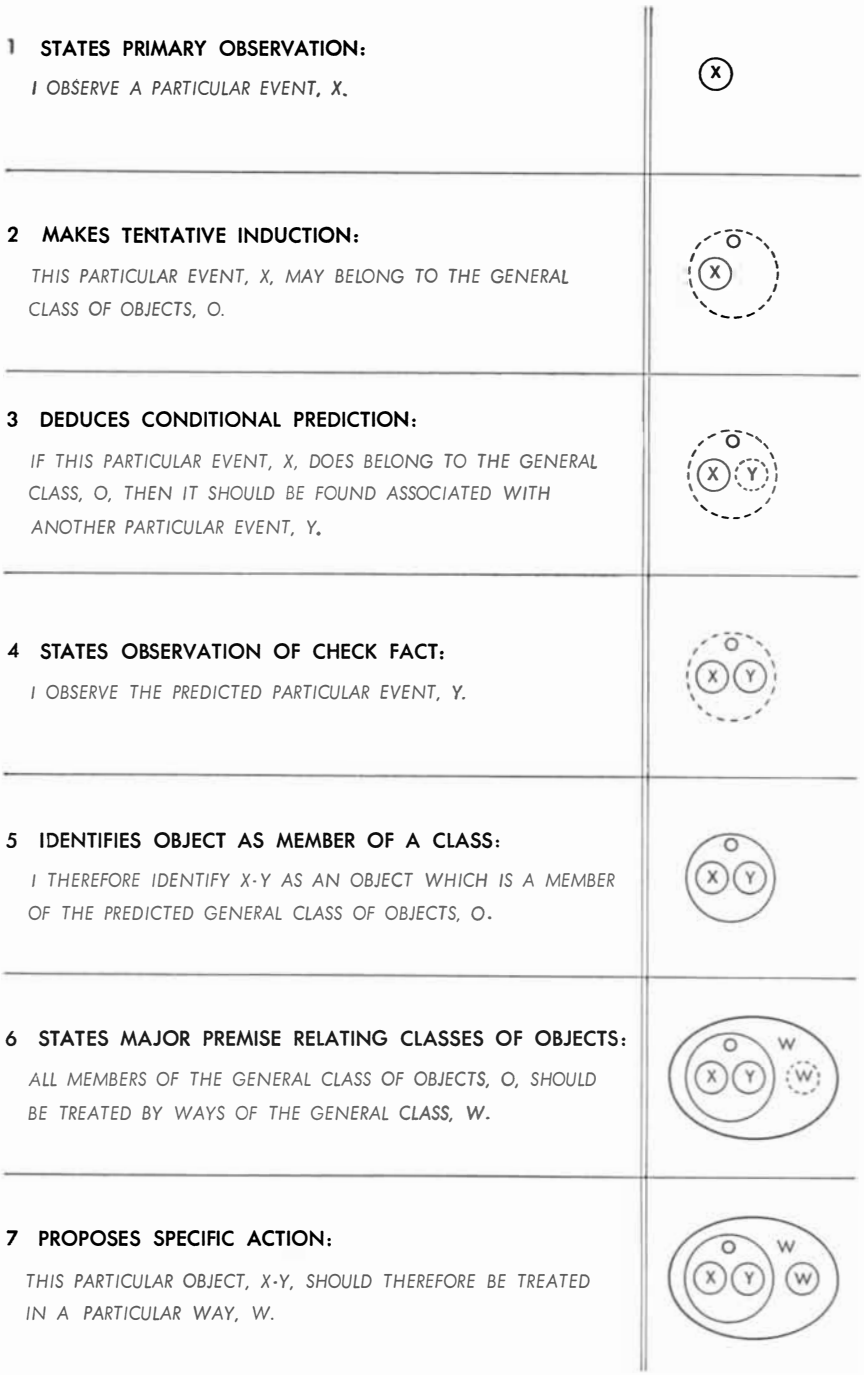


PATTERN OF ACTION of individuals in a discussion is illustrated statistically. When a member takes the floor, his first remark (*colored curve*) is likely to be a reaction to the preceding speaker. His next remarks (*black curve*) tend to be problem-solving attempts.

complete seven-step chains leading to agreement on specific points and the final conclusion. In a general way there is even a tendency for the steps to proceed in a regular order in time. During a session the rates of giving information tend to be highest in the first third of the meeting and to decline in the next two thirds [*see chart on page 35*]. Rates of giving opinion are usually highest in the middle portion of the meeting. Rates of giving suggestion are generally low in

the early period and reach their high point in the last third of the meeting.

Rates of both positive and negative reactions tend to rise from the first third of the meeting to the last third. These increases may be connected mainly with social and emotional problems of the group process itself. The ratio of negative to positive reactions tends to be higher in response to suggestions than in response to factual statements. The decision point is a critical bottleneck in the process. Once the decision point has been passed, however, the rates of negative reaction usually fall off and the rates of positive reaction rise sharply. Joking and laughter, indicating solidarity and tension release, become more frequent. With the problems of the task and common values stabilized for the time being by the decision, the interaction process apparently turns to restabilizing the emotional states of the individuals and their social relations to one another.



PROCESS IN REACHING A GROUP DECISION is analogous to the operation of a large-scale communication and control system such as the air-defense network. The steps consist of observing an object or event, comparing it with several possible identifications, considering the associated facts and, once its nature is understood, taking the appropriate action.

There is a good deal of evidence that the process of social interaction, like other processes involving feedback, tends to fall into oscillation as it "hunts" around a hypothetical steady state. Over a small time span the action tends to alternate every few acts between the problem-solving attempts of one person and the social-emotional reaction of some other. But this rapid oscillation is not quite rapid enough to keep all elements of the process in perfect balance. There is a drift toward inequality of participation, which in time has cumulative effects on the social relationships of the members. The reason for this drift may be seen fairly easily. When a person has completed one act, the chances are a little better than even that he will continue for another act. After each succeeding act his probability of continuing drops, but never as far as if he simply flipped a coin at each point to determine whether to continue or to yield the floor. In fact, relatively speaking, he exceeds this chance probability by a larger and larger fraction with each succeeding act.

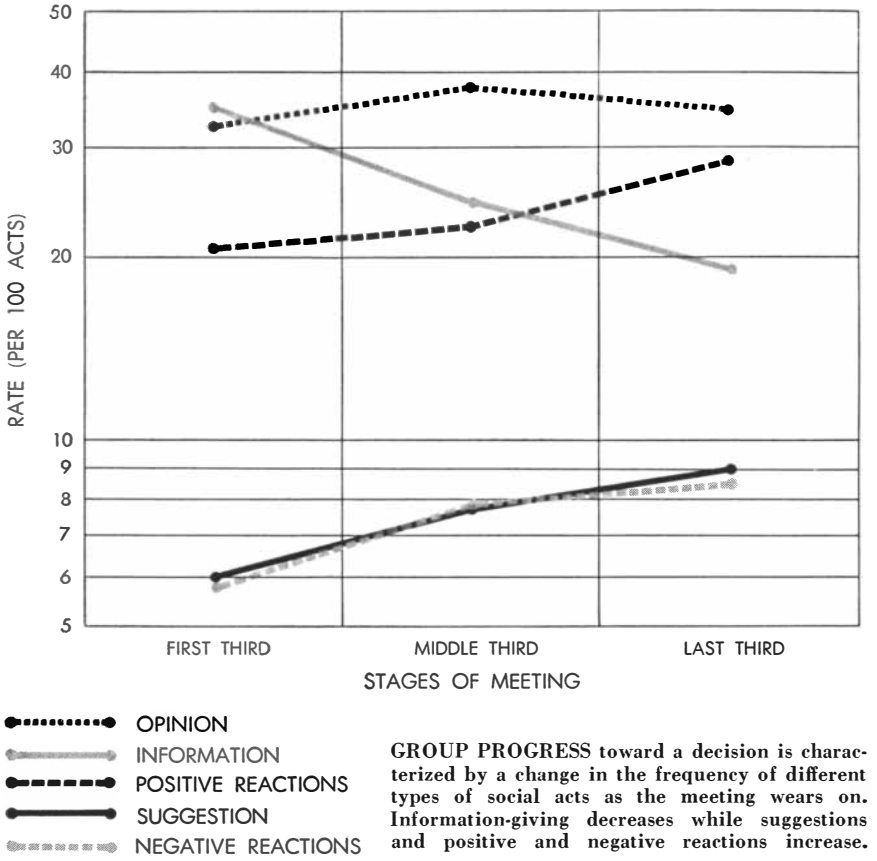
We have already noted that when a person continues several acts in succession the probability is very high that he is giving information, opinion or suggestion—in other words, specializing in problem-solving attempts. We may also infer from the seven-step theory of problem-solving attempts that the tendency to continue for several acts in succession is probably due in part to a felt need on the part of the speaker to provide inferences and check facts which will result in the acceptance of a more advanced step in the series, with an accepted suggestion as the goal.

This tendency toward inequality of participation over the short run has cumulative side effects on the social organization of the group. The man who gets his speech in first begins to build a reputation. Success in obtaining acceptance of problem-solving attempts seems to lead the successful person to do more of the same, with the result that eventually the members come to assume a rank order by task ability. In some groups the members reach a high degree of consensus on their ranking of "who had the best ideas." (The members are interviewed by questionnaire after each meeting.) Usually the persons so ranked also did the most talking and had higher than average rates of giving suggestions and opinion.

While one person becomes a specialist in advancing ideas, another is apt to be

developing a specialization on the reactive side. The men most commonly rated "best liked" typically have higher than average rates of showing tension release (mainly smiling and laughing) and showing agreement. It is not impossible for the man ranked at the top in ideas also to be best liked, but apparently it is difficult. In one set of experiments the top idea man had about an even chance of also being best liked at the end of the first meeting, but by the end of the fourth meeting his chances were only about one in 10. The best-liked man is usually second or third in the participation hierarchy.

The task specialist seems to "lock onto" the person who is most responsive to what he is saying and address more remarks to him than to the others. In turn, the best-liked man talks more and agrees more with the top-ranking idea specialist than with any other member. The idea specialist and the best-liked man often form a mutually supporting pair. However, the best-liked man may attract the idea specialist even though they are not always in agreement. Indeed, in order for a person to become established in the minds of other members as a social-emotional specialist, it is probably more important that he be representative of their reactions, both positive and negative, than that he should ardently support everything the task specialist says. Apparently reactions that are emotionally gratifying to other members tend to be generalized by them into liking for the person who expresses the reactions.



GROUP PROGRESS toward a decision is characterized by a change in the frequency of different types of social acts as the meeting wears on. Information-giving decreases while suggestions and positive and negative reactions increase.

Giving suggestions, necessary as it may be for accomplishment of the task, is more likely to arouse negative reactions than is giving information or opinions. This tends to put the task specialist in a vulnerable position. The group commonly develops a certain amount of negative feeling toward him. Not only is he likely to lose the status of being best liked, but he may lose his position as task leader unless he is sensitive to the problem and is well supported by other members. Even in a group which ends its first meeting with a high consensus on who has the best ideas, the second meeting is apt to see a challenge to his leadership, with a rise in rates of disagreement and antagonism and a precipitous drop in his popularity. But then, in a group where the original consensus was high, a peculiar thing seems to happen. Apparently as progress toward accomplishment of the task slows down, some members rally around the leader again and his popularity tends to rise. By the third meeting the rates of disagreement and antagonism go down. The task leader may not retain all the liking that was transferred to him in his time of need, but the net effect of the hunting kind of oscillation that takes place is a tendency to maintain the original rank order of task ability.

In a group that starts with a low degree of consensus on who has the best ideas, the developments usually are more dismal. There tends to be a high turnover in the top ranks throughout the four meetings, with one would-be leader replacing another. In such a group the man ranked as having the best ideas is less apt to be best liked. Furthermore an additional specialist is likely to appear—a man who talks more than anybody else but is neither best liked nor most highly respected for his task ability.

It appears probable that whether the members will agree on who has the best ideas depends to a large degree on how well they agree on basic premises or norms—what we may call the "common culture." If such consensus is not present, at least implicitly, at the beginning, it may take a long time to build. While consensus on major values does not solve all the problems of arriving at a stable social organization, probably no stable organization is possible without this control factor. If it is lacking, the interaction process becomes primarily a means for the expression of individual emotional states.

Our studies have made clear that social stability is an extremely complex achievement: it takes time and patience to arrive at a common culture extensive enough and sensitive enough to regulate strong counter motives, to promote task accomplishment, to harmonize social relationships and to rejuvenate itself whenever the conditions demand. A clear recognition of the complexity of cultural control of behavior should encourage us to believe that interminable series of meetings around the conference table, international and otherwise, are perhaps worth while after all.

Radio Telescopes

Their evolution accelerates the pace of astronomy. One now being built will have a reflector 250 feet across. Another proposed here would have a main antenna 2,000 feet long and 200 feet high

by John D. Kraus

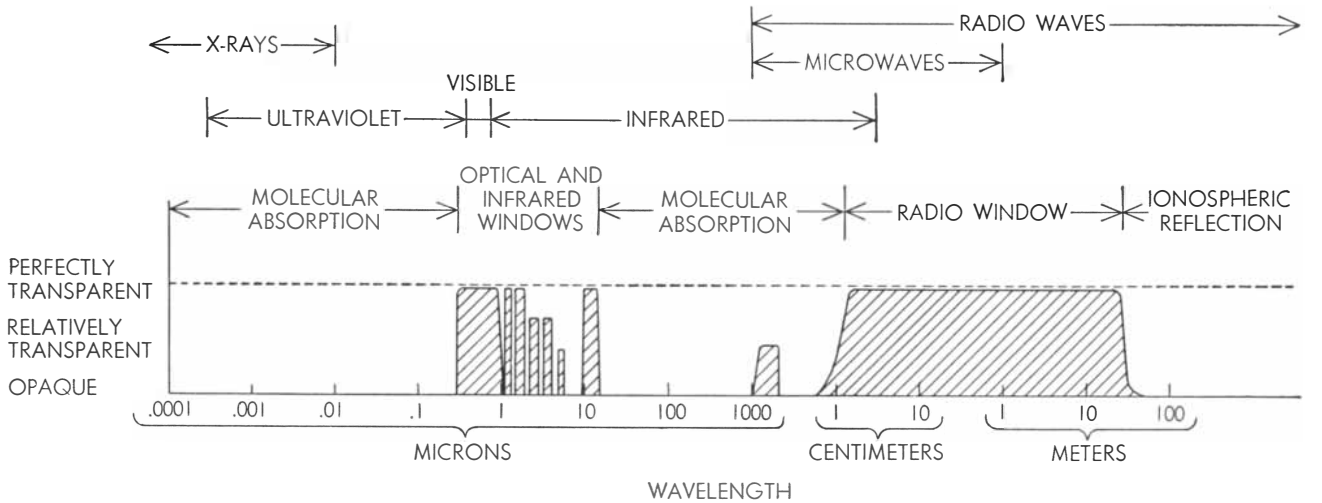
If our eyes were suddenly to become sensitive to radio waves instead of light, the sky would appear very strange. The sun would be much less bright, while the Milky Way would shine with tremendous brilliance. Hundreds of new "stars" would dot the sky, forming totally unfamiliar constellations. We would be able to see great turbulent clouds of gas in space, and the billowing gaseous remnants of exploded stars called supernovae. One of the brightest objects in the heavens would be a pair of galaxies in collision 200 million light years from us, which are visually so faint that they can be photographed only by long exposures with the largest optical telescopes.

The radio energy given forth by this source, called Cygnus A, startles even astronomers, who are used to large numbers. In a single second Cygnus A emits an amount of radio energy which, if concentrated and translated to heat, would supply all the earth's requirements of heat and power for the next trillion years. Its radio emission is so strong that it could easily be detected by a radio telescope even if it were 15 times farther away—a distance far beyond the reach of our biggest optical telescope, the 200-inch on Palomar Mountain.

Cygnus A dramatically illustrates the new window to the universe opened by the radio telescope. Radio "sight" opens up to us a much greater range of space than we are able to explore visually. It also brings into "view" for the first time shorter-range objects which are too cool to emit much light. And it clears away mists that fog our vision through optical telescopes; radio waves penetrate the clouds and haze of our atmosphere and the screens of gas and dust in interstellar space.

Radio astronomy today is in about the same stage of infancy as visual astronomy was soon after Galileo invented the first optical telescope. It has opened a new window, but it is still seeing "through a glass, darkly." With all its advantages, the radio telescope has a great inherent handicap: radio waves do not locate and resolve objects as precisely or sharply as light waves. Our present radio telescopes cannot pinpoint radio stars; their sharpest beams define the source only diffusely. But radio telescopes are developing swiftly. Plans for the building of larger and more ingenious versions are being announced almost every month, and we can look forward to more exciting discoveries.

The crux of the resolution problem is the radio telescope's antenna, which corresponds to an optical telescope's light-gathering and focusing reflector or refractor. Radio astronomers have given their imaginations free play in designing antennas, and today a strange assortment of dishes and arrays of sensitive radio



EARTH'S ATMOSPHERE has "windows" that admit light and radio waves. The wavelengths not admitted are absorbed or reflected. Here electromagnetic wavelength (*horizontal coordinate*) is plotted against the transparency of the atmosphere (*vertical*).

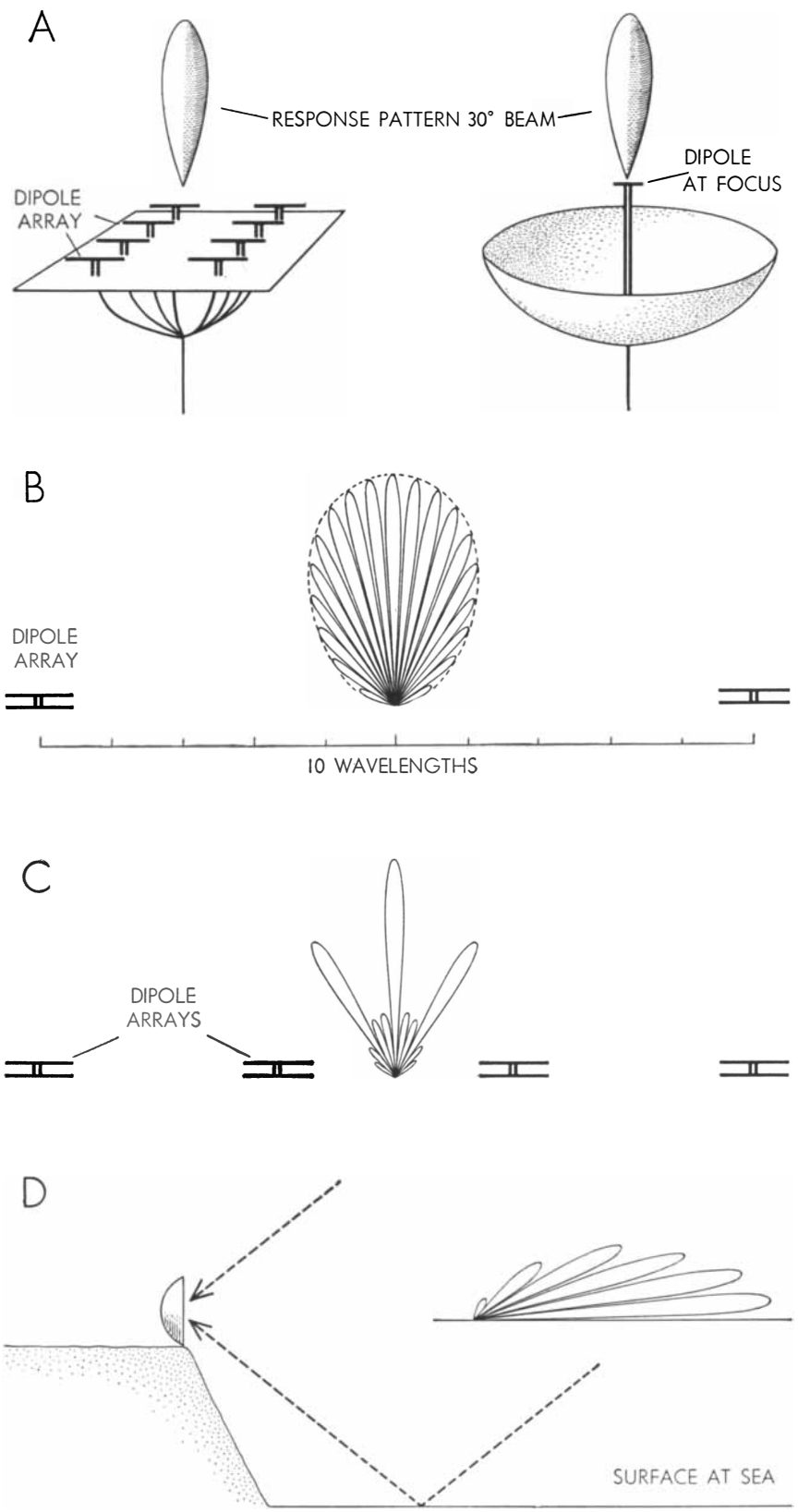
feelers is pointing skyward in various parts of the world.

Resolving power is the measure of a telescope's ability to distinguish separate objects that are close together. Ideally the radiation from a point source (a star or other single astronomical object) should be brought to a focus at a point to form an image as sharp as the source. In practice, even in an optical telescope, the image is never a point but a smeared-out dot, brightest in the center and fading off toward the edge. When two stars are so close together that their images overlap, the telescope fails to resolve them.

The resolution of any telescope—optical or radio—is proportional to its aperture expressed in wavelengths. The human eye has an aperture (pupil diameter) of about an eighth of an inch, which amounts to 6,000 wavelengths of light. It can distinguish between objects separated by an angle of about a hundredth of a degree. Radio's problem is that it is dealing with wavelengths immensely longer than those of light. To equal the resolution of the human eye, a radio telescope receiving signals at one meter wavelength would need an antenna nearly four miles across (6,000 meters). To match the resolution of the Palomar Mountain telescope, with its 200-inch aperture, a radio antenna receiving at the one-meter wavelength would have to be as large as the diameter of the earth!

No radio telescope will ever approach the resolving power of the optical instruments, but the gap can be narrowed. Some gain in resolution can be achieved by selecting for reception the shorter radio wavelengths of the celestial broadcasts. However, the major room for improvement lies in building larger antennas. This is desirable not only because a big antenna increases resolution but also because it collects more radio energy and hence can detect fainter sources.

In radio terms resolution is measured by beam width: the sharper the beam, the better the resolution. A beam in this sense means that the antenna receives the signal most strongly when it is pointed directly at the source; in other words, the antenna must be directional. As it swings away from the direction of the source, the directional antenna receives less and less of the signal's strength. Radio engineers picture the reception pattern schematically as a long lobe, with the peak of the lobe representing the maximum strength of the signal and the curvature of the lobe representing the fall in signal strength as



RESOLUTION of radio telescopes is expressed in terms of beam width, although the beam is received rather than transmitted. At the top are the single-lobed beams of a telescope consisting of an array of dipole antennas (*left*) and one consisting of a dipole and a parabolic reflector (*right*). Second is the multilobed beam of a radio interferometer with two separated dipole antennas. Third is the beam of an interferometer with four dipole antennas. Fourth is the horizontal beam of an interferometer using radio waves reflected from the sea.

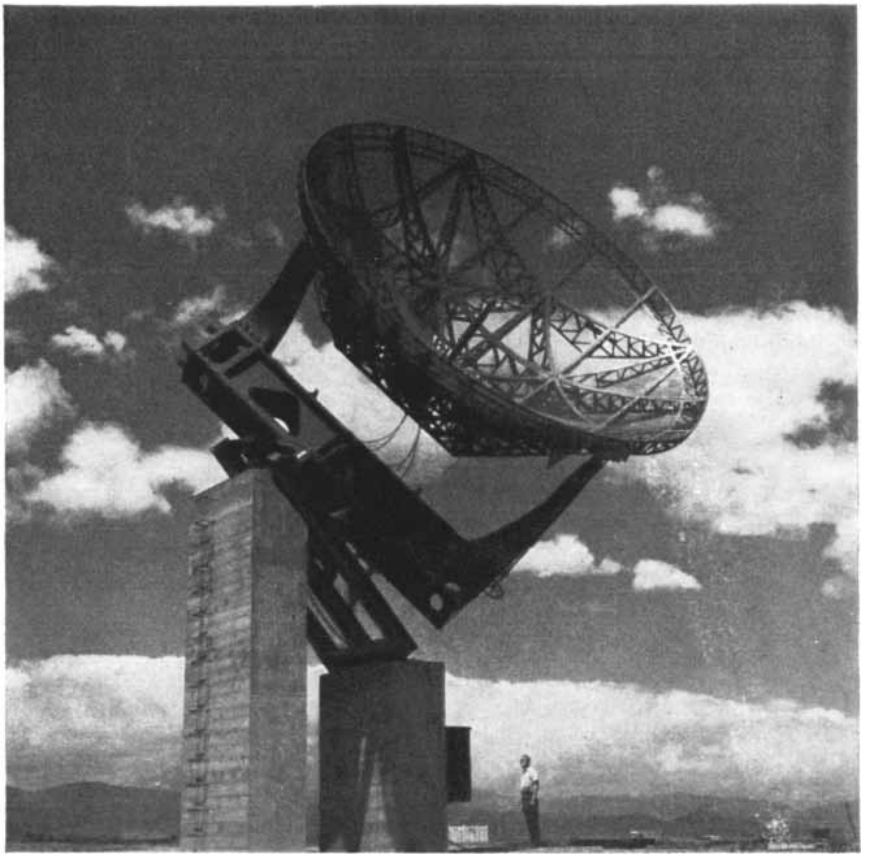
the antenna turns away from the direction of the source [*see upper diagram on preceding page*]. The resolving power is measured by the sharpness of the peak; it is usually expressed as the "half-power beam width," which means the width of the arc along which the antenna receives half or more of the maximum signal power. The smaller this arc, the more finely the antenna can pick out separate objects in the sky.

As we have noted, the aperture, or diameter, of the antenna and the wavelength of the signal determine the resolving power of a radio telescope. The half-power beam width is calculated to be 60 divided by the diameter of the antenna in wavelengths. Thus an antenna two wavelengths across has a beam width (or resolution) of 30 degrees; an antenna 20 wavelengths across has a beam width of three degrees. When the antenna is circular or square, its beam has the shape of a pencil or a cigar. When it is oblong, the beam is shaped like a fan or a beaver tail.

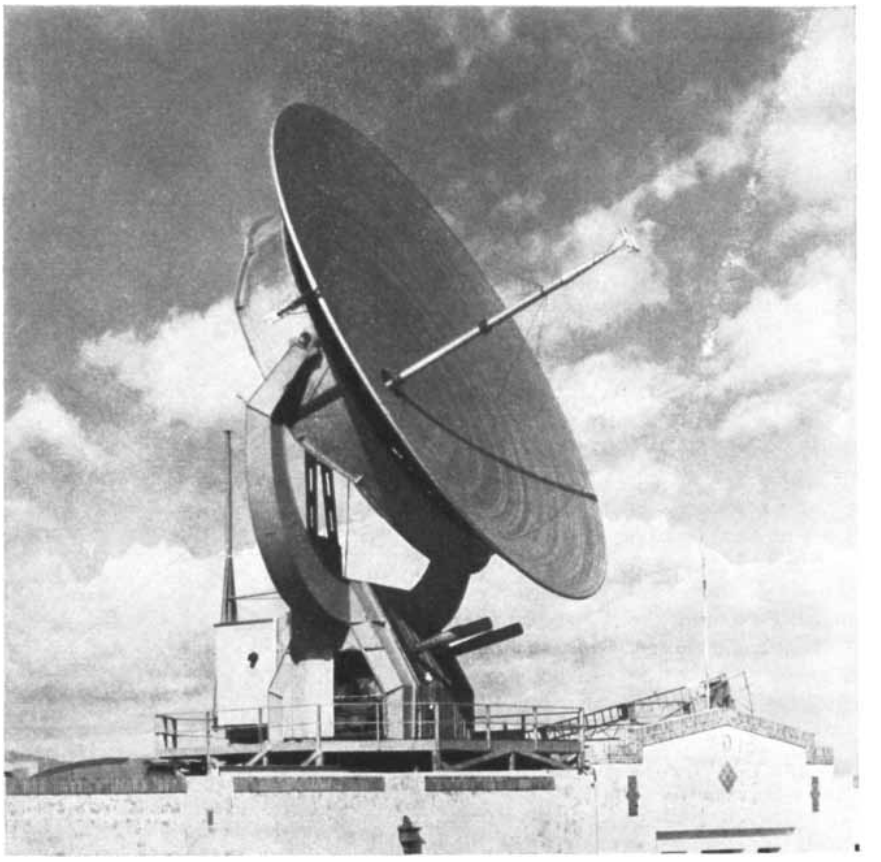
The function of the antenna is to focus the incoming radio waves at one point. That is, its action is essentially the same as that of a light-gathering telescope. One type of antenna is, indeed, very like the mirror of an optical telescope. A parabolic "dish," either solid or made of a wire screen, reflects incoming radio waves to a focal point, where a small dipole or rod picks up the energy and converts it into an electric current which is then conveyed by a cable to a sensitive receiver. The receiver amplifies the signal and records it graphically by means of a pen tracing curves on a sheet of paper.

Dishes of this kind are in use at a number of observatories today. Many of them are salvaged "giant Wurzburgs"—the 25-foot dishes built by the Germans as radar antennas during World War II. This antenna has a pencil beam which at a wavelength of 65 centimeters is five degrees wide. The U. S. National Bureau of Standards is using several such antennas at Boulder, Col., to study radio emission from the sun and its day-to-day effects on radio communication on the earth. At Harvard University Bart J. Bok, Harold I. Ewen and their associates are investigating the radio "song" of hydrogen in space with a similar parabolic reflector.

The nearest approach to an optical mirror in a radio telescope is a 50-foot parabolic antenna of cast aluminum at the Naval Research Laboratory overlooking the Potomac River in Washing-



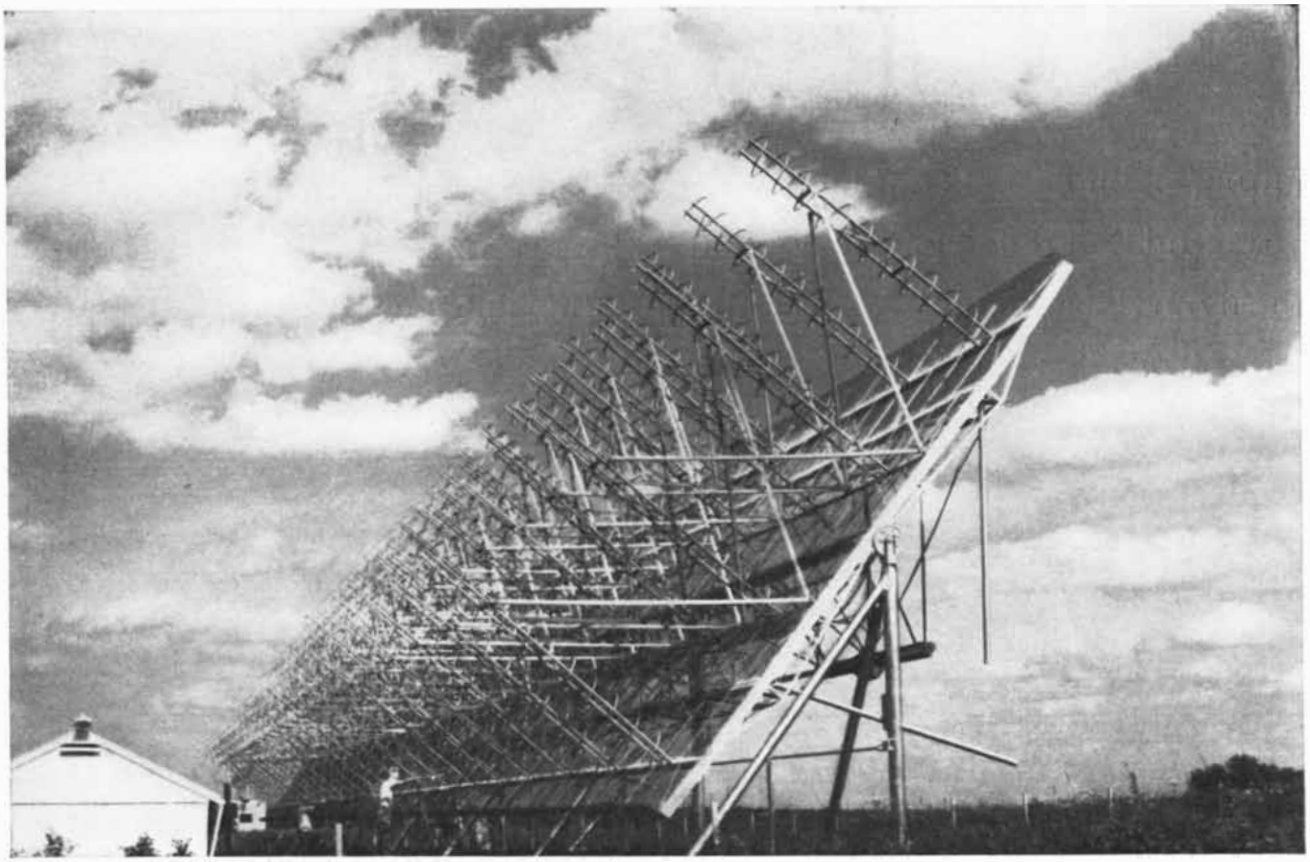
National Bureau of Standards radio telescope at Boulder, Col., is 25 feet in diameter.



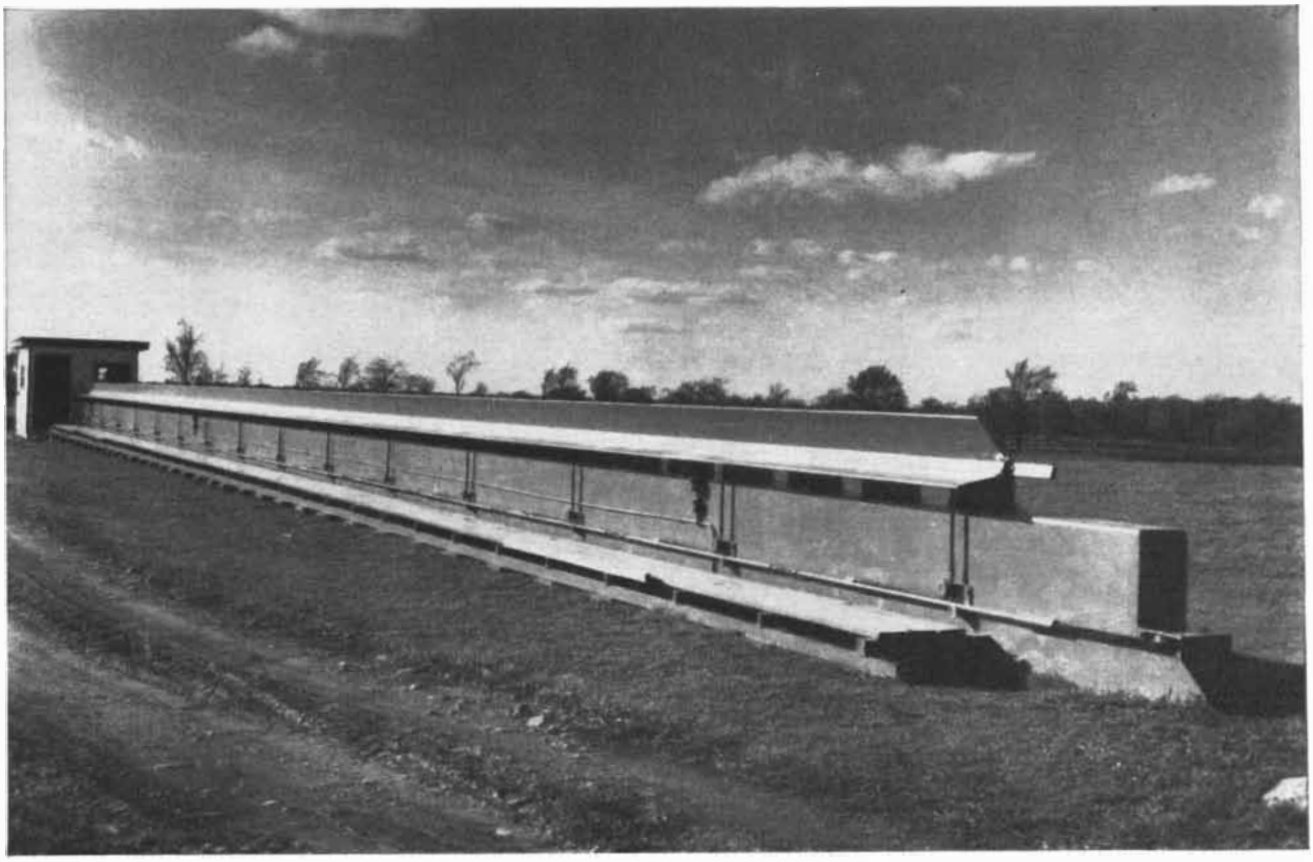
Telescope of the Naval Research Laboratory in Washington, D. C., is 50 feet in diameter.

Radio interferometer at Sydney, Australia, has a 700-foot array of 32 parabolic reflectors.

Larger telescope near Sydney has 600 dipoles mounted above a chicken-wire reflector 1,500 feet long.



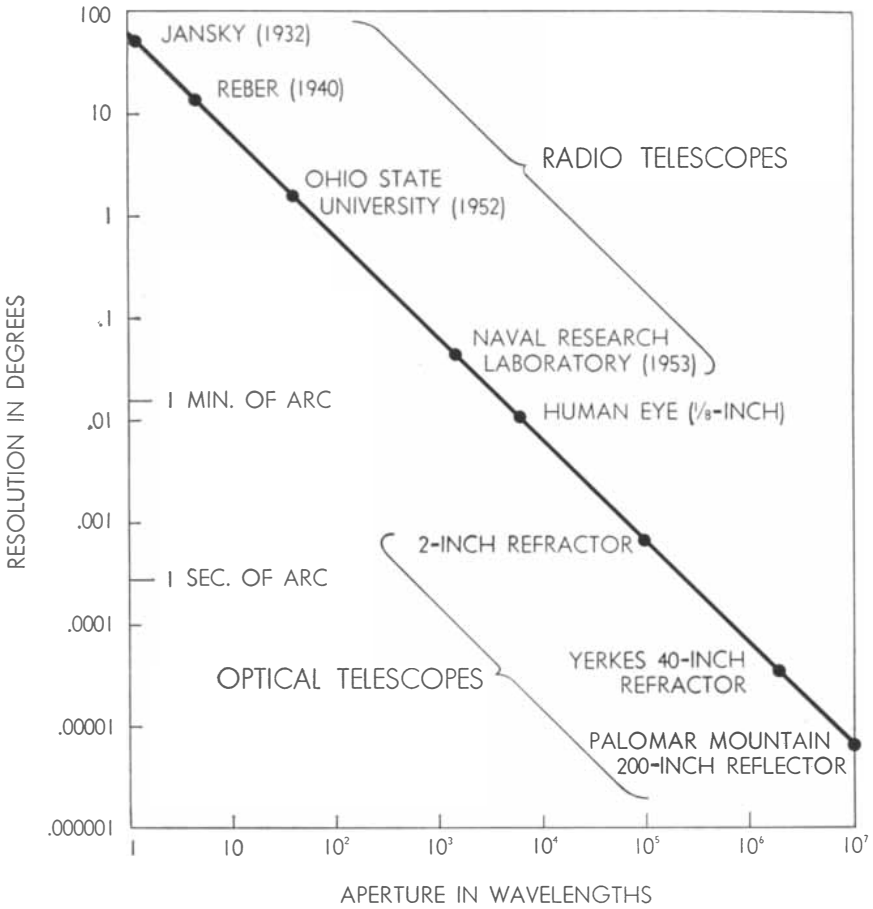
Radio telescope of the Ohio State University consists of 96 helical antennas



Telescope built at Ottawa by the National Research Council of Canada has a horn 150 feet long

ton, D. C. [*see photograph on page 38*]. This huge dish has a pencil beam less than one half of a degree wide at a wavelength of nine centimeters and an even sharper beam at shorter wavelengths. The surface of the dish is machined to such accuracy that it can be operated at wavelengths of one centimeter and less. At a wavelength of nine centimeters it has detected radio signals from a number of gaseous nebulae. The antenna, mounted on a converted gun platform, can be swung in both the horizontal and the vertical directions.

The largest steerable dish in the world is now under construction at Manchester, England [see "Radio Stars," by A. C. B. Lovell; SCIENTIFIC AMERICAN, January, 1953]. The parabolic bowl of this colossus will be 250 feet in diameter and weigh 300 tons. The telescope will operate over a considerable range of wavelengths and will be extremely versatile: it will be used to explore concentrated radio sources and the clouds of interstellar hydrogen, to locate meteors by radar, to bounce radar signals off the moon and possibly also from the planets. At a wavelength of 1.9 meters it will have a pencil beam less than two degrees wide.



APERTURE of an optical or radio telescope, expressed in terms of wavelengths, determines its resolution. Here the resolution of telescopes is plotted against wavelength. At the upper end of the curve are the early radio telescopes built by Karl G. Jansky and Grote Reber.

The parabolic reflector is only one of several devices by which radio waves can be focused. Another is a flat array of dipoles. When the array faces directly toward the radio source, the incoming wave front reaches all the dipoles simultaneously, and the signal is recorded at maximum strength. When the wave front comes in at a slight angle, it arrives at one dipole a little earlier than at the next [*see general illustration on page 43*]. The resulting interference of the out-of-phase waves reduces the strength of the signal. At a slightly greater angle, where the arrival at each dipole is a full wavelength behind the one before, the waves reinforce one another and there is an increase in signal strength, though not to the maximum recorded when all the dipoles face the source. As a result, the pattern of reception as the array scans the radio source is multilobed, with the big central lobe showing the maximum signal strength and the spaces between the lobes representing fade-outs of the signal due to wave interference. If the dipoles are placed close together (about a wavelength or less apart), the side lobes are largely suppressed and the central lobe stands out.

An array of dipoles 1,500 feet long was built recently on flat land near Sydney, Australia, by B. Y. Mills of the Commonwealth Scientific and Industrial Research Organization. This antenna has 600 dipoles mounted above a 1,500-foot horizontal reflector made of chicken wire. Because it is long and narrow, it has a fan-shaped beam. At a wavelength of three meters the beam is only one degree wide in its narrow dimension (*i.e.*, the fan is one degree thick). The dipoles are fixed, so that ordinarily the beam points only at the sky directly overhead. But by varying the lengths of the connections from the various dipoles to the receiver—a method called electrical phasing—the antenna can be "tilted," in effect, to sweep the sky as far as 45 degrees from the zenith.

To improve the resolution of this telescope a second array 1,500 feet long has now been built at right angles across the first, forming a huge cross. Where the two fan beams intersect, they produce a pencil beam, which at a wavelength of three meters is about one degree in diameter. This arrangement has as fine resolution as would an antenna 1,500 feet square, though it does not collect as much power.

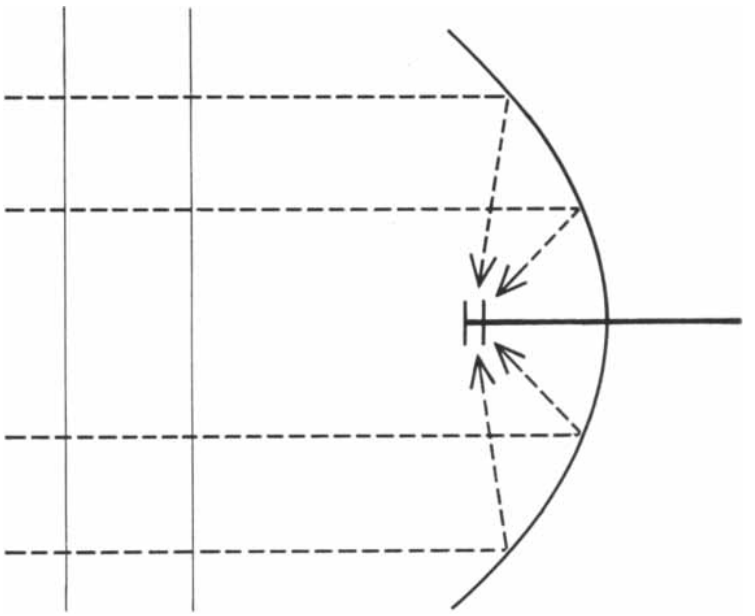
Instead of dipoles the antenna may use another kind of unit with a more efficient focusing action. It is a wire coiled in the shape of a helix. When a wave front arrives at the upper end of the helix, the part of the wave that strikes the wire is slowed down. The remainder of the wave, traveling faster through the air, is bent inward toward the helix, much as a light ray is bent by a lens. In this way a helix can gather in and focus much more radio energy than is intercepted by the cross-sectional area of the helix [*see bottom diagram on next page*].

An antenna consisting of an array of helices has been built at the Ohio State University [*photograph on opposite page*]. Its 96 helices are as effective as nearly 1,000 dipoles. The antenna has a fan-shaped beam which at a wavelength of 1.2 meters is one degree thick and eight degrees wide. The helices are mounted on a long steel reflector which can be pivoted on its long axis to sweep an eight-degree strip of the sky. With this antenna more than 200 localized and a number of extensive radio sources have been detected. One source of radio

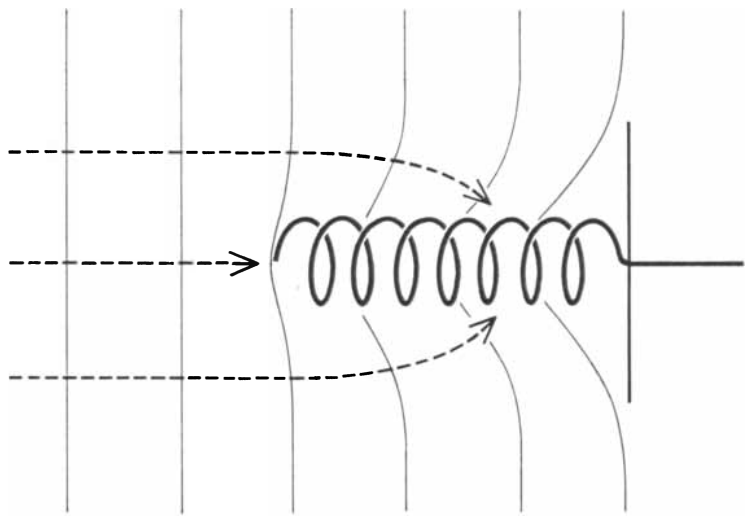
emission, extending over a long path across the sky, coincides with the plane of the supergalaxy of which the Milky Way is a part.

Still another device for focusing radio waves is borrowed from acoustics. It uses a horn to funnel the radio waves to a point. An antenna of this kind has been built by the National Research Council at Ottawa, Canada. It is shaped like a long trough, 150 feet long, 18 inches wide and only one foot deep. Radio energy collected by the horn pours through slots into a pipe (waveguide) which conducts it to the receiver. With this horn A. E. Covington obtains a fan beam one eighth of a degree thick by 22 degrees wide (at 10 centimeters wavelength). He has employed the beam to study the radio emission from small areas or spots on the sun.

Combinations of some of the foregoing methods are of course possible. For example, the features of a parabolic reflector can be joined with those of a dipole array by placing a line of dipoles along the focus of a cylindrical parabola.



PARABOLIC REFLECTOR collects radio energy and focuses it on a small dipole, which converts it into electric current. The reflector may be a sheet of metal or a grid of wires.



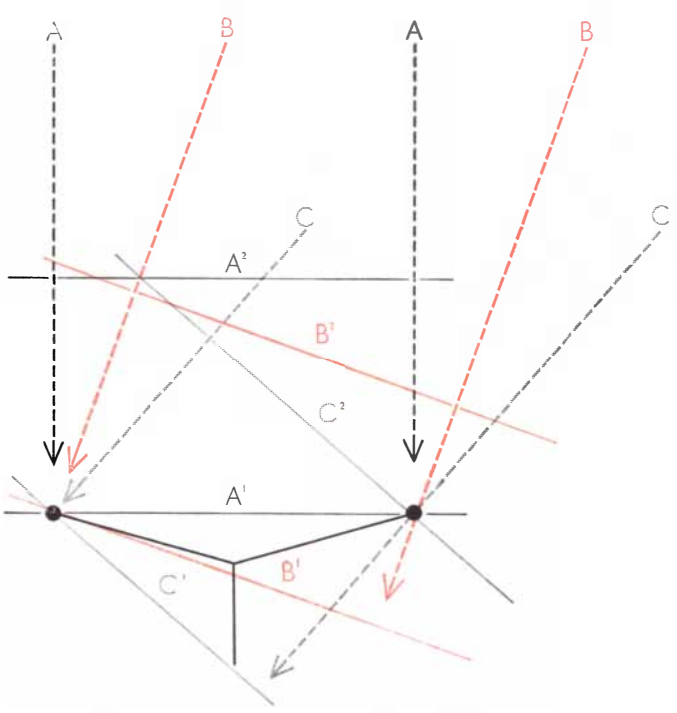
HELICAL ANTENNA refracts the fronts of incoming radio waves so that they are bent in toward it. This increases the area from which energy can be gathered by a single antenna.

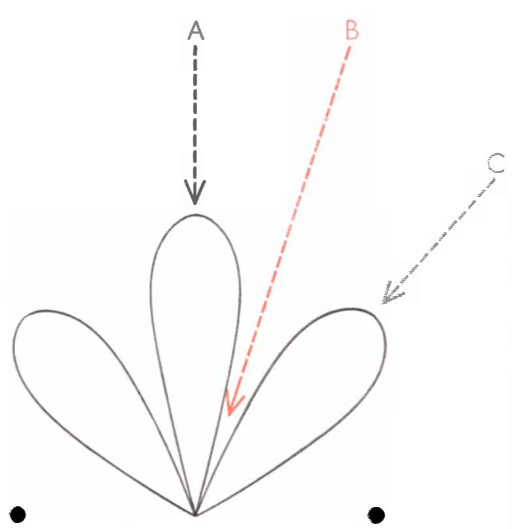
This has been done by Martin Ryle and his associates at Cambridge University in England. Their tiltable antenna has four such units, each 320 feet long and 40 feet wide. The total aperture is 51,200 square feet—the largest of any tiltable radio-telescope antenna so far built anywhere in the world.

It was inevitable that the principle of the interferometer should be applied to improve resolution without building a continuous antenna. Ryle's four units at Cambridge operate as such an interferometer, for they are placed at the corners of a rectangle 1,800 feet long by 180 feet wide. Some systems have been set up with antennas several miles apart. The interferometer effect can also be obtained in another way: namely, by setting up a single antenna near a large reflecting surface so that it receives a radio wave both directly and by the longer path it takes when reflected. J. G. Bolton of Australia has built such an interferometer on a cliff over the sea near Sydney. The ocean surface acts as the reflector, and as the antenna he uses an array of dipoles. Grote Reber, the pioneer radio astronomer, has recently constructed a similar interferometer atop a 10,000-foot volcanic peak on the island of Maui in Hawaii. There he has an unobstructed view of the ocean around almost the entire horizon.

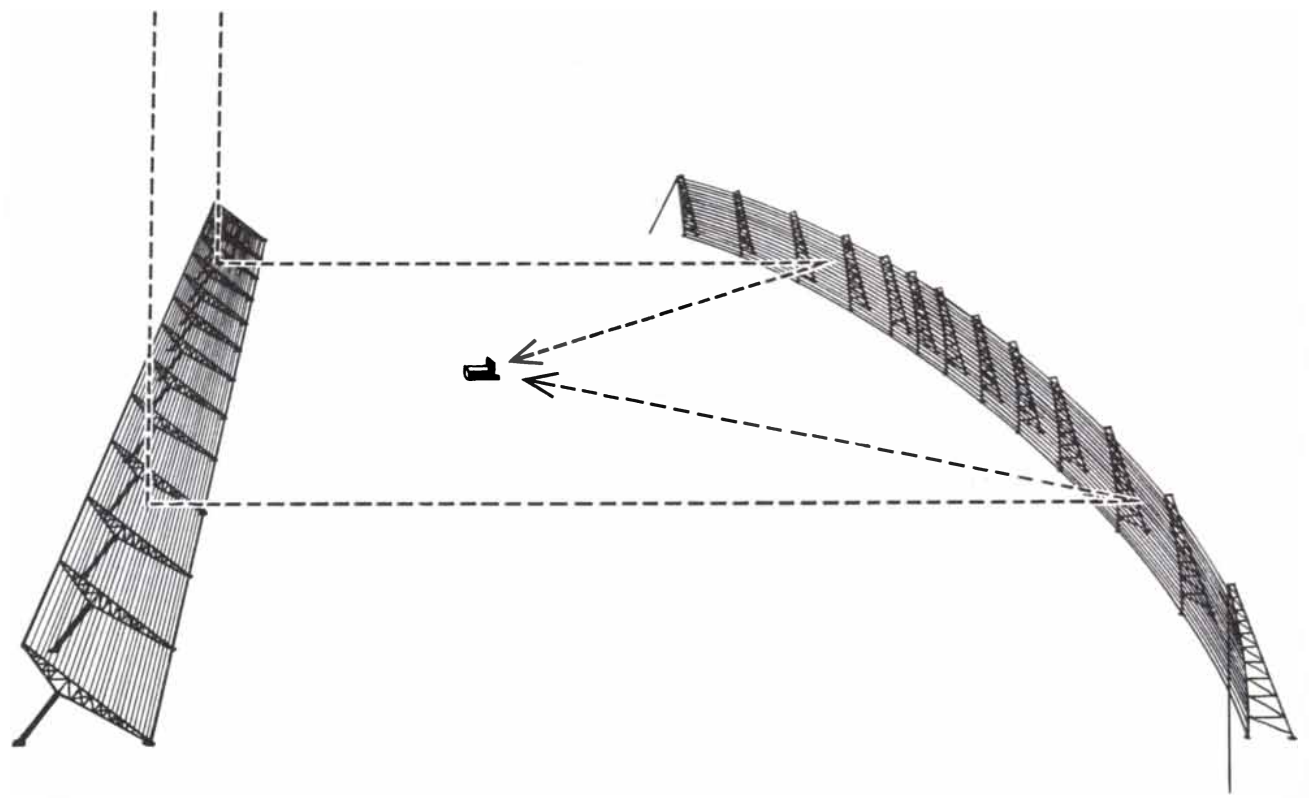
Radio telescopes more huge and finer-beamed than any described here are now on the drawing boards. At Ohio State we are testing a small-scale model of a new design for a super telescope. Its antenna would be a paraboloid 2,000 feet long and 200 feet high, made of tightly stretched horizontal wires which would collect radio waves efficiently but offer little wind resistance. A flat reflector of the same construction and about the same dimensions would deflect radio waves into the paraboloid. The reflector would be tiltable vertically from north to south, and the earth's rotation would provide the scan in the other direction. The radio waves would be brought to a focus point at the receiver in a building located near the center of the antenna layout.

This antenna would have a tiny fan beam only a tenth of a degree thick and one degree wide at a wavelength of one meter. Its cost would be no more than that of a much smaller, completely steerable type, but its enormous aperture of 400,000 square feet would give it a range several times that of existing telescopes, and would bring into "view" tens of thousands of radio "stars" within the range of the instrument.





RADIO INTERFEROMETER works by this principle. Signals from direction A have a wavelength of from A^1 to A^2. The crest of each wave arrives simultaneously at two antennas (*two dots at left*); thus the signal is reinforced. Signals from direction B have the same wavelength (B^1 to B^2). The crest of each wave arrives at one antenna while the trough arrives at the other; thus the signal is canceled. Signals from direction C also have the same wavelength. The crest of each wave arrives at one antenna while the crest of the next wave arrives at the other; thus the signal is reinforced. The phenomenon gives rise to the beam pattern shown at the right.



HUGE RADIO TELESCOPE has been tested on a small scale at Ohio State. The antenna (*right*) would be 2,000 feet long and 200 feet high. Radio waves would be directed into it by a tiltable flat reflector (*left*). Antenna's aperture would be 400,000 square feet.

THE CURTAIN WALL

The walls of a large building once had to support their own weight; today they are hung from a skeleton. They are susceptible to further specialization to preserve the internal environment of the building

by James Marston Fitch

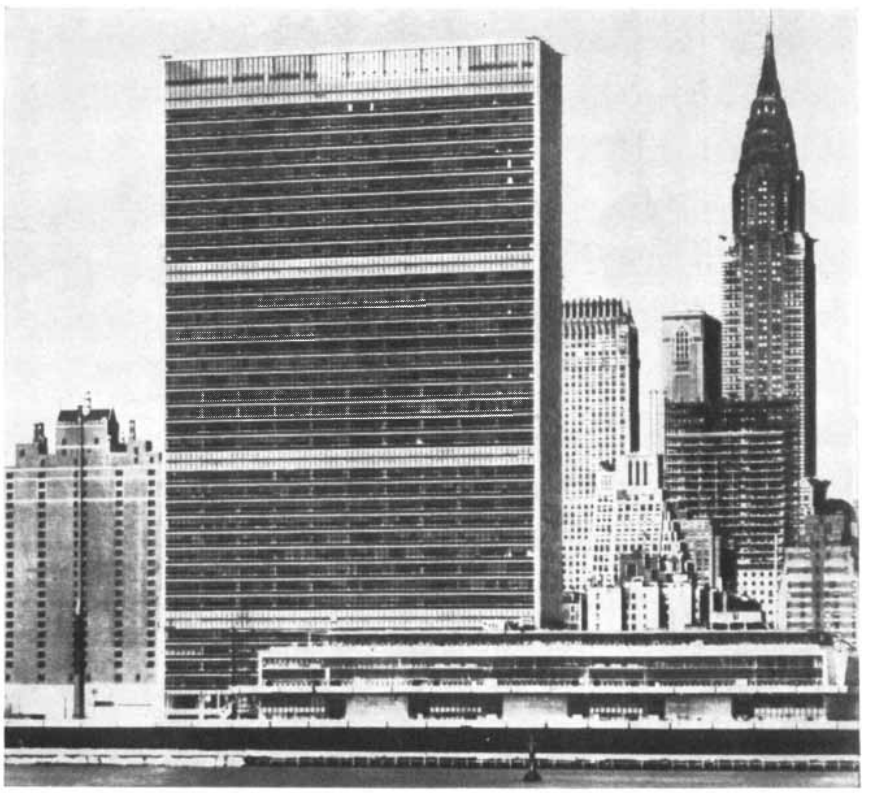
The term "curtain wall" is used nowadays to describe the sheath, or "skin," of a modern building. It looks quite different from its predecessor, the old load-bearing wall, and in fact it represents a big advance in architectural evolution. The structural specialization involved in separation of the skin and the skeleton in a building corresponds to the specialization of tissue in biological evolution. And it has equally powerful consequences. The evolutionary step from the load-bearing wall to the curtain wall has made possible a new order of performance by buildings.

Any architectural structure has two quite different tasks to perform. The first is simply that of carrying loads, vertical and horizontal. The second is that of controlling the environment within the building—regulating the interchange of light, heat, cold, sound, air, water, vapor pressure and so on. These two tasks are, generally speaking, mutually exclusive. Concrete, for example, is an excellent load-bearing material but an exceedingly poor thermal insulator. Plate glass is an excellent transmitter of visible light but has no load-bearing value. Wood is fairly strong in tension and compression but all too pervious to water and vapor pressure.

Wood, possessing properties which enable it to serve as the skeleton of a building, permitted the first steps toward specialization. But even in those countries where wood was plentiful the fire hazard tended to limit its use to floor and roof beams. In general, the material used for the wall (commonly masonry) remained an undifferentiated tissue serving both for load-bearing and for enclosure—and performing neither well. Moreover, it severely limited the size and shape of the building.

At the very first moment that materials appropriate for specialization became available, the English architect Joseph Paxton produced a stunning revolution in construction. His Crystal Palace for the London Exhibition of 1851 was a phenomenal structure in many respects. It had a light, completely articulated skeleton of prefabricated cast-iron and wrought-iron members. It had a skin of the new rolled glass, stretched like the membranes of a bat's wing or a water-lily pad to enclose the huge spaces within. It was quickly erected and could be quickly dismantled. And, though the skin did not yet protect the skeleton from climatic attack, it showed a complete separation of structural function.

The Crystal Palace was shortly followed by two other breath-taking demonstrations of the power of specialization in structure: the Brooklyn Bridge and the Eiffel Tower. In them steel, a new material with extraordinary new properties, was exploited to achieve unprecedented span and height. And steel bridges and towers were soon followed by steel-skeletoned enclosed buildings—skyscrapers clothed with a curtain wall.



UNITED NATIONS SECRETARIAT building dominates Manhattan's eastern shoreline. Its glass walls are double-paned to provide insulation and are tinted green to reduce glare.

There were three reasons for this quick development. First, the load-bearing masonry wall had reached the limit of its practicable height: in the 16-story Monadnock Building in Chicago the walls had to be seven feet thick at the sidewalk line! Second, it was impossible to achieve high standards of heating, insulation, daylighting or comfort with the load-bearing wall. Third, the rising cost of labor gave an economic impetus to the new structural system. Here were large, light, prefabricated elements which could be riveted together rapidly into an immensely strong frame and which could reduce the wall to a small fraction of its former weight and bulk.

With the steel skeleton perfected, architectural attention focused on the skin. As early as the 1890s a light and reasonably satisfactory curtain wall consisting of cellular glazed clay tiles and large sheets of plate glass was expertly employed in Chicago by Daniel Burnham in his Reliance Building and, even more impressively, by Louis Sullivan in his Schlesinger Building.

Decades were to pass before Sullivan's formula could be improved upon. The logical next step was to dispense with masonry entirely and prefabricate the entire skin in large, light units made of new sheet materials, such as stainless steel, porcelain-enameled steel, lightweight concrete, aluminum or plastics. Together with synthetic finishes and new heat-insulating materials, these panel materials promised walls only three inches or less thick. But this development was delayed for half a century, mainly by two factors: the opposition of building trades unions and municipal building codes. The bricklaying craft and others tied to the old techniques naturally resisted change. And the building codes had built-in preferences for masonry and ceramic products. Their specifications were in terms of how a wall should be built rather than of what performance should be expected of it. Only after World War II did a non-masonry curtain wall become legal in most U. S. cities.

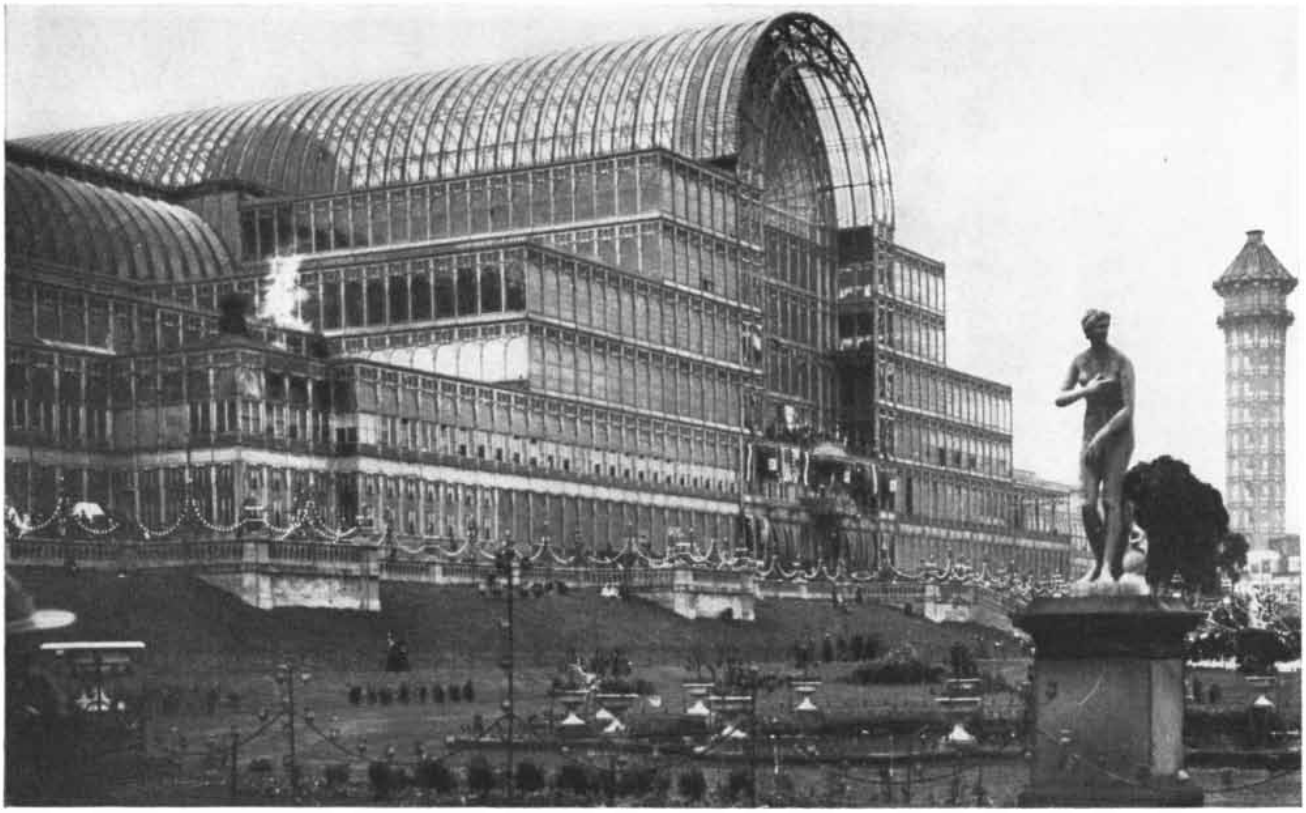
The first skyscraper with such a skin was built in 1948. Pietro Belluschi's Equitable Loan Building, in Portland, Ore., has a wall made chiefly of glass (85 per cent) with aluminum panels covering the reinforced concrete skeleton. The curtain wall was thus reduced to a membrane less than an inch thick.

The glass curtain wall is the product of a whole series of developments in glass technology. The first industrial production of rolled plate was accomplished by the 1880s. But for all its remarkable properties, ordinary glass leaves much to be desired. It is of course transparent to light and infrared, but it has a high coefficient of heat transfer. In cold weather it is therefore wasteful of heat and produces troublesome condensation. What made the glass wall practicable in Belluschi's Portland skyscraper was the glass sandwich—two sheets separated by a hermetically sealed partial vacuum. The double pane increases the insulating value by 51 per cent. Another recent improvement in glass as a skin material has to do with its optical qualities. If the entire wall is to be of glass, the intensity and direction of transmitted light must be controllable. There are all sorts of shading devices in use, usually placed inside the glass in the U. S. and outside in Central and South America, where the problem is to control heat as well as light. But now the glass itself has been modified to reduce the amount of visible light transmitted. Blue-green glass cuts off some of the glare and infrared radiation of sunlight. When used as the outer leaf of an insulating sandwich, it provides a membrane which gives fairly good control of light and heat, radiant as well as convected. It is this glass that gives many of the new skyscrapers, including the Equitable building in Portland and the Unit-

EQUITABLE LOAN BUILDING, built in 1948 in Portland, Ore., was the first skyscraper to incorporate a non-masonry curtain wall.

ALCOA BUILDING in Pittsburgh illustrates the present tendency away from all-glass walls in favor of prefabricated metal sections.

PITTI PALACE in Florence is a classic example of load-bearing wall architecture. Its walls are six feet, six inches thick. This method of construction, already ancient in 1446 when the palace was built, was not to be superseded for another four centuries.



CRYSTAL PALACE, erected in London in 1850, demonstrated for the first time how supporting and enclosing functions could be separated. The glass-and-iron building was damaged by fire in 1936 and torn down in 1941 because it was a landmark for bombers.

ed Nations buildings and Lever House in New York, their sea-green color.

Parallel with these improvements in skeleton and skin, major advances were made in the design of the internal "control organs" of the skyscraper. A climate like that of North America, with its immense variations, places severe environmental stresses on both human performance and industrial process. The individual suffers from large and abrupt variations in temperature, humidity, air movement and so on, while many industrial processes demand a set of absolutely stable environmental conditions. These twin factors led to the development of year-round air conditioning with precise control of temperature, humidity, air movement and air purity (through electric filtration and ultraviolet irradiation).

Such advances place further demands upon the performance of the building skin, requiring improved thermal insulation and more efficient vapor barriers. These demands have led to the concept of the hermetically sealed building, in which any desired set of environmental conditions may be maintained. The first expression of this concept was the "windowless factory." But this made workers feel so shut in that the opaque wall was given up for the continuous glass wall.

The sealed-envelope concept has many virtues, especially for such processes as pharmaceutical production (where sterile atmospheres are mandatory) and broadcasting (where control of sound must be very precise). Even in a skyscraper complete sealing has certain advantages. It makes the wall simpler to design and erect, and it eliminates such troublesome elements as movable sash, with their drafts, heat losses, rattles and leaks. Nevertheless, the sealed curtain wall, especially in the glass form, raises a whole new set of problems for the skyscraper. One is a simple thing such as window washing. Always a problem in skyscrapers with movable sash, it becomes a major operation in the new sealed-glass towers. Further, even the glare-reducing glass sandwich does not give sufficient control of light and heat. It still requires shades, blinds, curtains—as a glance at the new skyscrapers will prove—to modulate the flow of visible light into the rooms. And the transparency of these sandwiches to solar heat, a virtue in cold weather, becomes a liability in hot weather. To correct this, it would be necessary to use shades outside the glass, as the Latin Americans do. But problems of icing and corrosion have so far prevented the use of this technique in the northern U. S. It is true that another new heat-absorbing window glass has been developed which rejects about two fifths of the sun's infrared radiation. But for most efficient use it has to be placed outside and free of the building proper, with space for an air wash between. And theoretically it should be used only in summer, since solar heat is highly desirable in winter.

HOME INSURANCE BUILDING, built in Chicago in 1883, was the first skyscraper which had a separate steel skeleton and a curtain wall. It was designed by W. L. B. Jenney.

For reasons such as these, some of the newest buildings have returned to a markedly smaller proportion of glass and the movable sash. Their curtain wall consists of panels completely prefabricated of stainless steel or aluminum with a core of the new foamed glass or plastic insulation materials. The panels are so large, thin and light that a new 23-story skyscraper in New York City recently was completely sheathed from sidewalk to penthouse in a single working day.

The physiologist Ivan Pavlov once defined the animal organism as a system "which exists in surrounding nature only by means of a constant balancing between this system and its environment." In such a system, obviously, the marvelous animal epidermis plays a critically important role. The function of a building is analogous, yet no building skin today approaches the performance of the biological world. The curtain wall is passive, lacking the power to adjust to the fluctuating external environment. It should be able to intervene actively in

the building's struggle to maintain its internal stability.

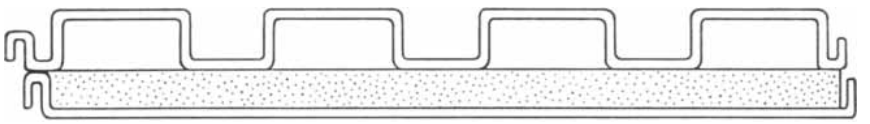
Consider the thermal problem. On a cold, sunny, windy winter day, the climate at the outer surface of the skyscraper will vary widely from one exposure to another. The south wall, shielded from the north wind and heated by the sun, may have the climate of Charleston, S. C., while the north wall, chilled by the wind and untouched by the sun, may have the climate of Manitoba. In summer the contrast may be equally extreme. Thus the climatic spread between the north and south walls might more properly be expressed in hundreds of miles than in tens of feet.

Now an air-conditioning engineer can easily calculate the gross heating or cooling loads imposed by such conditions and provide sufficient capacity to handle them. But this by no means guarantees that, from the standpoint of either human comfort or mechanical efficiency, the building will operate at an optimum level. To begin with, air conditioning by definition manipulates the air temperature; only indirectly does it influence the radiant temperature. Thus in a building heated to an air temperature of 72 degrees an office worker sitting in the sun behind the south glass wall may be in an environment with the equivalent of a 90-degree air temperature, while a worker near the north wall, radiating heat from his body to the cold glass, may be in the equivalent of a 60-degree ambient temperature.

Ideally the two walls should have quite different properties. On a cold sunny day the south wall should be able to absorb the solar heat and then transport it to the north side, where it is needed. And the north wall should be as opaque to heat transmission as possible. Under different weather conditions the properties of the walls should change to handle the new circumstances. One obvious way to accomplish this would be to introduce into the skin a capillary heating and cooling system such as a warm-blooded animal has.

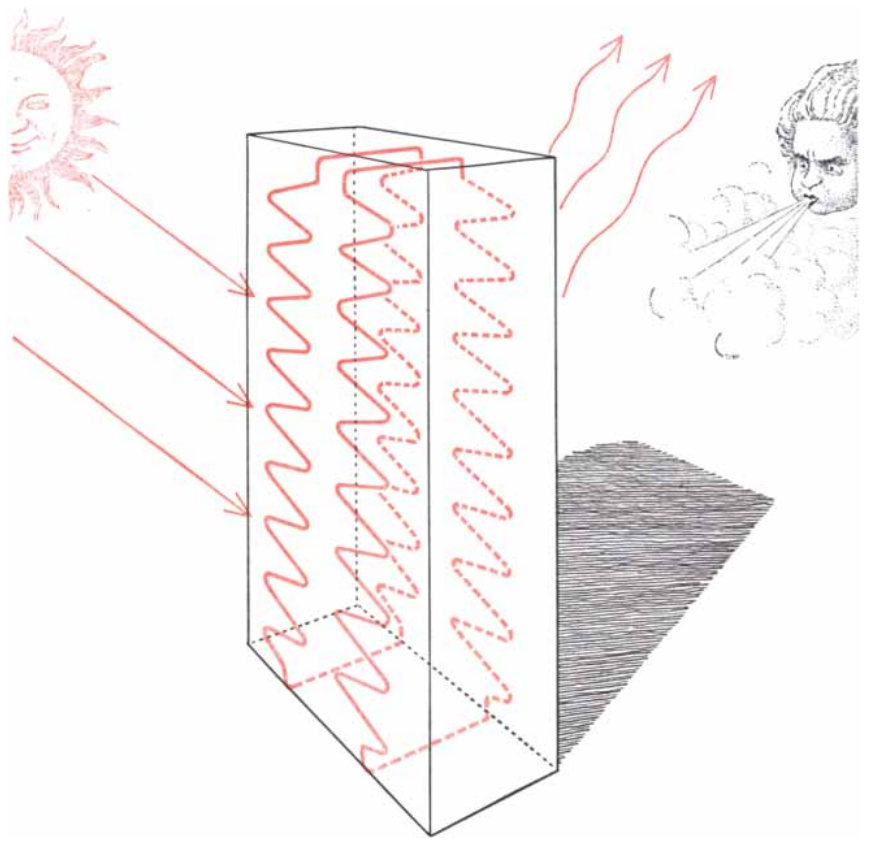
Something of this sort has been attempted in at least one U. S. skyscraper—the Bankers' Life Building in Des Moines. Completely air conditioned in a conventional manner, the structure also has a capillary system embedded in its curtain walls. The inner membrane of the walls consists of porcelain-enameled steel panels to the backs of which are attached flat coils of copper tubing. These coils circulate either chilled or heated water. Each of the four exterior walls is independently controlled by its own thermostats so that its capillary system can operate either to heat or cool that wall, depending on the climate of its exposure. On a sunny winter day the capillary system in a shaded wall will circulate hot water, while that in a sunny wall will circulate none or even conceivably chilled water. On a hot summer day the sunny walls will call for chilled water while those in shade will require less or none at all.

Such a capillary wall today is too complex and expensive for any building except one in which precise environmental control is mandatory for the conduct of its activity. Yet when the problem of the storage of solar energy is finally solved, it should be possible to have a building skin whose capillary system could absorb enough solar energy to meet a large part, if not all, of the energy requirements of heating and cooling around the year. Then building tissue would begin to approach the living world in its exploitation of the external environment. A building, like a living organism, would meet Walter B. Cannon's criterion of homeostasis, that "nearly thermostable state" which was "one of the most valuable advances in biological evolution."



ALUMINUM PANEL cross section shows metal surfaces surrounding a layer of insulating material. Outer aluminum layer (*top*) is corrugated to give the panel structural rigidity.

GLASS PANEL for a curtain wall, seen in cross section, has two panes which enclose a partial vacuum. It is 51 per cent more effective as a heat insulator than a single pane.

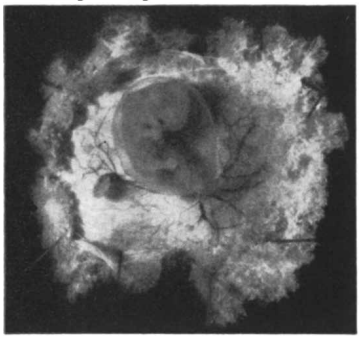


DESIGN OF THE FUTURE will use sun's heat efficiently. Coils in the curtain wall, shown in color, will absorb heat on the sunny side and carry it to the cold wall facing north.

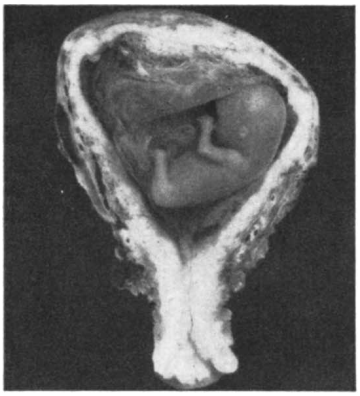
Kodak reports to laboratories on:

magnificent pictures of the human embryo . . . the parent member of the isatoic anhydride series . . . the low-down on motion pictures for industry

The beginning



This is a 39-day human embryo. The chorion has been opened and pinned back to show the fetus in the intact amnion.



This is a 10-week human embryo in the intact amnion. The uterus has been opened to show embryo and fetal membranes *in situ*.

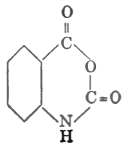
These are two of 14 photographs reproduced in "A Chart of Human and Primate Embryonic Development." They begin with a photomicrograph that shows sperm clinging to the periphery of the ovum and end with a 56-day embryo.

These magnificent pictures have been supplied us by the Carnegie Institution of Washington, Department of Embryology. The chart is on heavy paper, 32 inches wide and 22 inches high. The supply is limited. We are now prepared to present a copy without charge to any person or institution who will assure us that it will be used under conditions consonant with the dignity of the subject.

Requests should be addressed to Eastman Kodak Company, Medical Division, Rochester 4, N. Y. No gagsters need apply.

Extramural apathy

There was an inquiry from a customer as to whether we could supply isatoic anhydride:



Too frequently, perhaps, such an inquiry piques our curiosity enough to try out an idea or two. First thing we know, there is the compound, purified and in a bottle on the shelf. So we write back and tell the inquirer that we have it now, then find he doesn't really want it—just wondering if we could supply it, which is his privilege. That is how *Isatoic Anhydride* became Eastman 6975.

There, presently, one of our own chemists from another part of the enterprise noticed it and put in a requisition for a few grams. Shortly afterwards another of our laboratories wanted some. Then another internal requisition, and another. Apathetic though the rest of the world might be about *Isatoic Anhydride*, it was apparently doing us good inside.

Surely we are not alone in our interest in this echo of Baeyer's work of eighty years ago on indigo chemistry. *Isatoic Anhydride*, a creamy powder melting at 240 C with decomposition. The name, easily misread, is from *isatis*, Greek for woad.

We stock some 3500 organic compounds in addition to Isatoic Anhydride. *They're all in our List No. 39, available without charge from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Breaking into the movies

Madison Avenue is a thoroughfare in the Borough of Manhattan, City of New York, and a place-symbol for the art practiced there of creating your neighbor's aspirations and anxieties. (Not yours, your neighbor's.) Appropriately housed at No. 285 is the headquarters of the Association of National Advertisers, to which belong about 500 of the principal corporations that endeavor successfully to preserve the economy from stagnation.

In this endeavor it appears that money is spent like water. Millions for a single television comedian. Millions for microwave relay networks, for costumes and sets, for writers of international repute, for multi-page, multi-color inserts in magazines of multi-million circulation, for mountainsides of timber converted to coupons and point-of-purchase displays, for neon waterfalls and consulting psychologists and puppeteers.

Yet in their madness there is method. No super-cyclotron builders ever had crueler fiscal watchdogs to placate. No civil engineers ever had more faith in figures than these watchdogs.

We wish now to draw attention to one particular set of their figures. These will interest persons who contemplate the production of a movie. Movies primarily entertain, but sometimes they exhort. Sometimes nothing else exhorts as well. Movies can exhort chairmen of boards, admirals, or 8-year-old girls. They can be subtle. They can be direct. They can put an attractive face on a complicated idea. They cost money.

How much they cost, where the money goes, how many people of what kind are reached, how they're reached, what the life span of a film is, why it's done in the first place, and a great many other questions are answered through statistics in a new book called "The Dollars and Sense of Business Films." It has well-illustrated charts and hard covers and is based on hitherto confidential data supplied the Association of National Advertisers by 67 of the nation's leading companies about 157 non-theatrical films representing a total investment of $12,000,000.

The book is available for $5 from Association of National Advertisers, located, as we said, at 285 Madison Avenue, New York 17, N. Y. By helping publicize it, we hope to assist anyone with a big story to tell. This is little enough for us to do. The movie business is a very good customer of ours.

Price quoted is subject to change without notice.

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

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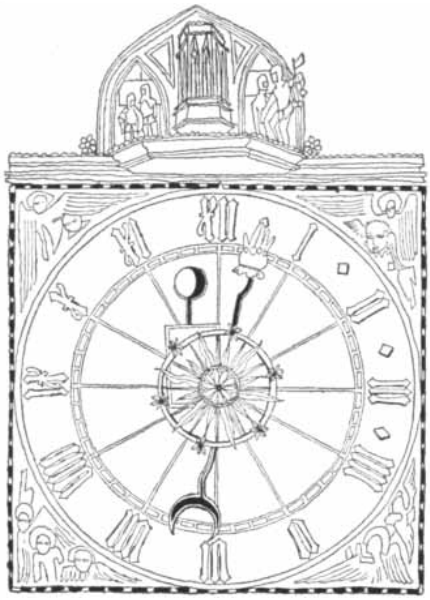
TRADE-MARK

SCIENCE AND



Atomic Energy Progress

The opening weeks of 1955 saw a number of events signaling progress toward useful nuclear power.

At the United Nations a committee of scientists from seven nations prepared an agenda for this summer's international conference on the peaceful uses of atomic energy. The meeting, to be held at Geneva, will begin on August 8. At least 80 states will be invited, all of them members of the UN or of its specialized agencies. I. I. Rabi, Columbia University physicist, heads the planning group. The conference president will be Homi J. Bhabba, chairman of the Atomic Energy Commission of India, and its secretary-general will be Walter G. Whitman of Massachusetts Institute of Technology.

From the U.S.S.R. came an announcement of a 5,000-kilowatt nuclear power station. *Pravda* published pictures of the installation, claimed to be the first industrial plant in the world. The unit has been operating since July, 1954. The Soviet government said that it would disclose detailed information about the power reactor at the Geneva conference.

On the expectation that a good deal of information will be declassified after the Geneva conference, the Engineers Joint Council has scheduled a nuclear engineering congress in December, 1955. The meeting will be held in Cleveland. According to John R. Dunning, chairman of the Council's committee on nuclear engineering, the declassification of data will make possible "open discussion and planning toward wider-scale peaceful uses of atomic energy."

The U. S. Atomic Energy Commission announced that it has set a schedule of prices for nuclear materials. It will sell or lease natural uranium, thorium and heavy water to private users and lease U-235, U-233 and plutonium. It will buy plutonium and U-233 produced as by-products in reactors. The prices are classified and available only to properly cleared persons. The AEC also invited specific proposals from industry for building experimental nuclear power plants. Chairman Lewis L. Strauss said the Government would offer assistance "within the limits of available funds" to firms with acceptable plans. The help may include supplying fissionable materials free of charge, providing research and development work in AEC laboratories and paying contractors for technical and economic information growing out of their programs.

At Groton, Conn., atomic motive power became a reality. The new submarine *Nautilus* backed away from her dock, swung around 180 degrees and headed down the Thames River to the sea under nuclear power. Watching the craft glide her smokeless way through the water, a young naval officer jeered: "I think she's running on batteries."

Account Closed

The U. S. has agreed to pay, and the Japanese government to accept, $2 million for damages resulting from last March's hydrogen bomb tests. Although the distribution of the money is "in the sole discretion of the Government of Japan," the U. S. stated that some of the funds are for the fishermen who were injured by radioactive ash and some for the fishing concerns whose cargoes were contaminated. These concerns had placed their damages at $5 million. The U. S. note said the payment was made as "an additional expression of its concern and regret" but "without reference to the question of legal liability."

Last Laugh

The Reece Committee's investigation of tax-exempt foundations amused much of the nation, but it effectively accomplished its purpose, according to Robert M. Hutchins, president of the Fund for the Republic, Inc. In a speech to the National Press Club in Washington last month Hutchins asserted that the

foundations, which should be supplying the "risk or venture capital in the field of philanthropy," now find it safe only to "attract no attention, arouse no discussion, create no controversy." He declared: "Congressman Reece was scoffed at. It was agreed that his investigation was a farce. I think he had good reason to be satisfied with himself. I think he won. Without firing a single serious shot, without saying a single intelligent word, he accomplished his purpose, which was to harass the foundations and to subdue such stirrings of courage, or even of imagination, as could be found in them."

Slightly Secret

A new Government agency indicated last month that it was seeking a "voluntary" censorship of some nonclassified technical information. Representatives of the U. S. press immediately objected.

The agency was the creation of Secretary of Commerce Sinclair Weeks. Called the Office of Strategic Information, it is to advise publishers about nonclassified material which it thinks might help a potential enemy. Secretary Weeks said the agency would assure "that in the necessarily free exchange of scientific data we do not provide nations whose interests are inimical to our own with material which they could some day use against us." R. Karl Honaman of the Bell Telephone Laboratories was named to head the office.

The American Society of Newspaper Editors labeled the agency "the most serious threat to freedom of information that has developed in the Eisenhower administration." Honaman replied in a letter to *Editor & Publisher*, stressing that the censorship would be "truly voluntary" and that no decisions had yet been made on what should not be published. J. R. Wiggins of the A.S.N.E. commented that Honaman's statement removed none of the publishers' apprehensions.

Wiggins found most editorial opinion on his side. *Editor & Publisher* called the plan "abhorrent to a free press." *Chemical and Engineering News*, the weekly journal of the American Chemical Society, said "there is no need for an agency like O.S.I." The *Wall Street Journal* said "the whole plan ought to be junked right now."

How Long Is a Second?

As the measuring techniques of science grow more precise, units of measurement tend to blur. Thus the astronomical time unit—the mean solar day—is known to have varied by as much as one part in 10 million during the last 80 years. The U. S. standard kilogram seems to have put on two thousandths of a milligram since it was last weighed in 1937. The value for the force of gravity accepted for the past half-century is probably a few thousandths of 1 per cent too large.

These were some of the problems discussed last fall at the Tenth General Conference on Weights and Measures at Sevres, France. Held at six-year intervals, the congress of standards experts from 35 nations decides on definitions of units. A summary of the meeting by one of the U. S. delegates, E. C. Crittenden of the National Bureau of Standards, appeared in *Science* recently.

The Conference approved a suggestion of astronomers that the unit of time be nailed down by referring it to a specific year. Accordingly the International Committee is to define the second as: 1/31,556,925.975 of the tropical year 1900. (A tropical year is the period between successive vernal equinoxes.) In another change, the absolute temperature scale was redefined in terms of a single fixed reference point—the triple point of water. The temperature of that point (at which ice, water and water vapor can exist in equilibrium) is now, by definition, 273.16 degrees Kelvin. This step was first suggested 100 years ago by Lord Kelvin himself.

The International Bureau reported to the Conference that it had recalibrated various national standard kilogram weights against the international standard. Revision of the value of the force of gravity was postponed until the next meeting to permit further measurements, as was the matter of redefining the standard meter in terms of the wavelength of the light in a single spectral line. The Conference could not make up its mind whether to choose the red line of cadmium, the green line of mercury or certain lines in the spectra of krypton and xenon.

Muscle Fuel

Biochemists have become more and more confident in recent years that adenosine triphosphate (ATP) is the source from which animal muscles get their energy. Last month the British journal *Nature* published startling news.

Two groups of researchers reported that muscles can contract without using up any of the ATP they contain.

One series of experiments was carried out by A. Fleckenstein and J. Janke of the University of Heidelberg in Germany together with Nobel laureate H. A. Krebs and his colleague R. E. Davies of the University of Sheffield in England. This group stimulated contractions in bits of slow-moving frog muscle, abruptly stopped the process (both physical and chemical) by freezing the muscle in liquid nitrogen and then compared the ATP content of the contracted tissue with noncontracted but otherwise identical controls. They found no decrease in ATP in the working muscle. A similar investigation of turtle muscle was carried out by W. F. H. M. Mommaerts of the Western Reserve University School of Medicine. Instead of measuring the ATP, he looked for compounds it would produce if broken down. He found no breakdown products.

The European investigators did discover that the total quantity of organic phosphates in the muscle decreases after a contraction, and that inorganic phosphates increase. If all of the latter come from the breaking of phosphate bonds like those in ATP, there would be just enough energy to account for the work done by the muscles, assuming the bond energy is used 100 per cent efficiently. The biochemists are now searching muscle tissue for unknown phosphate bond compounds. They are also checking other possible energy sources, such as an uneven concentration of ions in the tissue. These sources presumably pick up their energy from ATP (produced by the burning of carbohydrates) and store it for use in the muscle.

Mommaerts remarks: "The possibility of a new revolution in muscle physiology is clearly discernible."

Yellow Peril

The U. S. is one of the few nations in the Western Hemisphere where urban epidemics of yellow fever are still possible, and it is the only country which is doing nothing about the problem, according to a report at a recent Washington conference of the Pan American Sanitary Bureau, regional office of the World Health Organization.

Most American countries have eradicated the *Aëdes aegypti* mosquito, the yellow fever transmitter, but it still flourishes throughout the southern third of the U. S., along the seacoasts of Mexico and down into Guatemala. The Guatemalan jungle, like all other such tropical

areas in the Hemisphere, is a bottomless reservoir of the yellow fever virus. Monkeys harbor the germ, and it is carried in the jungle by a large variety of mosquitoes and probably other insects as well. Only by the greatest vigilance can the infection be kept from spreading to nearby civilized regions. From 1924 to 1948 there were no human cases of yellow fever in Central America. But since 1948 a wave of the disease has moved slowly and steadily up from Panama to Honduras. If it should reach Guatemalan cities, either from the jungle interior or from Honduras to the south, it might spread to the southern U. S. and erupt explosively.

Public health authorities at the conference urged that this country join in the program to wipe out *Aëdes aegypti*. They also discussed the need for a better yellow fever vaccine. The present vaccine must be refrigerated, and so is almost useless in the tropical jungle where it is needed most.

New Animal

A tiny primitive creature which no zoologist has ever seen before, and which gives new insight into the ancestry of crustaceans, has been discovered on the bottom of Long Island Sound by a Yale University graduate student. The animal differs so widely from known types that it has been placed in a new subclass of crustacea called *Cephalocarida* ("head shields"). It is "certainly one of the biggest subdivisions of living animals ever described in this country," according to Daniel Merriman, director of the Bingham Oceanographic Laboratory at Yale. Howard Sanders, the discoverer, has given his animals the genus name *Hutchinsoniella*, in honor of G. E. Hutchinson, professor of zoology at Yale. He named the species he found *macracantha*, meaning large-spined.

Hutchinsoniella macracantha is less than a tenth of an inch long and thin enough to swim easily through the eye of a needle. Its eyeless head resembles a tiny horseshoe crab. It has 18 body segments and a forked, spiny tail. The large number of body segments marks it as a very primitive form, Sanders says. Also, its feeding organs are rudimentary and its appendages unspecialized. The anatomy of *Hutchinsoniella macracantha* shows striking similarities to three sharply differentiated higher forms: *Malacostraca*, which include lobsters, crabs, shrimp and most of the other well-known crustaceans; *Copepoda*, which are part of ocean plankton; *Branchiopoda*, which live in fresh-water

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ponds. Thus the new subclass may be much like the ancestral form from which the others developed. The find is significant because little has been known about the evolution of crustaceans.

Nine individuals have turned up so far, all female. They come from observing stations about 30 feet deep off the Connecticut coast where Sanders has been studying bottom life in connection with a complete oceanographic survey of Long Island Sound. He described the animal in *The Proceedings of the National Academy of Sciences.*

Caves and Villages

In recent months the men who investigate the evolution of man and his way of life have reported two discoveries of fundamental interest. One sheds light on the life of men in a South African valley some 150,000 years ago. The other, made in Iraq, provides new information about men living in the agricultural revolution of 7,000 years ago.

In *Nature* the South African workers C. K. Brain, C. Van Riet Lowe and Raymond A. Dart published a series of papers on their study of a remarkable cave at Makapansgat. The original rock floor of the cave is overlaid with more than 50 feet of sediment, a lower layer of which is rich in the bones of the man-like ape *Australopithecus prometheus.* Immediately above this bone-rich stratum was a layer of gravel containing many chipped stones. Brain wrote that there was no great difference between the ages of the two layers. Van Riet Lowe indicated that at least 17 of the stones could only be tools shaped by man. Thus it seems certain that man came to Makapansgat either while man-like apes were there or very shortly afterward. The two layers of sediment are only early pages in a story that unfolds continuously down to the present. According to Dart the find "opens up the astonishing prospect that Makapansgat may place within our grasp in a single South African valley a continuous story of human handiwork and a consecutive chronology of mankind from the dawn of the Pleistocene to the present day."

At M'Lefaat in northeastern Iraq Robert J. Braidwood, University of Chicago archaeologist, dug into the site of a primitive village. The inhabitants of the village practiced agriculture, but had no pottery. Braidwood believes that M'Lefaat is even older than Jarmo, until now the oldest known habitation of men who practiced agriculture (see "From Cave to Village," by Robert J. Braidwood; SCIENTIFIC AMERICAN, October, 1952).

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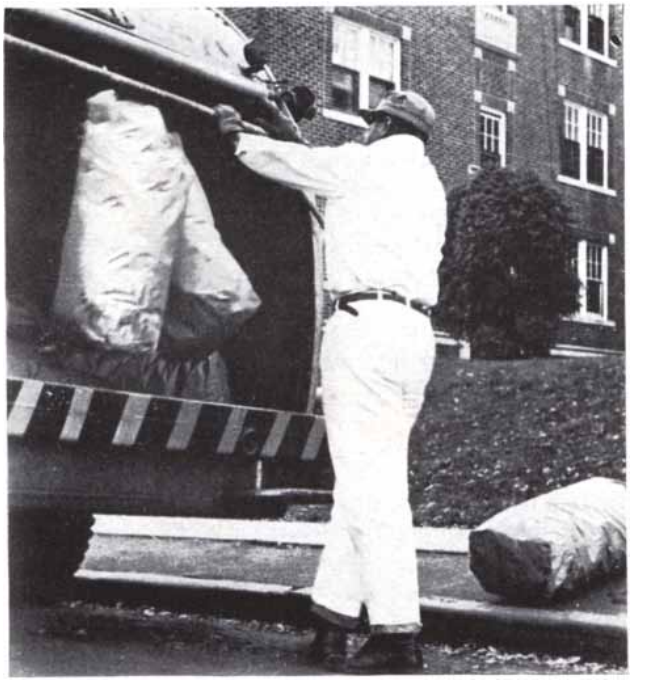
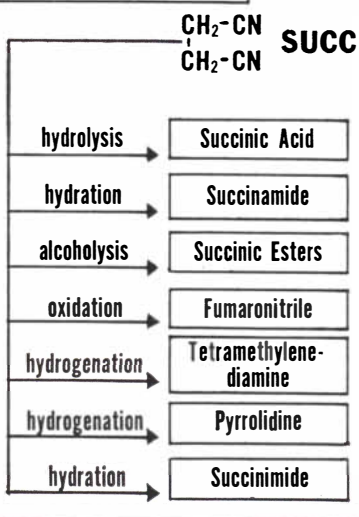


"MOST GLAMOROUS GARBAGE IN THE WORLD." That's what residents said of a new garbage collection system tested by Hartford, Conn., and Cyanamid and Union Bag and Paper Corp. It eliminates garbage spillage, odors, return trips by the collector, banging of cans on sidewalk and truck. This "package system" uses a paper bag made with Cyanamid's Melostrength® Resin, which gives paper exceptional strength, wet or dry. **(No. 2)**

Life ...on the Chemical

New Product News



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The reactions of succinonitrile may be utilized to prepare a variety of bifunctional chemicals which find application in the fields of resins, pharmaceuticals, surface active agents, and dyestuffs. **(No. 3)**

VAT DYES GIVE LASTING LIFE to colorful vacation fashions. *Vat dyes are the best dyes* for cotton and viscose rayon fabrics repeatedly exposed to sunlight, salt water, perspiration, rubbing and washing. These characteristics of vat dyes account for their popularity. Cyanamid, producer of Calco® Vat Dyes, works closely with textile finishers to help get top color performance. **(No. 4)**

AROUND THE CLOCK SERVICE to Cyanamid's customers is provided by modern phosphate mining, processing and handling facilities at Brewster, Florida. The rotary stacker-conveyor (above) helps expedite customers' shipping schedules of high-grade phosphate of the desired analysis for both agricultural and industrial uses. In this system, the boom stacker dumps rock at the rate of 800 long tons per hour from a height of 86½ feet. Underneath the piles of rock is a kidney-shaped tunnel—approximately 1,025 feet long—which contains two 24" belt conveyors for carrying the phosphate rock to the Drying Plant in the background. There the rock is dried, further sized if customer requires, and loaded for shipment. Equally specialized equipment also speeds mining and processing, helping Cyanamid to give unusually flexible service to users of this basic chemical. **(No. 5)**

Newsfront

STARTER CLUTCH MECHANISMS for the sleek new Martin B-57b bomber are getting a new carburizing treatment. Made by General Electric's Aircraft Accessory Turbine Dept. at Lynn, Mass., these parts are carburized in Cyanamid's new high-speed AEROCARB® S and R Carburizing Compounds. They give deep, rapid penetration, minimum distortion. **(No. 6)**

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UNKNOWN VIRUSES

In Africa and South America investigators discovered 11 viruses not identified with any disease. These are now studied because they are potentially dangerous and shed light on the behavior of all viruses

by George W. Gray

A U. S. foreign correspondent whose assignment had taken him to Calcutta awoke one morning with a burning headache. He called a doctor. After examining him, the British physician said:

"Looks like three-day fever."

"And what's that?"

"Nobody knows, really. There are any number of uncatalogued diseases that crop up sporadically. If this *is* three-day fever you should be over it in three days. If you aren't, we'll guess something else."

Incidents like this are not peculiar to India or other places where one might perhaps expect to encounter strange infections. Even in the best U. S. hospitals, with their modern facilities, specialists and diagnostic aids, a patient's chart is occasionally labeled PUO, meaning pyrexia (fever) of unknown origin. The contagion now called St. Louis encephalitis appeared suddenly about 20 years ago as a PUO. In recent years many other odd infections have cropped up in the U. S., among them rickettsial pox, Q fever and Coxsackie virus disease.

It has become almost automatic with physicians, when confronted with an unidentified infection, to attribute it to a virus. Such diagnosis is far from scientific, for only by laboratory test can one determine whether an agent is a virus, a bacterium or a protozoon. However, viral species are so numerous, varied, elusive and widespread that if one must give a snap judgment the odds are best for guessing "virus." Most of the pathogenic viruses were discovered by the triple process of encountering a patient with an unknown infection, suspecting a virus and then testing for it by well-established laboratory techniques.

Some years ago bacteriologists of the Rockefeller Foundation found themselves in the opposite situation: they discovered some strange viruses and had to go looking for diseases which these viruses might cause! While surveying the extent of yellow fever in Africa and South America, these workers isolated 11 viruses which no one was able to identify with any previously recognized disease. The new viruses were preserved and brought to New York for further testing.

Since 1949 these viruses have been the focus of an intensive research on a world-wide scale, with headquarters in the New York laboratories of the Rockefeller Foundation's Division of Medicine and Public Health and field stations in Asia, Africa and South America. Important results are already appearing. New aspects of the nature of viruses are being brought to light, as well as new techniques for exploring them and a previously unsuspected pattern of kinship among viruses which suggests possible hereditary relationships among them.

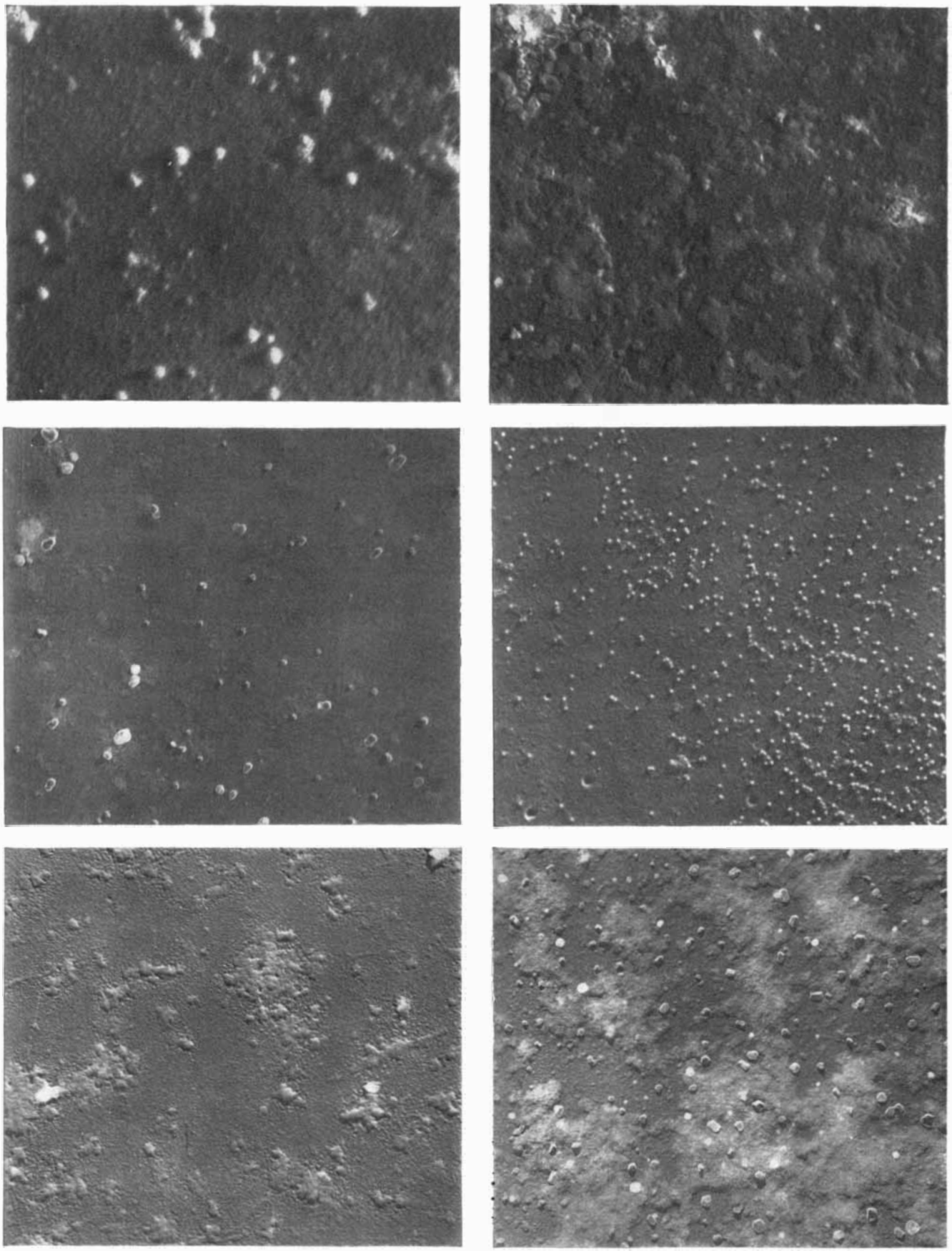
The Sequence of Discoveries

Seven of the unknown viruses were discovered in the British protectorate of Uganda, where a Rockefeller team was working in collaboration with a British group at the Virus Research Institute. The protectorate borders on the vast jungle belt of central Africa in which yellow fever is endemic, and the Institute was seeking to find out whether yellow fever was active in Uganda. During the winter and spring of 1937-1938 there was considerable illness among several hundred native workers who were building a highway in Bwamba County in western Uganda. Most of the infections proved to be well known—malaria, dengue and so on (though no yellow fever was found in this particular outbreak). But one day in December, 1937, a worker came to a dispensary complaining of severe headache, backache and fever. A. F. Mahaffy, a member of the Rockefeller staff, found no recognized microbe in the man's blood, but when he injected serum from the patient into the brains of mice, most of the animals died.

Dr. Mahaffy, with the assistance of Kenneth C. Smithburn and J. H. Paul, began a systematic laboratory investigation of the serum. It evidently contained a virus. Tested in rhesus monkeys, it proved infectious but not fatal to them, and after their recovery from the illness the monkeys' blood carried antibodies which neutralized the virus. Meanwhile, during the next several months, eight additional cases of the same infection were encountered among the road laborers. The agent was named Bwamba fever virus after the county where it had been discovered.

In the same month that the Bwamba virus turned up, another staff man of the Virus Research Institute discovered a second strange virus in the West Nile district of Uganda. A 37-year-old woman was being examined in a general check by British colonial medical officers to detect possible cases of African sleeping sickness. She denied feeling ill (perhaps to avoid hospitalization), but was found to have a temperature of 101.6. Dr. A. W. Burke tested her serum on 10 mice, and it killed nine of them. Burke took the serum to the laboratory and there studied it with the collaboration of Smithburn, Paul and T. P. Hughes. The four virologists found that the new virus, which they named West Nile, was more potent and more destructive to nerve tissue than the Bwamba virus.

The Rockefeller field researchers proceeded to test the blood of natives in many parts of Africa for immunity to



SIX "UNKNOWN" VIRUSES appear in these electron micrographs. At upper left is the Bwamba virus; at upper right, the Semliki Forest virus; at left center, the Bunyamwera virus; at right center, the Japanese B virus; at lower left, the Anopheles A virus; at lower right, the Anopheles B virus. All are enlarged 16,500 diameters except the Semliki Forest (30,000) and Japanese B (29,000).

VIRUS	SIZE (MILLIMICRONS)
GROUP A	
SEMLIKI FOREST	69-61
EASTERN EQUINE	25
WESTERN EQUINE	25
VENEZUELAN EQUINE	
SINDBIS	
GROUP B	
NTAYA	150
WEST NILE	69-61
ILHEUS	61-53
ZIKA	61-53
UGANDA S	53-42
ST. LOUIS ENCEPHALITIS	30-20
DENGUE A	25-17
YELLOW FEVER	25-17
RUSSIAN SPRING-SUMMER	25-15
JAPANESE B	22-15
MURRAY VALLEY FEVER	22-15
UNKNOWN	
ANOPHELES A	170-163
ANOPHELES B	170-163
WYEOMYIA	170-163
BWAMBA	163-151
BUNYAMWERA	151-140
SAND FLY	60-40
COLORADO TICK	50-35
RIFT VALLEY	35-23
CALIFORNIA	

VIRUS GROUPS are established by the fact that antibodies against one virus sometimes react with certain other viruses. The relationships of nine viruses shown here are unknown, as are the diameters of three.

these two strange microbes. In every village they found persons whose blood carried protective antibodies—evidence that they had had these infections at some time. Surveys in the Anglo-Egyptian Sudan and in the West Congo showed as high a frequency of immunity as was found in Uganda; in some settlements 80 to 90 per cent of those tested were immune. Clearly both diseases were prevalent—and yet the only active infections encountered in the field at the time were the nine cases of Bwamba fever among the road workmen and the single case of West Nile fever in the woman in whom that virus was discovered. Some of the researchers, however, became infected with the viruses in the laboratory—Mahaffy suddenly found his blood teeming with the antibodies of Bwamba fever. Most of these infections were mild.

Bwamba and West Nile had been under investigation for five years before the next unknown was spotted. It was found not in human beings but in mosquitoes. The yellow-fever hunters made a practice of trapping mosquitoes and testing filtrates from their bodies for the presence of virus. In 1942 Smithburn processed a batch of mosquitoes which had been caught by A. J. Haddow in the Semliki Forest. This material yielded another virus unlike any in the catalogues. Injected into the brains of mice, it proved to be the most potent yet of the new microbes, more potent even than yellow fever. In a dilution of one part in a hundred million it killed nearly 100 per cent of the mice. No case of human illness from Semliki Forest virus was ever found, but blood tests showed that numerous persons in Uganda and many wild monkeys caught in its forests carried immunity.

Uganda mosquitoes yielded two other viruses in 1943. Named Bunyamwera and Ntaya, they were isolated by Smithburn with the assistance of Haddow and Mahaffy. In 1947 came two more, spotted by G. W. A. Dick, a British member of the team, and isolated with the help of Haddow and Smithburn. Uganda S virus was found in three species of mosquitoes captured in Bwamba County, and Zika virus was first detected in the blood of a monkey that had been tethered on a tree platform in the Zika forest, a dense wood on an arm of Lake Victoria.

While these discoveries were accumulating in Africa, a similar yellow fever survey in South America turned up four more unknown viruses—three in Colombia and one in Brazil. The Colombian finds were made in 1940 by Manuel Roca-Garcia of the Carlos Finlay Institute in Bogotá. Two of the virus species were isolated from Anopheles mosquitoes, a genus known to transmit the malaria parasite but not previously known to harbor any kind of virus. These two viruses were named Anopheles A and Anopheles B. Roca-Garcia made a third discovery in a batch of Wyeomyia mosquitoes, and accordingly named the microbe Wyeomyia virus.

The Brazilian virus was isolated in 1941 by Hugo W. Laemmert, Jr., and Thomas P. Hughes, who were connected with the Yellow Fever Research Service of Brazil. Derived from mosquitoes captured near the town of Ilhéus, in the state of Bahia, the virus was named Ilhéus.

Each of the 11 new-found viruses has its own individual characteristics, but all have three properties in common: they are transmitted by the bite of an insect, they have a peculiar affinity for nerve tissue and they infect man.

A Dark Continent

Andrew J. Warren, director of the Rockefeller Foundation's Division of Medicine and Public Health, observes that "virology is one of the dark continents of medical science, and yet its subject matter includes some of the most destructive and crippling diseases known to man." This explains why the Foundation embarked in 1949 on a concentrated study of the 11 new viruses. It was a natural follow-up to the 30 years of research that the Foundation scientists had devoted to yellow fever. "When our staff entered upon this search in 1918," says Warren, "we were aware of no experimental animal for studying yellow fever; the infectious agent was unknown and was believed to be a form of spirochete; there was no sure laboratory test for diagnosing a case of the disease and determining who was immune. During those 30 years staff scientists discovered the susceptibility of the rhesus monkey, and with this animal as the experimental subject they proceeded to isolate the agent of infection and identified it as a virus. This was accomplished in the 1920s. The next step was to devise the mouse-protection test for detecting the presence of yellow fever virus and identifying its antibodies. Then, a few years before the outbreak of World War II, Foundation virologists developed the 17-D vaccine, which effectively served the Allied armies and navies in the tropics. The final phase of our study was

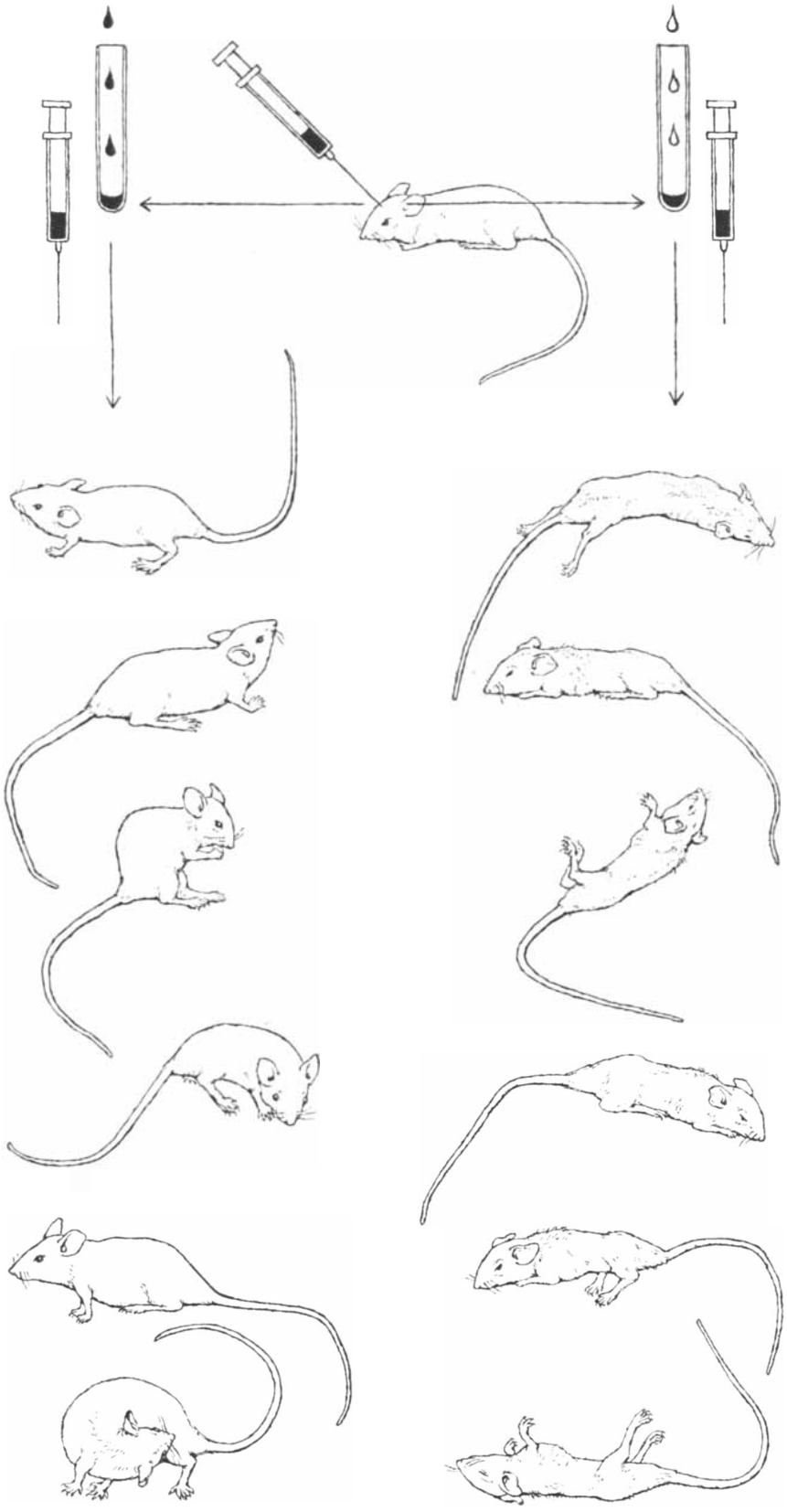
the survey of selected areas of Africa and South America in which yellow fever was suspected of being endemic.

"The studies were terminated in 1949, when it became clear that governmental agencies of the countries most concerned were in position to take over full responsibility for yellow fever control. At the same time we realized that much of our knowledge was empirical. There was an enormous lot of basic information yet to be learned of viruses—their nature, their modes of action, their points of weakness and strength. Now we had in our laboratory refrigerator a whole new collection of unknown viruses. The situation not only gave us an unusual opportunity for comparative studies at the fundamental level but also imposed on us an obligation to track down the operations of these new-found agents of infection, to find out how widely spread they were and to determine the nature of the diseases they caused. Since all 11 of the viruses were transmitted by insects, we decided to compare them with other arthropod-borne viruses and see what lines of kinship and points of difference could be found."

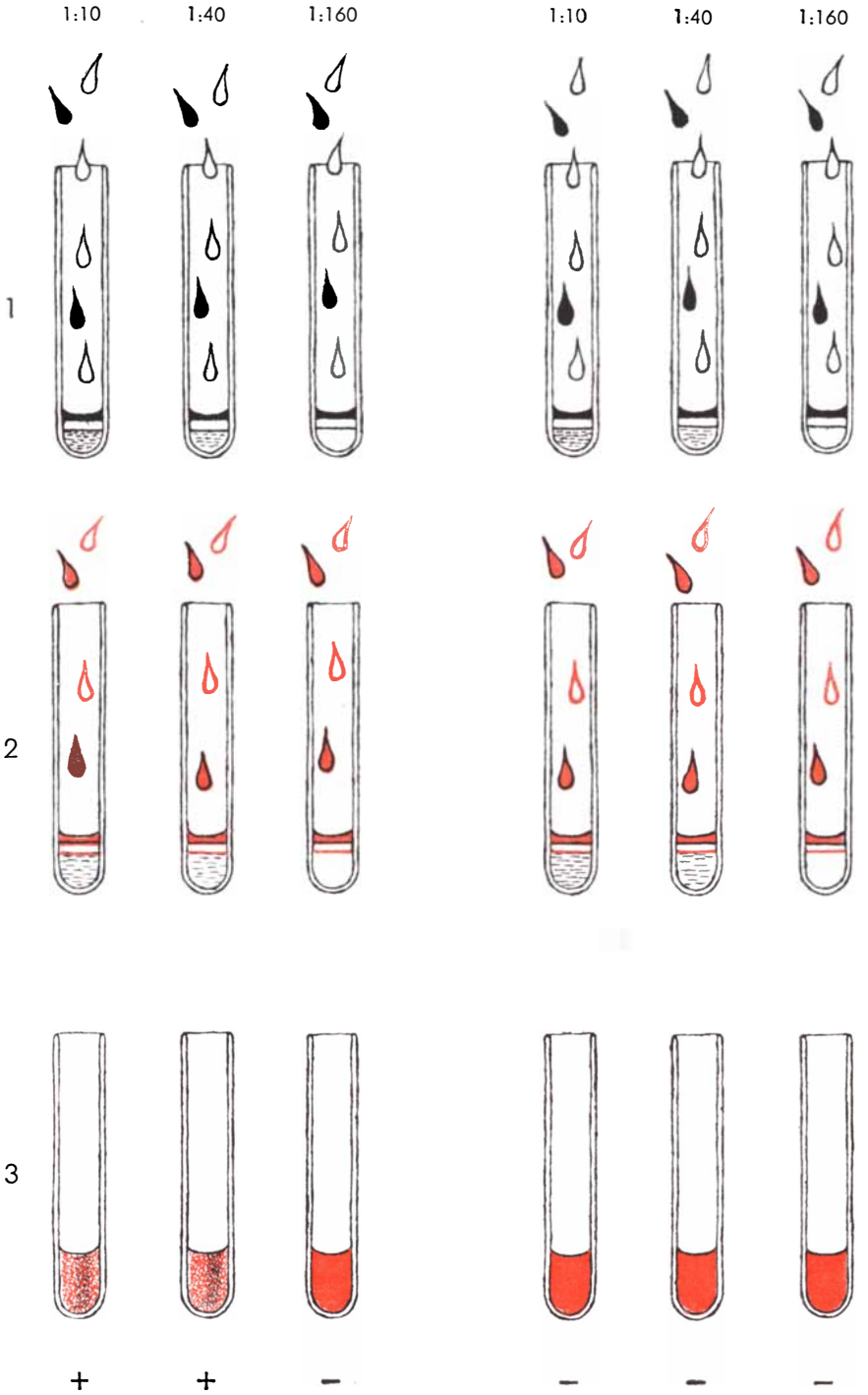
Field Stations

The first of the field studies under the new program was begun in India. A Virus Research Center was established in 1951 at Poona, in the province of Bombay, with J. Austin Kerr of the Rockefeller Foundation in charge. The laboratory is operated in collaboration with the Indian Council of Medical Research. One of the main reasons for starting the research in India was to find out whether any of the newly discovered viruses had bridged the Indian Ocean from Africa to Asia. Through all the centuries yellow fever has never made the crossing. But it soon became apparent that other viruses have. Blood specimens taken from natives of Bombay and neighboring provinces were found to carry antibodies to the Ntaya, Uganda S, West Nile and Zika viruses. Although no active cases of any of these infections were encountered, it was clear that there had been active illness in the recent past.

The next site selected for field study was Egypt, which lies more than 2,000 miles north of Uganda. During an epidemiological survey of infantile paralysis in a village north of Cairo in 1950, John R. Paul of the Yale University School of Medicine had obtained blood specimens from children, and three of them later turned out on laboratory analysis to con-



NEUTRALIZATION TEST begins with the injection of an unknown virus into the brain of a mouse (*top center*). Serum containing antibodies against a known virus is then added to a sample of a virus preparation made from the brain of the infected mouse (*top left*). Serum containing no antibodies against this virus is added to a second sample of the virus preparation (*top right*). The mice into which the second mixture is injected sicken (*right*). The mice into which the first is injected remain healthy (*left*). This indicates that the antibodies have neutralized the virus, and that the known and unknown viruses are related.



COMPLEMENT-FIXATION TEST is used here to determine whether serum from an individual contains antibody against a known virus, and, if so, how much. Three test tubes (*top left*) contain different dilutions of the serum (*ratios at top*). To these tubes is added (1) a preparation of the virus and (2) complement, a blood fraction that is "fixed" only by a complex of an antigen (such as the virus preparation) and the antibody against it. To the same three tubes (*left center*) two more substances are added: (1) red blood cells from a sheep and (2) antibodies against these cells from a rabbit. Now the first two tubes (*bottom left*) contain a settling suspension of sheep red cells. The third contains a clear red fluid. This indicates that the serum does contain antibodies against the virus, but not enough to fix the complement in a dilution of 1:160. In the first stage the complement was fixed. Thus in the second and third stages there was no complement left to collaborate with the sheep antibodies in destroying the sheep red cells: the cells merely settled out. The three test tubes on the right side of the diagram trace what happens when the serum contains no antibodies against the virus. In the first stage no reaction occurs; hence in the second stage there is complement left to collaborate with the rabbit antibodies in destroying the sheep cells. In the third stage these tubes contain only clear fluid.

tain active West Nile virus. The find was electrifying, for no one had seen a human case of this infection since the original one in 1937. The Rockefeller Foundation assigned Richard M. Taylor to inaugurate studies in Egypt. The U. S. Naval Medical Research Unit in Cairo appointed him to its research staff and placed him in charge of its division of virology. In this capacity Taylor has had the collaboration of U. S. naval personnel as well as the Egyptian government.

The Egyptian studies soon showed that Egypt was a hotbed of West Nile infection; close to 100 per cent of the adults tested were found to have antibodies. The only human blood from which Taylor was able to isolate active virus, however, was that of children. He concluded that West Nile fever was predominantly a disease of childhood.

An interesting sidelight on these observations comes from Israel. It was discovered that epidemics there in the summers of 1950, 1951, and 1952, which had been diagnosed as dengue, were actually West Nile fever. Moreover, quite in contrast with the situation in Egypt, the great majority of the victims were grownups—a susceptibility easy to account for when you remember that Israel's inhabitants are predominantly emigrants from Western Europe who probably never before had been exposed to West Nile infection, as nearly all Egyptian children must be.

Taylor and his associates have isolated West Nile virus not only from Egyptian children but also from mosquitoes (of the Culex genus) and from hooded crows and pigeons. A survey in the Sudan has demonstrated the presence of West Nile antibodies in baboons, hedgehogs, wart hogs and gazelles. This is a remarkable range of hosts—from insects through birds and lower mammals to man.

Of the other new viruses, the only one found to have left its mark in Egypt is Ntaya. About 40 per cent of the population surveyed carries antibodies to Ntaya, which would suggest past infection of epidemic proportions—although no Ntaya virus has yet been isolated.

Egypt presently contributed a strange virus of its own. Isolated from Culex mosquitoes captured near the village of Sindbis, it was thought at first to belong to the family of Coxsackie viruses, but the Sindbis virus is now believed to be a new one and is under intensive investigation in New York.

Other field stations are at Johannesburg, South Africa, under Smithburn; at Port-of-Spain, Trinidad, under Wilbur G. Downs, and at Belém, Brazil, under Ottis R. Causey. Like the outposts in

India and Egypt, each is a cooperative project with health agencies of the host countries. Downs has already found that the natives of Trinidad carry a high percentage of immunity to Ilhéus—the virus discovered in Brazil more than a dozen years ago. (Quite surprisingly, Downs and his associates last year spotted in Trinidad 14 cases of yellow fever, three of them fatal.) In the Amazon Valley Causey has discovered that wide immunity exists not only to Ilhéus but also to the Semliki Forest virus of Africa. This Semliki Forest microbe seems to have the most general dispersal of all the unknowns; Smithburn found antibodies to it in Malaya and Borneo, and now it turns up as the first of the African viruses to leave a mark on the New World.

Laboratory Studies

In the New York laboratories of the project, housed on two floors of the Rockefeller Institute for Medical Research, all the facilities and manpower have been turned to the one objective of unmasking the unknowns. Special attention is being given to test-tube procedures for identifying and characterizing viruses, to the chemical and biological behavior of these agents and to their relations with the insects which transmit them. Max Theiler, a veteran of two decades of yellow fever research, who was awarded a Nobel prize in 1951 for his part in the development of the 17-D vaccine, is in general charge of the basic studies.

"Viruses are by definition small," said Theiler. "They were first distinguished from bacteria by the fact that they were filtrable, whereas the pores of the ordinary porcelain filter blocked the passage of bacteria. But there are degrees of smallness, and one of the first investigations we undertook was aimed at determining sizes and other physical properties. This appraisal was begun by John C. Bugher in 1949, and the plan was to use collodion filters, the ultracentrifuge and the electron microscope in a triple attack. But in 1951 Bugher was granted a leave to serve in the Atomic Energy Commission's division of biology and medicine, and in his absence the filtration studies were completed by Smithburn."

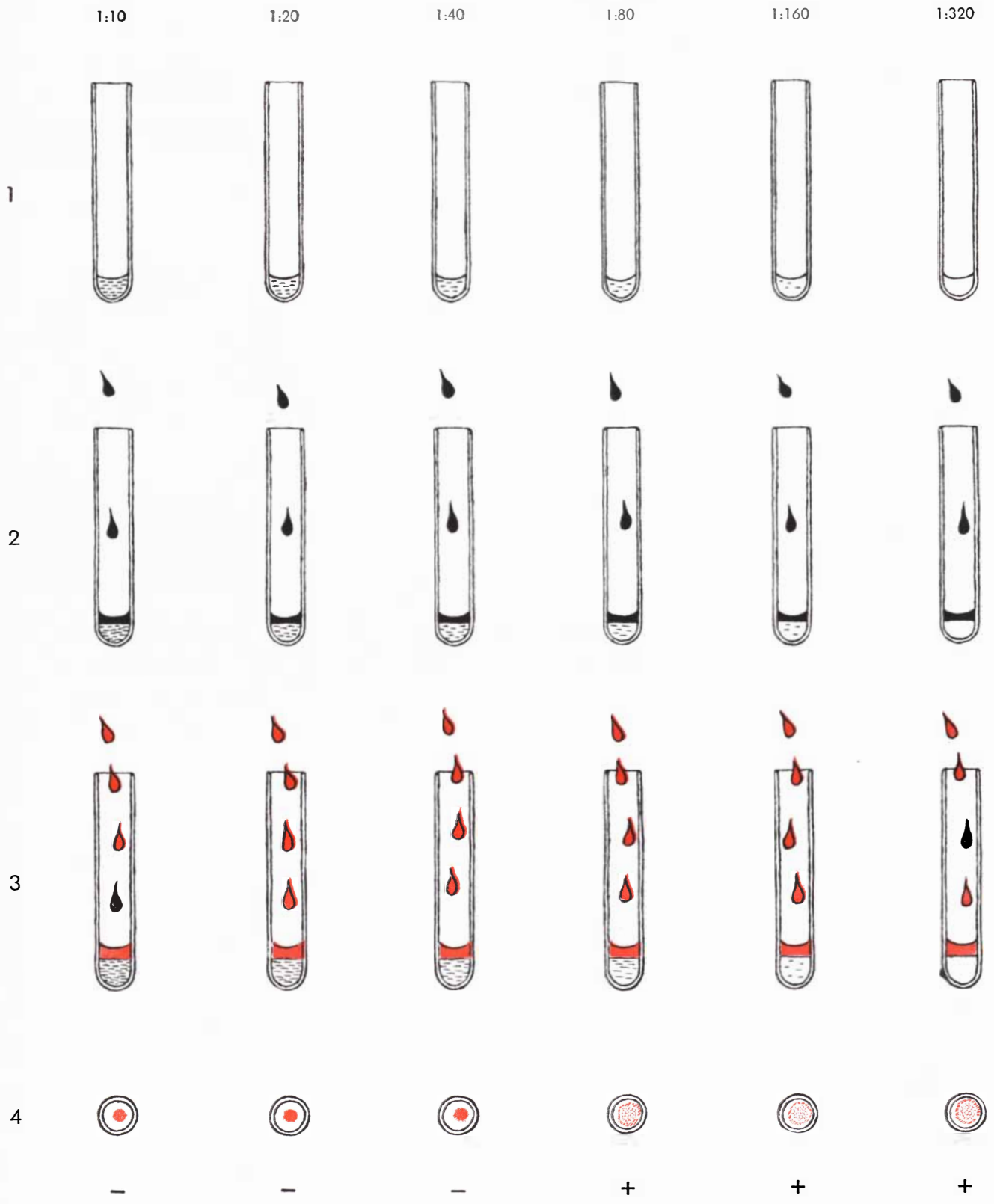
Collodion, the plastic-like material which is widely used for dressing wounds and in other surgical procedures, can be cast into films with pores so small that not even the tiniest virus is able to slip through. By controlling conditions under which the collodion solidifies, it is possible to control the size of the pores. For the virus studies, a series of films was cast, with progressively smaller pores. By such filters the size range of each of the unknown viruses was measured. Six of them were found to be relatively large as viruses go (comparable to that of influenza), while the other five were small (like yellow fever).

A strange network of kinships among the viruses has been revealed by cross-immunization tests. The usual way of telling whether a person has antibodies to a given virus is to inject some of the subject's blood serum, along with a suspension of the virus, into the brains of mice. If the mice die, that is a sign the blood contains no antibodies to this specific virus. If antibodies are present, they will neutralize the virus and the mice will survive. A cross-immunization test is one which seeks to find out whether antibodies to one virus will neutralize a different virus. If they do, the likelihood is that the two viruses are similar or related in some way. In experimental work, antibody, or what is known as immune serum, is produced by injecting virus into an animal.

In the early 1940s it occurred to Smithburn to use the neutralization test to compare West Nile with two other viruses: St. Louis encephalitis and Japanese B encephalitis. He found that antibodies against Japanese B would also protect animals against West Nile and St. Louis encephalitis; St. Louis encephalitis antibodies gave protection against West Nile, but not against Japanese B. On the other hand, West Nile antibodies did not protect against either of the other two viruses. These mixed results were hardly consistent, but they did suggest that some relationship must exist among the three viruses.

The New York laboratory decided to employ the neutralization test to compare each of the 11 new viruses with various other insect-borne viruses, such as the agents of yellow fever, dengue, louping ill, Murray Valley fever, Russian encephalitis, Eastern, Western and Venezuelan equine encephalitis and St. Louis and Japanese B encephalitis. All of these, incidentally, are small viruses.

The test established that a number of the viruses are related to one another. Theiler notes one curious anomaly. The Ntaya virus is a large one, yet its antibodies give cross-immunity against the small West Nile, Uganda S and St. Louis encephalitis viruses. "The discovery of this overlap," says Theiler, "makes us want to refilter Ntaya to make sure that our previous size determination is not in error. The other large viruses—Anopheles A and B, Wyeomyia, Bwam-



HEMAGGLUTINATION TEST is based on the fact that red blood cells agglutinate, or clump, when virus is added to them. Here again the test is used to determine whether a serum contains antibodies against a known virus, and, if so, how much. In the first stage six test tubes contain different dilutions of serum (*ratios at top*). In the second stage a preparation of the virus is added to the tubes. In the third stage red blood cells from a chick are added. If the serum contains antibodies against the virus, the virus is prevented from agglutinating the red cells and they merely settle out in a neat pile. If the serum does not contain such antibodies, the virus causes the cells to agglutinate in a flatter clump. In the fourth stage the appearance of clumped and unclumped cells is shown from the bottom of the test tubes. The cells in the first three tubes are not agglutinated, indicating that the serum contains antibodies preventing agglutination by the virus through a dilution of 1:40. The cells in the last three tubes are agglutinated.

ba and Bunyamwera—have shown no clear-cut indication of overlap, either among themselves or with other viruses."

From Animals to the Test Tube

The neutralization tests have been using mice at the rate of 2,500 a week. Moreover, each test takes from a week to a month to yield a conclusive result, the time depending on the kind of virus. So the virologists went looking for ways to speed up the study. They sought a procedure that could be performed quickly in a test tube without having to await the development of biological symptoms in animals—and they found two that proved useful.

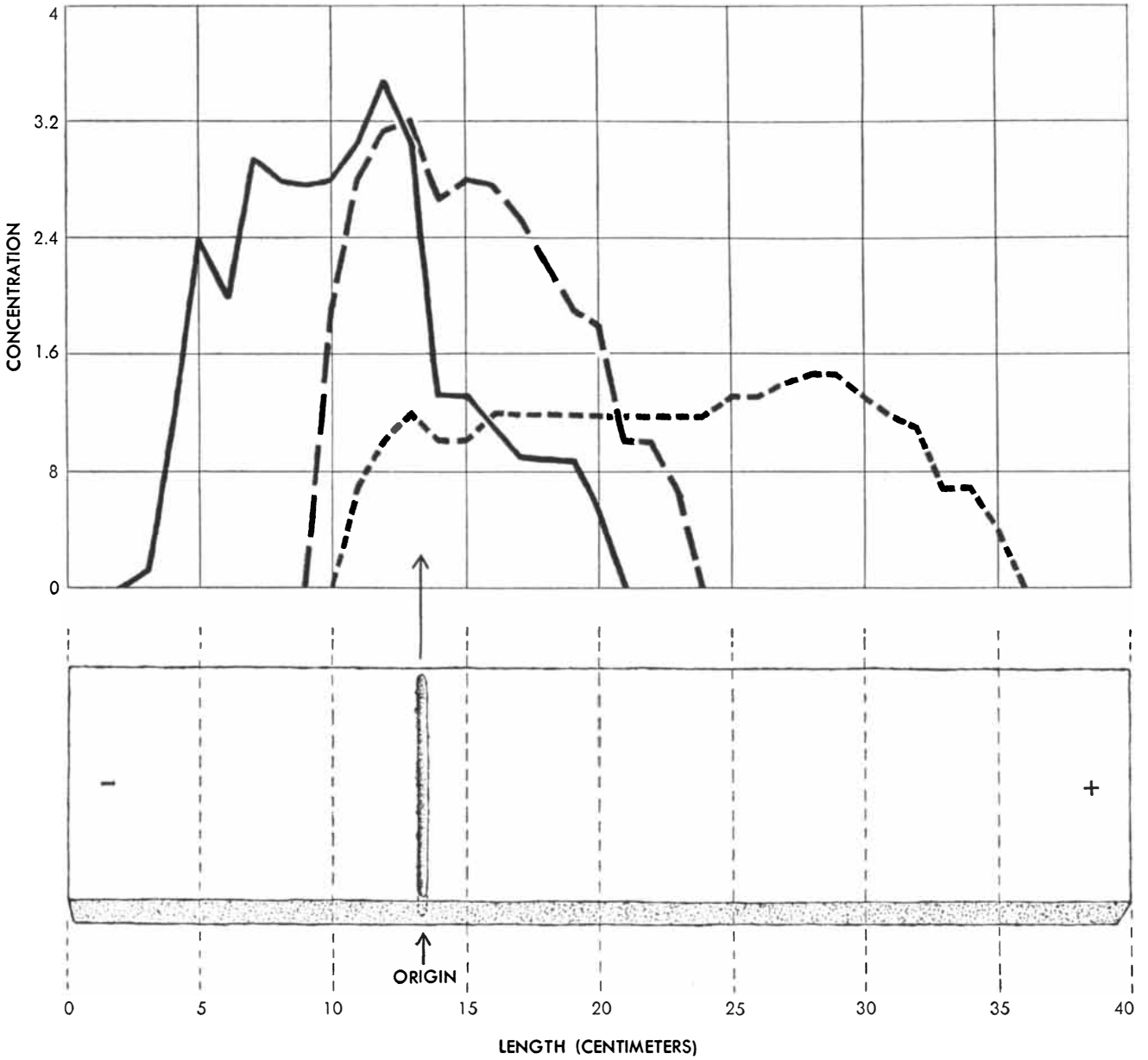
The first is the well-known complement-fixation test. It uses the same type of reaction that has been harnessed in the Wassermann test to detect syphilis. Complement is a mysterious natural component of blood which collaborates with antibodies in reacting with viruses, bacteria and other antigens. It cannot act alone; both the antigen and the antibody must be present to make the reaction with complement go. As the test is used in the virus research program, three substances are poured into a test tube: the antigen (a solution containing the virus), the antibodies (serum from the subject whose blood is to be tested) and complement (a carefully measured quantity of it taken from guinea-pig blood). Before the serum containing the antibodies is added, it is heated moderately to destroy any complement naturally present and insure that only the measured quantity is there. The test tube containing this mixture is placed in the cold-room overnight, and by morning the answer to the test is waiting.

If the antibodies in the serum are specific to the virus, the complement will have combined with them and the virus and there will be no free complement left in the solution. If, on the other hand, the antibodies are of some species foreign to the virus, then no such fixation will occur, and the complement will remain unchanged in the solution. To find out which of these alternative events has happened, the experimenter adds to the mixture some red cells taken from sheep blood and the serum of a rabbit which has previously been inoculated with sheep red cells. As a result of this inoculation the rabbit serum has developed antibodies to sheep red cells, and if any free complement remains in the test tube it will combine with these antibodies and attack the red cells. Such action will be shown by the disintegration of the cells and a red discoloration of the liquid. But if no free complement is present, the antibodies will be powerless to act and the red cells will settle to the bottom of the test tube undamaged. What happens to the sheep cells thus tells the experimenter what, if anything, happened to the complement during the night. It thereby reports very precisely whether there is an immunological relationship between the virus and the suspected viral antibodies.

The other testing technique is the hemagglutination test. In 1940 George K. Hirst of the same laboratory noticed that influenza virus, which had accidentally been added to serum containing the red blood cells of a young chicken, caused the cells to clump together. Investigation showed that if antibodies specific to the virus were present, the agglutination did not occur. The test was found to apply to many viruses other than influenza. It is now one of the main weapons in the attack on the 11 unknowns. Jordi Casals, who is in charge of the complement-fixation and hemagglutination studies, reports that the latter technique is the most sensitive device yet tried for prying into the hidden ways and immunological kinships of viruses.

By means of the agglutination test Casals has been able to distinguish two families of viruses: Group A includes Eastern, Western and Venezuelan equine encephalitis, Semliki Forest and Sindbis (the new agent discovered in Egypt last year); Group B is made up of Ilhéus, Ntaya, West Nile, Uganda S, St. Louis encephalitis, Japanese B encephalitis, yellow fever, Russian spring-summer fever and dengue types 1 and 2. The antibodies of any virus within the same family inhibit all the viruses in its group from agglutinating the red cells, but they have no effect on viruses of the other family. There are certain conditions of temperature and acidity without which the reaction of hemagglutination does not occur, or if so, only poorly. For Group A these conditions are a temperature of 37 degrees centigrade and a pH of around 6.5, which is on the acid side. For Group B the hemagglutination will occur at either 4 or 22 degrees C. and at a pH of 7, which of course is neutrality.

A few months ago Casals applied the agglutination test to specimens of the virus of sand-fly fever, a common disease of the Mediterranean area. This virus agglutinated red cells only at 37 degrees C. and a pH of around 6.5. "At once I thought we had another member of Group A," he says, "but on testing its antibodies against the viruses of that family I was unable to get any inhibi-



ZONE ELECTROPHORESIS was used to show that virus material consisted of three fractions, each with a different property. The virus material is placed in a groove on a slab of starch (*bottom*). When an electric current is applied across the ends of the slab, each fraction migrates in a characteristic way. The slab is then cut up and the contents of each section analyzed. The analysis of a strain of the West Nile virus yielded the graph at the top. The solid line represents the infective fraction of the virus; the long-dashed line, the hemagglutinating fraction; the short-dashed line, the complement-fixing fraction. The latter two fractions have been multiplied by 10.

tion, and similarly the antibodies of Group A were impotent to prevent the sand-fly fever virus from agglutinating the red cells. I can only conclude that sand-fly fever belongs to a third family of viruses, and we are now searching for other members of this provisional group."

Although the complement-fixation and hemagglutination tests are much more rapid than the neutralization test (they take only 24 hours), Casals observes that the latter is still needed, because it is the most specific indicator of an unknown antibody. On the other hand, the test-tube techniques show the overlaps more sensitively, the agglutination more so than the complement-fixation. Thus the three procedures represent an ascending scale of sensitivity and a descending scale of specificity.

Viruses as Molecules

Interviral relationships excite the imagination, but they are disturbing to chemists who expect law and order to reign among the molecules. An antibody has been visualized as a molecule that is "anti" to a specific disease molecule. How, then, can antibodies react so promiscuously with different viruses? How can one explain, within the discipline of biochemistry, the fact that the antibody of West Nile fever, for example, is able to inhibit the agglutinating activity of all the viruses of Group B?

For years biochemists have speculated that a virus may be not one molecule but a complex of several, and conversely that infection may stimulate the blood to produce not a single form of antibody but one for each molecular component of the virus. Delphine H. Clarke, who is in charge of the biochemical part of the Rockefeller virus program, decided to explore virus structure by means of electrophoresis. This technique separates

substances in a mixture according to their different electric charges [see "Electrophoresis," by George W. Gray; SCIENTIFIC AMERICAN, December, 1951]. Dr. Clarke utilized the method known as zone electrophoresis, in which the medium is a solid. Usually it is a sheet of absorbent paper, but Dr. Clarke employs as the medium a thin slab of starch (a variation recently introduced by Henry Kunkel). The slab is some 16 inches long and four inches wide. She digs a little trough near one end and pours into it the virus preparation to be analyzed. An electric current applied through two electrodes in contact with the ends of the slab causes the preparation to separate into its constituent substances, or molecular fractions, which move along the slab at speeds determined by their electrochemical properties, their sizes and their shapes. Each fraction comes to rest in a different region. After sufficient time has passed for all the ingredients to have migrated, the slab is cut into about 40 slices, and the contents of each piece are investigated.

Analyzing virus extracts from infected mouse brains in this way, Dr. Clarke has succeeded in separating the virus material into what seem to be three different fractions, each possessing a single property of the virus. The first fraction shows only the property of infecting mice; the second combines with complement in the presence of appropriate serum; the third causes red blood cells to agglutinate. The analysis of virus material is still far from complete, but experiments with other analytical techniques—for example, ion exchange combined with high-speed centrifugation—have strengthened the concept of the virus as a multiple structure.

"We call the picture we have arrived at the 'tangerine' hypothesis," says Dr. Clarke. "The fully infective virus, which attacks tissue cells and causes disease, is represented by a whole tangerine, complete with rind. Stripped of its rind, the tangerine becomes a model for the part of the virus which, while powerless to cause infection of tissue cells, can cause red cells to agglutinate. Finally, the little segments inside the tangerine represent the parts that fix complement but presumably have no power to infect or to agglutinate. The three-part virus may cause the production of two or three kinds of antibodies: one to combat the rind and oppose infection, another to block the agglutinating element and a third to cause the fixing of complement. But at present we have only indirect evidence of that."

The tangerine hypothesis, Dr. Clarke hastened to add, "is highly speculative, and needs to be taken with many grains of salt, but it serves as a useful working model of what we think the virus may be. It suggests, for example, how an immune serum may have one kind of antibody that is very specific for a certain antigen, represented by the rind, and yet have others which show overlap with other antigens when it comes to the properties of agglutination and complement fixation."

The biochemical studies have contributed in an important way to the refinement of the test procedures, to the extraction of viruses from infected tissue and to other chemical separations. They have even contributed to the study of viruses in relation to their vectors—for Dr. Clarke has found a sharp distinction between insect-borne viruses and others, such as polio and Coxsackie, which are not transmitted by the bite of an insect. The two orders of microbes behave quite differently in the ion-exchange column, showing that they differ in molecular structure.

Loring Whitman, in charge of entomological studies at the laboratories, is exploring the capacity of the unknown viruses to multiply in mosquitoes of different genera. He has found that all the viruses tested seem to be well adapted to *Aëdes aegypti* mosquitoes, famous as the vector of yellow fever, and that several in addition multiply in two species of Culex. The fact that Culex mosquitoes feed on birds raises a question as to a possible avian role in the spread of certain of the viruses—particularly since the West Nile virus has been found in hooded crows and pigeons.

There is field evidence that ticks may have a part in the transmission and perpetuation of some of the viruses. Ticks are able to infect their own eggs and thus may pass the virus indefinitely from one generation of tick to the next, Whitman points out. Mosquitoes, by contrast, cannot transmit virus to their offspring. It is possible that infected mosquitoes surviving from one season to the next may carry the virus over, but Whitman suggests that the possible role of ticks in perpetuating the "mosquito-borne" viruses is a promising subject for exploration in the field.

Are They Dangerous?

A lulling aspect of the new viruses is their apparent mildness. Mahaffy had Bwamba fever without knowing it. West Nile is depressing and debilitating for a few days, but no instance of death from it has yet been encountered. Except for

one case of human infection with Zika virus (a native man in Nigeria who was found ill of a jaundice-like disease), none of the other viruses picked up in Uganda and none of those in South America has been found in a human being.

Theiler, asked whether these African and South American curiosities present a serious future threat, replied:

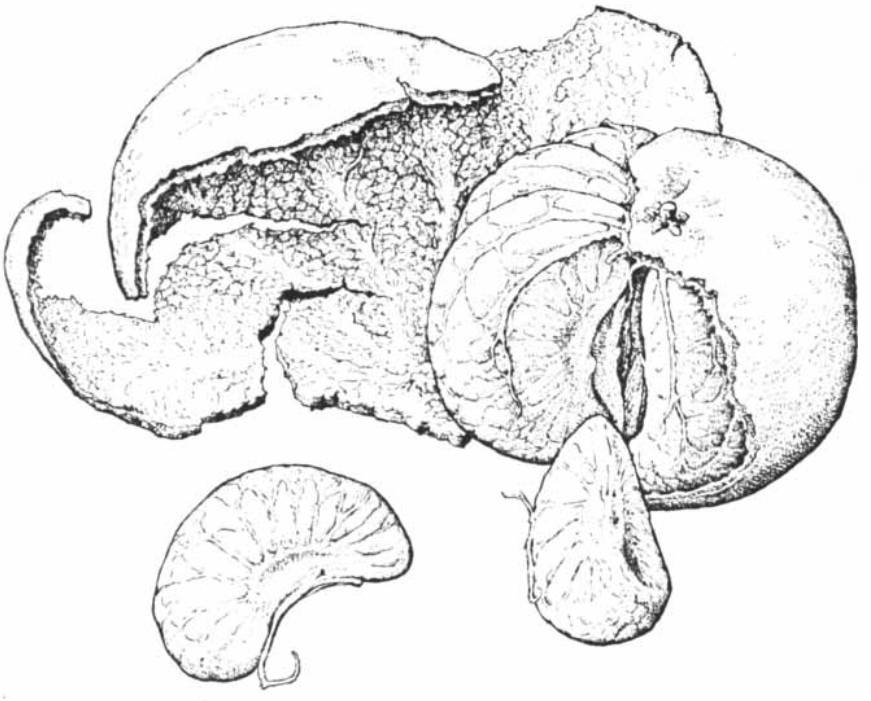
"It would be dangerous to discount the potentialities of any infectious agent. The history of Rift Valley fever is worth recalling. This disease appeared in the Rift Valley of Kenya about 25 years ago, after sheep raising was introduced into that region of Africa. The epidemic killed a number of lambs, and investigation showed that the cause was a virus. It was regarded as a curiosity. Then, in 1951, the disease suddenly appeared in South Africa. There it not only killed more than 50,000 sheep and 500,000 lambs but infected 20,000 people.

"Soon after our troops landed in Korea in 1950, many of them came down with a strange affliction which turned out to be Japanese B encephalitis. This disease, although known in Japan, had never before been reported from Korea. Neutralization tests disclosed, however, that a large proportion of the native Korean population had previously encountered the infection and were immune.

"It is my opinion that the virus of Rift Valley fever had been in South Africa all the time—just as was the case with Japanese B in Korea. When circumstances became favorable, the viruses were able to sweep over whole populations. It could happen again. The fact that so many of the new-found agents are related to St. Louis encephalitis, Japanese B encephalitis and yellow fever is highly suggestive.

"In Africa yellow fever is usually a mild disease. But every now and then a severe epidemic occurs: one that swept the Nuba Mountains region a few years ago killed thousands of people. Any of the new-found viruses might follow the same pattern, given a setting where the combination of vectors, susceptible population and other conditions was ripe for a destructive epidemic."

The discovery of relationships among the viruses is profoundly significant, in Theiler's opinion. "It suggests that the viruses of Group A, for example, may have descended from a common ancestral stock, and similarly that the lineage of Group B may trace back to one viral forefather. Mutations such as those in genes, which have made possible human evolution, may operate in a similar way among the viruses to diversify them. We know that the infective nature of a virus may change in the course of a series of laboratory experiments. While the change often moderates the microbe's virulence, we must never forget that the odds in nature are just as strong for a change in the opposite direction."



TANGERINE HYPOTHESIS is a model for a virus with three properties. The whole tangerine represents the fully infective virus. The tangerine without its skin represents the fraction causing the agglutination of red cells. The segments represent complement-fixing fraction.

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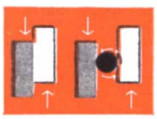

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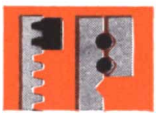

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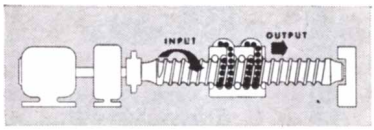

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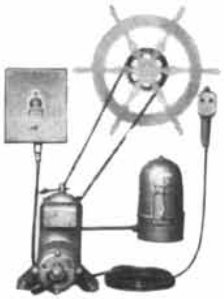

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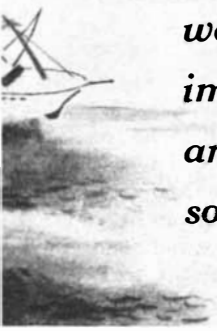

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The Growth of Crystals

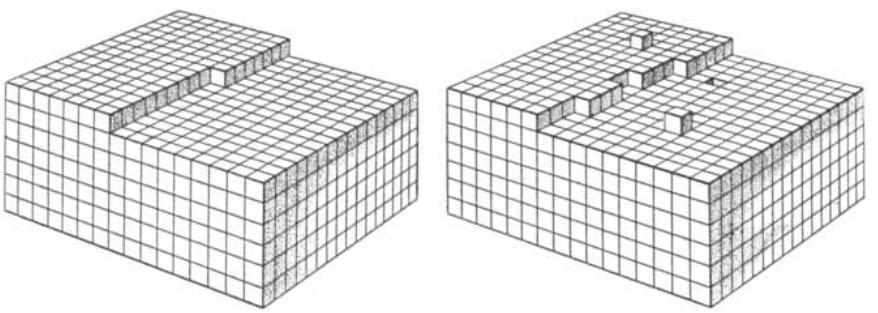
How do atoms or molecules in a vapor or solution form the regular architecture of a solid? Much can be explained by the assumption that they fall into place rather like the bricks laid in a spiral ramp

by Robert L. Fullman

All metals, indeed nearly all the basic solid materials of modern technology, are made of crystals. Hence an understanding of how crystals are built—how they grow—is an important aspect of the science of materials. Like many other seemingly simple phenomena, the construction of a crystal is not as neat and orderly as it looks at first sight. Twenty-five years ago physicists thought they had a reasonable notion of how crystals grow. Then an elementary experiment disabused them. It led to a series of surprising discoveries and to a new picture of crystals.

Nature builds a crystal somewhat as a bricklayer builds a brick wall. From a jumble of atoms or molecules heaped in no particular order (*i.e.*, in gas or liquid form) it takes suitable bricks one by one and stacks them in a regular array. If we picture the units (atoms or molecules) as little cubes and suppose that they line up consecutively and stay put, a perfect crystal in course of construction would look like the illustration at the left below. But of course atoms or molecules ordinarily have kinetic energy and are in random thermal motion; they may light anywhere on the crystal surface, and quickly take off again. Thus even in this idealized picture the growth of the crystal is not so orderly as the laying of bricks but proceeds in a more haphazard fashion, illustrated by the second drawing [*at the right below*]. A unit that alights on the crystal surface is likely to stay bound to the crystal only if it migrates to a niche where at least three of its six faces are bonded to units already fixed in the crystal. Moreover, a layer needs a certain minimum number of units to assure growth, for if too large a proportion of its members are at corners or edges, they will not stick.

The rate of escape from a solid to a surrounding vapor depends on the intensity of the molecules' motion—*i.e.*, on the temperature. The rate of return from the vapor to the solid depends on the concentration of molecules in the vapor—*i.e.*, on the vapor pressure. For every temperature there is a "saturation vapor pressure" at which the rates of escape and of deposit at a step balance. Under these conditions the crystal does not grow. It can grow only when the vapor is supersaturated. This model suggests, further, that after a layer on the crystal surface has been filled, continued growth becomes more difficult; that is, it should take a higher degree of supersaturation to start a new layer than to fill one already well started.

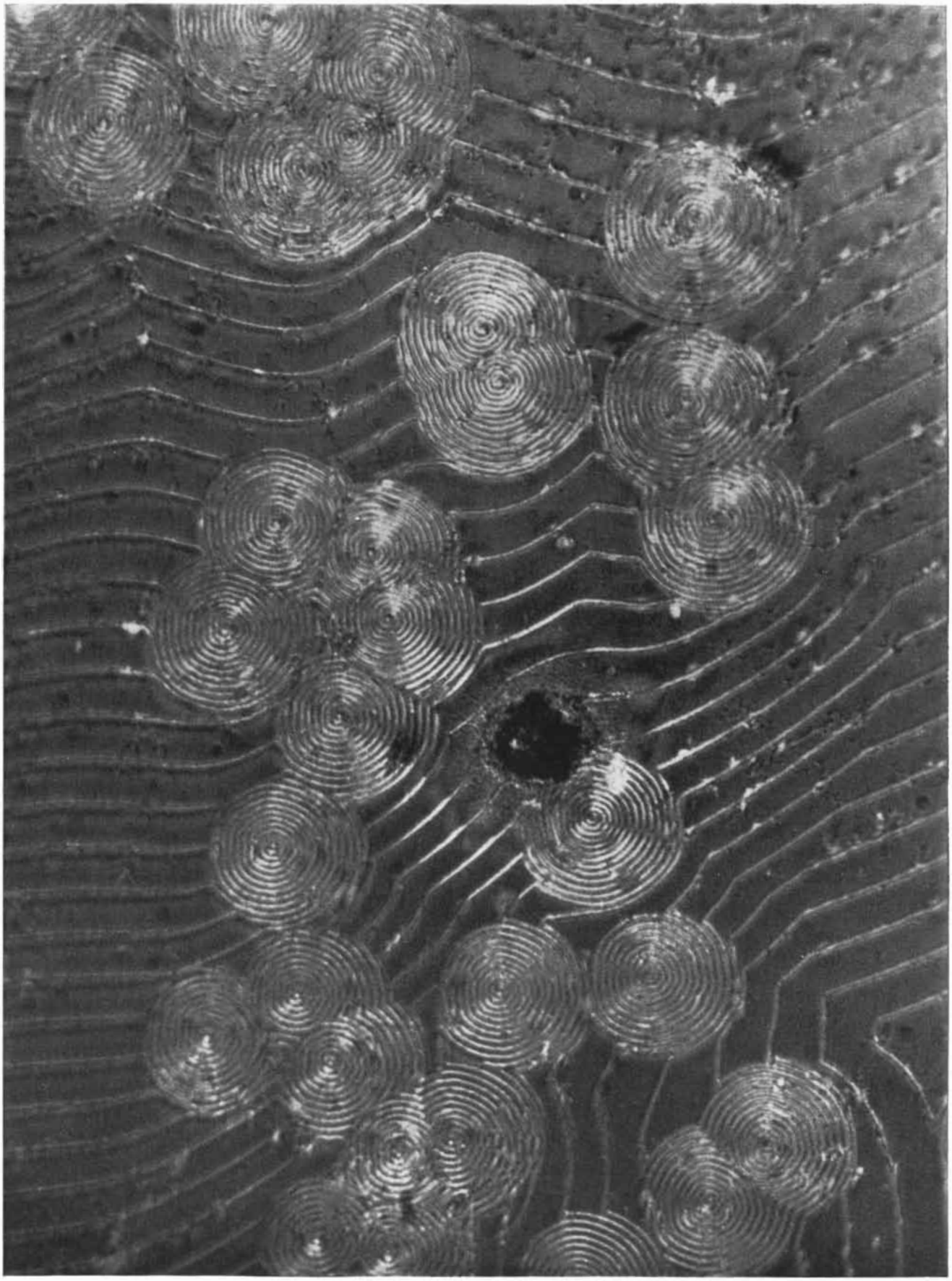


GROWING PERFECT CRYSTAL at an arbitrary point in its development would appear as at left, if its molecules had no thermal motion. Drawing at right shows the effect of this motion. Each cube in these highly schematic drawings represents a single molecule.

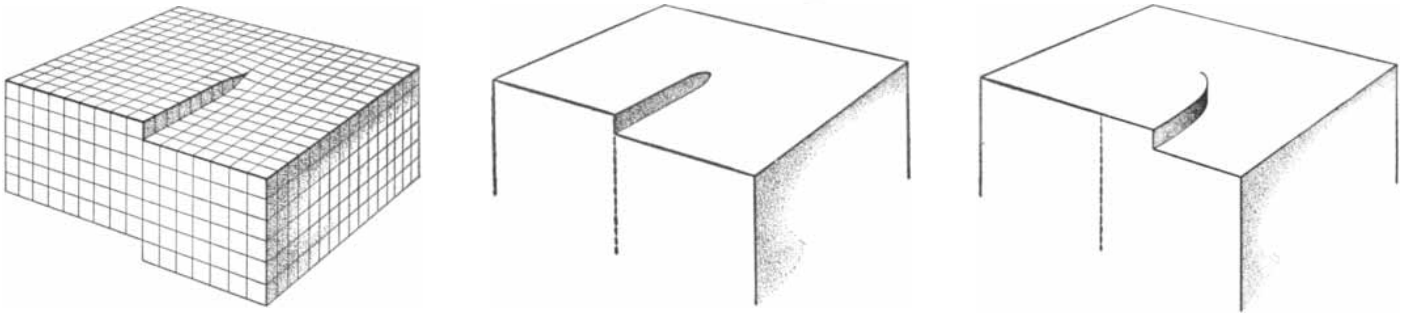
It was at this point that the classical model of crystal growth fell apart. Calculations had indicated that the formation of islands, or nuclei, large enough to start new layers, so that a crystal could grow, required a vapor pressure at least 25 to 50 per cent greater than saturation. But in 1931 the German physicists M. Volmer and W. Schultze succeeded in growing crystals from vapor with a supersaturation of only 1 per cent. The theoretical prediction of the rate at which a crystal should grow at this saturation turned out to be too small by a factor of 10^{1000}—which may well be the all-time record for discrepancy between theory and experiment!

How could a crystal initiate and build new layers so easily? Physicists went back over their analyses and calculations, but they could find no answer that made sense on the basis of the old model. The problem remained baffling until, in 1949, an English physicist suggested a new model. F. C. Frank, of the University of Bristol, pointed out that the growth of a crystal could easily be accounted for if one supposed that its layers were not laid independently one upon the other but were built spiral fashion by a continuous process. This could occur if the crystal contained an imperfection of the type known as a "screw dislocation."

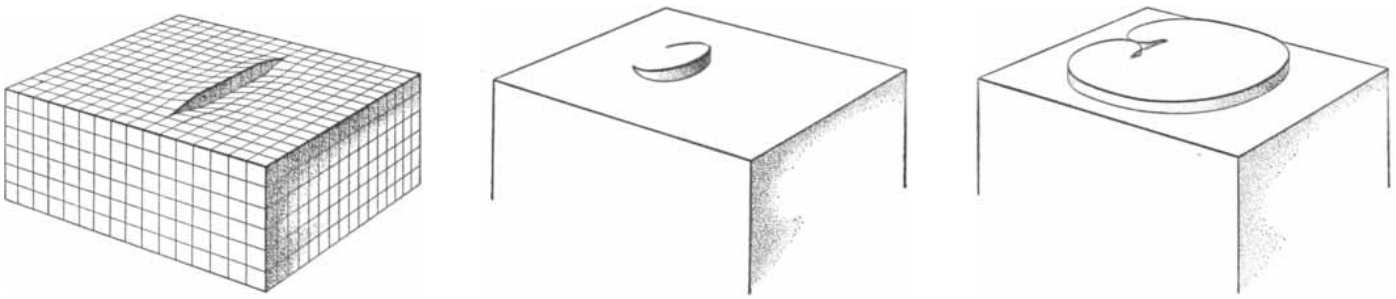
Imagine a crystal lattice in which two adjacent sections are sheared along part of their length, so that one partial section is displaced a full layer below the other [*see first diagram on page 76*]. The reason this is called a screw dislocation can be illustrated by the fact that if a tiny observer were to walk in a circle



CRYSTAL GROWTH SPIRALS on the surface of a silicon carbide crystal are seen magnified 250 diameters. Each spiral step originates in a defect called a screw dislocation. From the side, the surface looks like an ascending ramp wound around a flat cone.



SCREW DISLOCATION, illustrated at left, produces its spiral growth steps in the manner indicated by the succeeding diagrams. A screw dislocation is the type of imperfection that would result if a cut were made part way through a crystal and the two sides slipped over one another. The result is a permanent step extending across a portion of the crystal face and anchored at the boundary of the cut.

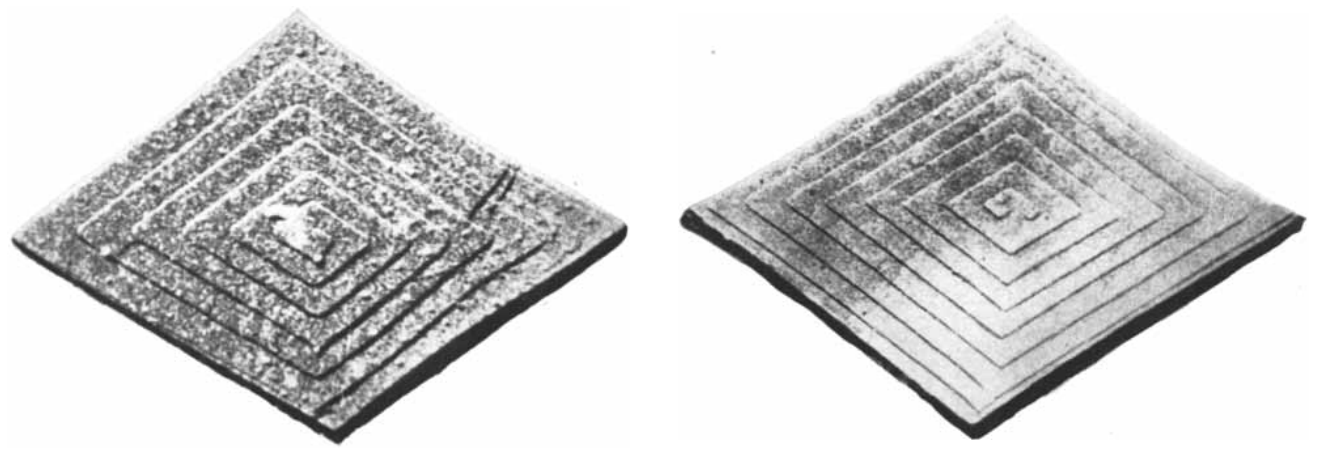


CLOSED GROWTH LOOPS can arise from a step which begins and ends within the surface (*left*) connecting a right-handed screw dislocation with a left-handed one. This step is anchored at both ends and can grow only by bulging. The second drawing shows the bulging step just beginning to turn back on itself. In the next figure its parts have met behind its original position. Finally the inner section detaches from

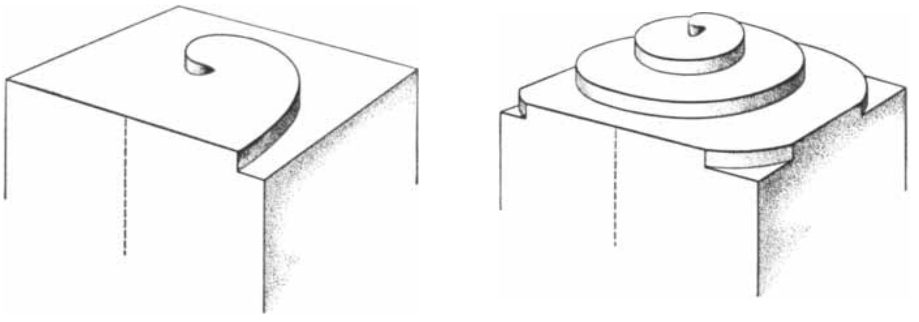
around the end of the cut, starting at the top, he would find himself one level lower at the end of each circuit, as if he were descending a spiral (actually helical) ramp. The model shown here is known as a right-handed screw dislocation because the path spirals downward to the right.

Now Frank realized that such a dislocation would provide a constantly open step at which atoms or molecules could easily gain a foothold and build the crystal without ever having to start a new layer. The step would sweep around the crystal face as new units were added to it. But in the process it would bend [*see drawings in upper row above*]. To understand why this is so, consider a line of skaters pivoting around one end. In order to keep a straight line, the skaters at the outer end must go faster than those nearer the pivot, because they have farther to travel. In the case of the crystal step, the outer end does not build faster, for units attach themselves at random, which is to say at a more or less uniform rate, along the length of the step. Thus in the build-up the swing of the outer part of the step around the circle falls steadily behind, and the step bends to form a spiral.

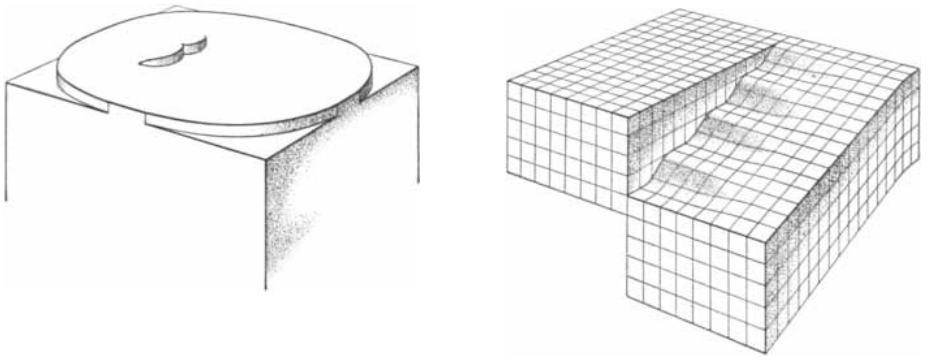
Was Frank's radically new picture of crystal growth correct? It did not have to wait long for confirmation. At the meeting of scientists where his theory was presented, L. J. Griffin of the University of London showed some photomicrographs of crystal surfaces exhibiting the predicted spiral step patterns.



GROWTH STEPS on paraffin crystals are revealed by photomicrographs. Spiral (*left*) is broken up into a series of straight segments, and the loops (*right*) are polygons. The reason for this departure from circular form predicted by the theory is that these crystals do not grow equally fast in all directions. The straight sections advance in the directions of slowest growth along the surface.



Molecules depositing on the surface from a vapor would lodge against the step, causing it to advance. Since one end is fixed, the step would pivot around that point, with the outer points falling behind the inner, producing a never-ending spiral layer on the surface.



the completed layer and shrinks inward until it becomes a new straight step located on top of the growth loop first formed.

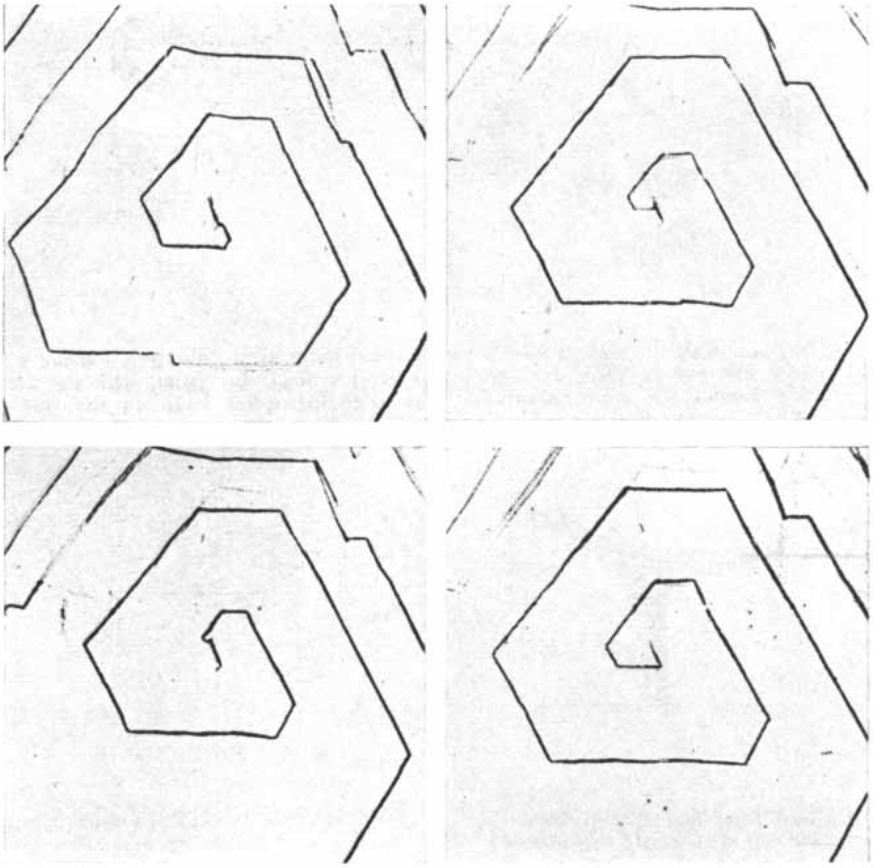
FOUR-LAYERED STEP is formed by four closely-spaced dislocations of the same kind. Larger groups give many-layered steps.

What is more, since then intensive examination of crystals under the microscope has brought to light various growth patterns which can only be explained, indeed were predicted, by the screw dislocation theory.

Nature rarely makes a perfectly regular crystal. There is usually at least one dislocation—as we have seen, it is a necessary condition for growth at low supersaturation. Generally a crystal has more than one dislocation. The presence of several dislocations complicates the crystal's growth pattern. For instance, two neighboring dislocations, one right-handed and one left-handed, may form a step anchored at both ends [*first drawing in second row on opposite page*]. As new units build onto this step, it takes a semicircular shape [*second diagram*]. Eventually the build-up produces a ring-shaped step [*third diagram*] which then builds out to complete a layer on the crystal. But in the meantime a new step has been formed on top of the original one, and it becomes the nucleus for a new layer [*fourth diagram*]. As the process repeats, the crystal grows in layers which are closed rings rather than spirals. A photograph of such a crystal is shown on the opposite page [*bottom right*]. The steps here are straight-sided polygons, rather than curved rings, because growth has not proceeded evenly all around the periphery.

The height of a crystal step can be measured. Usually the step is just one unit high. But some crystals have been found to have steps many layers high. The theory suggests that multilayered steps may arise from a group of dislocations which are close together and all of the same sense—right-handed or left-handed. Each dislocation contributes one layer to the thickness of the step. The photographs on the next page show a cadmium iodide crystal with a step many layers high. The short, straight line at the center of the spiral marks the initiating array of screw dislocations.

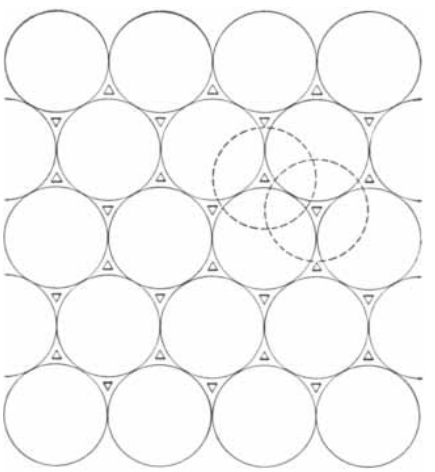
Here the theory helps to clear up a peculiarity of crystal structure which has long mystified crystallographers. It has to do with the stacking of layers in a crystal. To follow the reasoning we must discard the oversimplified picture of building units that we have been using for illustration so far. The building blocks of a crystal—its atomic or molecular cells—are not cubes but more like spheres. Certain crystals have a close-packed structure, which means that the spherical units are piled not one directly above the other but in the manner of a mound of cannon balls, with



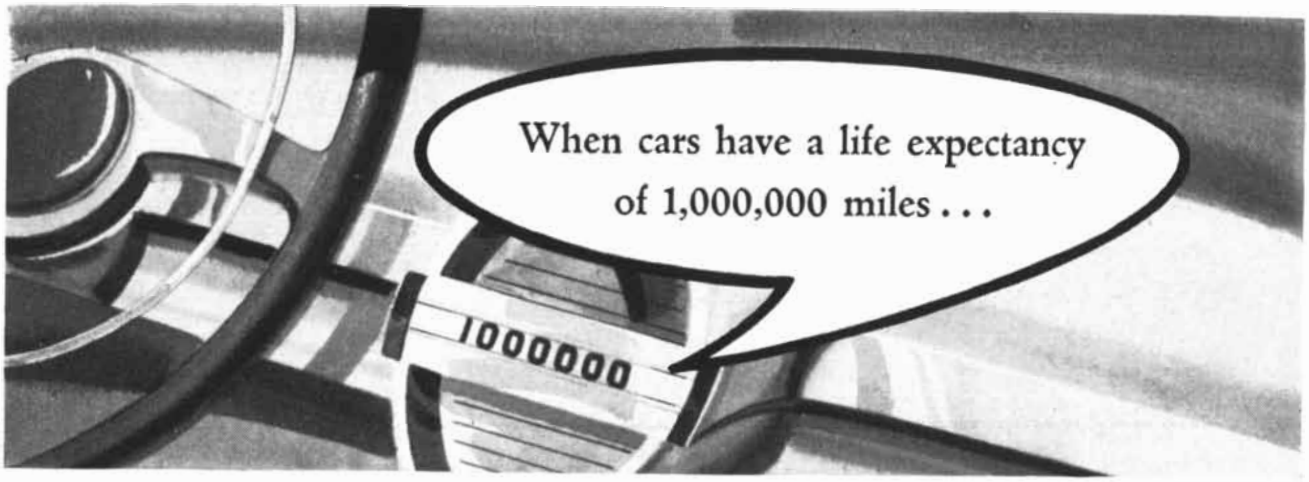
GROWING SPIRAL is seen in four successive positions on a crystal of cadmium iodide. This step, which is many layers high, is produced by a large group of screw dislocations.

each ball nestling in a pocket between its neighbors. Now a look at such an array shows that each successive layer may be stacked on the one below in one of two positions. In the diagram at the right, viewing a layer from above, the positions are marked △ and ▽. When a layer is placed on this one, close packing requires that all the balls be laid either in the positions marked △ or in those marked ▽. The next layer again may be stacked in either one or the other set of positions. If the layers are stacked alternately in one position and then the other, the sequence is denoted by △▽. But crystals often stack up in much more complex patterns. For example, one kind of silicon carbide crystal has the pattern △△▽▽▽, △△△△△, *etc.* Here the group forming the repeat in the pattern consists of five layers. In some crystals of silicon carbide the repeat unit has been found to be as large as 29 layers.

How can information about the pattern be transmitted over so great a distance; that is to say, how can each unit be matched to one 29 units away? Classical crystallography could suggest no explanation other than the possibility of some unknown long-range force between molecules. The dislocation theory of crystal growth now provides a simple, though incomplete, answer. A series of screw dislocations may generate a step many layers high, which then becomes the pattern unit that repeats again and again as the crystal grows. One aspect that the theory does not explain is the fact that only 14 such variations of the crystal pattern have been found in silicon carbide; the theory suggests that there should be an almost unlimited



CLOSE-PACKED molecules are represented by circles, with possible positions for members of the next layer shown dotted.



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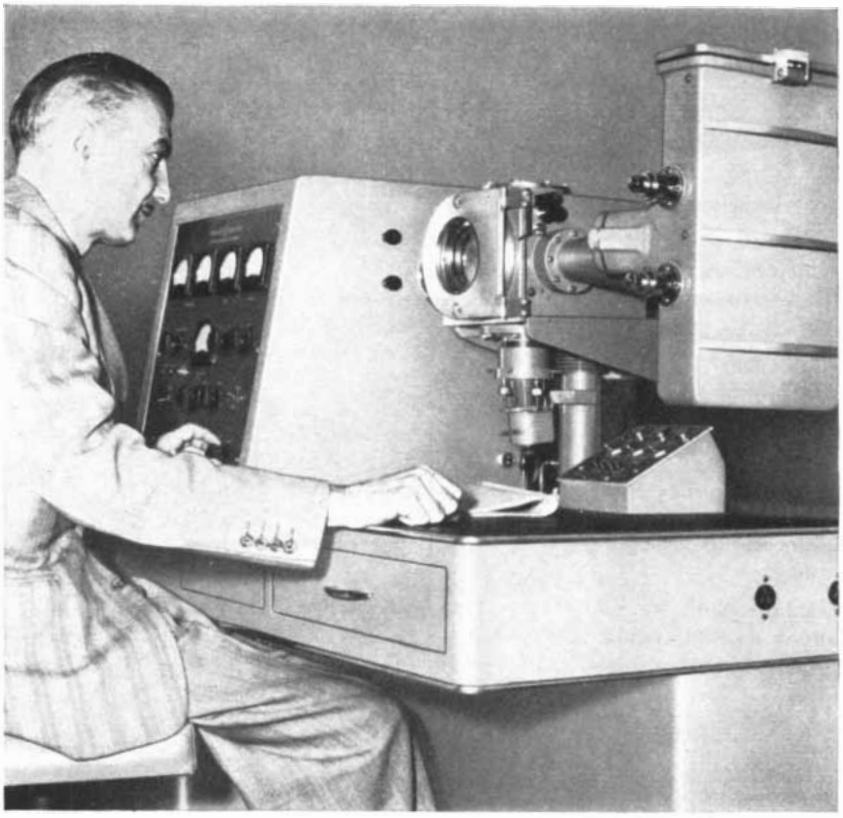

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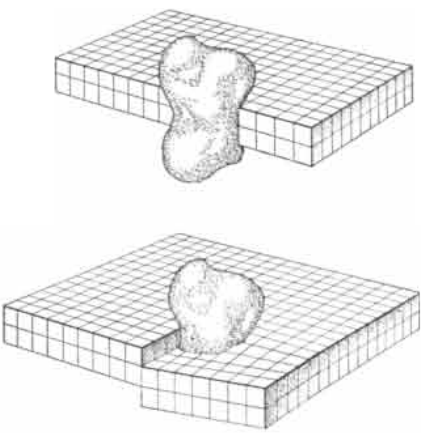
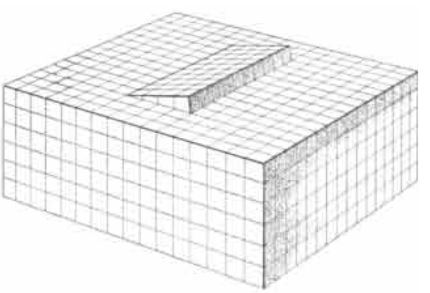
number of possible patterns in the crystal structure.

How do screw dislocations arise in the first place? This is still a largely speculative question. Almost all crystals begin their growth on some small foreign nucleus, just as raindrops condense on dust particles. Some of these nuclei may have surface irregularities which correspond to screw dislocations and are passed on to the growing crystal. Other crystals may pick up dislocations as they grow. A strong mechanical disturbance may cause a thin growing crystal to buckle and shear; indeed, thin crystals have been induced to grow by pressing a fine needle point against them. Dirt particles picked up during growth also may introduce dislocations.

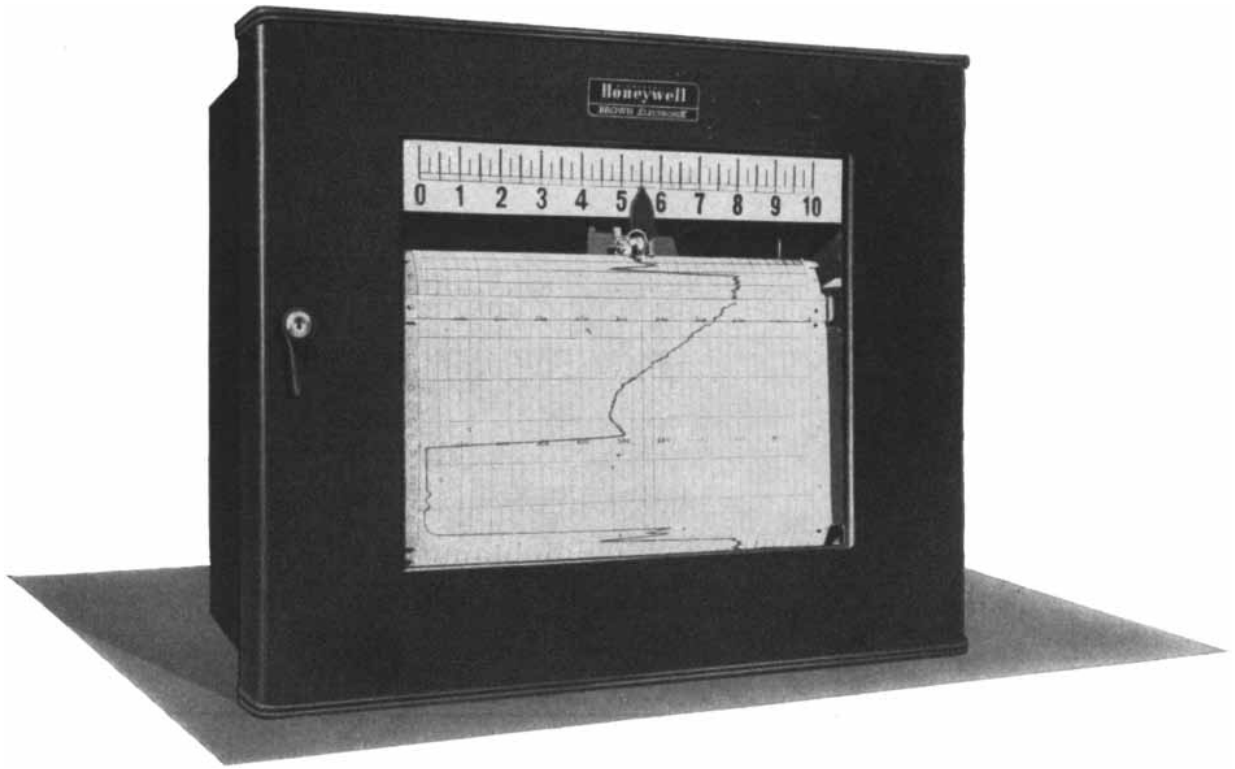
The preparation of metals and other crystal materials in useful sizes without weakening dislocations is a still unsolved problem. If ways can be found to circumvent the restrictions nature normally places on the growth of crystals, truly revolutionary materials will become possible. Whether or not this goal is achieved, the dislocation theory has shed light on a number of properties of crystals—their strength, the rates at which atoms diffuse through them and the rates at which they grow.



DISLOCATION SOURCE may be a dirt particle encountered by the advancing edge of a thin crystal plate which is growing in area.



LOOP SOURCE could be formed if growing crystal picked up a foreign particle tilted with respect to its molecular layers.



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The Continental Shelf

Around the borders of the continents the bottom of the ocean slopes off gently for as much as 400 miles before it plunges into the deeps. This terrace provides an active natural laboratory for the geologist

by Henry C. Stetson

Throughout geologic time, as far back as we can read the rocks, the continents have repeatedly been invaded by the oceans. The seas have left the record of their passage in the form of sedimentary rocks—sandstones, shales and limestones formed from the sediments deposited on the inundated continental areas. Every part of the North American continent, for example, except possibly a certain area in northeastern Canada, has been submerged time and again. After each invasion the shallow waters gradually receded. Today the continents happen to be largely emergent. But around the shores of each there is a margin which is still submerged. This underwater borderland between continent and ocean, called the continental terrace, is a shelf of varying width—from a few tens of miles to as much as 300 or 400 miles off some coasts. At its seaward edge it pitches steeply into the deep ocean basin.

The continental terrace is one of the main subjects of investigation in submarine geology today. It is, for one thing, an active geological laboratory—a place where geologists can investigate the processes of transportation and deposition at work. It is also the site of a major geological mystery—the mystery of the lost ancient boundary between the continents and the oceans. The continental and oceanic blocks of the earth's crust have different densities and have been distinguishable throughout geologic history. What was the boundary between them like in the distant, primeval past? Presumably there were terraces then, but if so, they have sunk without a trace. The present comparatively young continental terraces, built up within the last 100 million years or so, rest not on older sediments but on basement granite. What could have happened to the earlier terraces? Perhaps we shall find the answer to that riddle some day; in the meantime the probings of geologists into the present terraces tell an interesting story of their evolution and the repeated advances and retreats of the sea.

Ever since rain began to fall and the oceans came into being the rivers of the continents have been building aprons into the sea with their wash of silt, clay, sand and gravel. Let us examine in some detail two terraces which, though ancient, are primitive in structure and serve as excellent examples of the early stages of terrace construction. They are the terrace in the Atlantic Ocean off the eastern coast of the U. S. and that in the Gulf of Mexico off the southern coast. The existence of both terraces is familiar to most Americans; the one in the Gulf has recently had a great deal of attention as the scene of the dispute over "tidelands" oil.

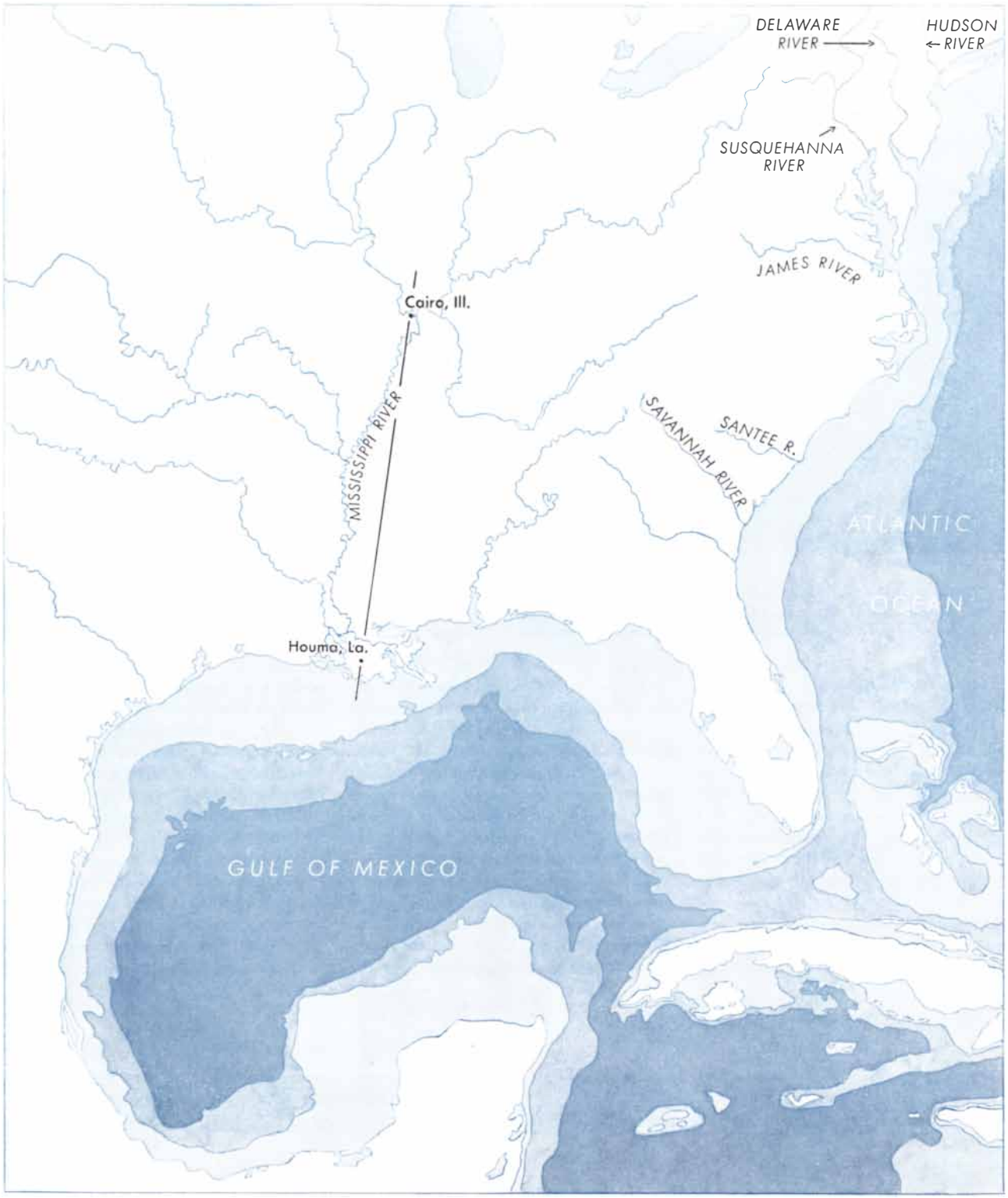
Both terraces have been growing in thickness and in width ever since the Lower Cretaceous Period some 100 million years ago. They have the same general structure—a stratified wedge with the thicker edge on the seaward side. In the Atlantic terrace the thin edge of the sedimentary wedge reaches inland to the "fall line" (a zone of waterfalls) on the eastern side of the Appalachian Mountains. The part of the Gulf terrace now above water stretches far up into the middle of the continent; its thin edge overlaps the southern end of the Appalachians and reaches to Cairo, Ill., the high-water mark of the Cretaceous seas. This great sedimentary platform, the dumping ground of the wash of soils from the midcontinent, is some 700 miles wide from Cairo to the end of its apron in the Gulf, and at the present shore line of Louisiana and Texas it is estimated to be more than 40,000 feet thick.

The terrace sediments in the Gulf and in the Atlantic are very different. In the Gulf the shelf—the offshore sea bottom—is muddy; in the Atlantic it is dominantly sandy. A whole series of notably muddy rivers, including the Mississippi and the Rio Grande, is dumping silt and clay into the Gulf faster than the sea's currents can carry it away. On the seaward face of the terrace even the ridges and plateaus are covered with a blanket of this fine material.

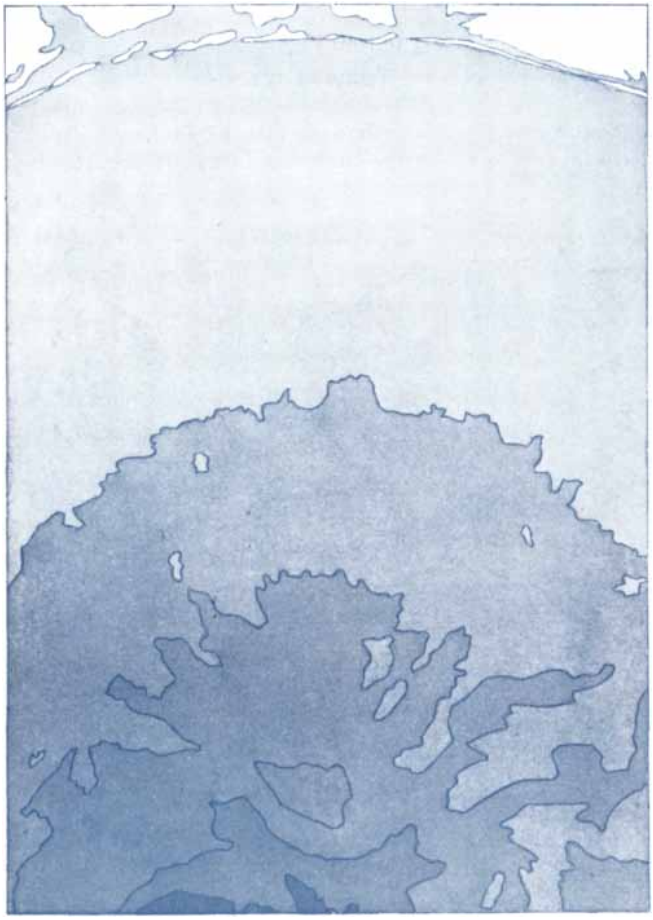
Mud is common in continental terraces; what is unusual is the clean, sandy surface of the Atlantic shelf. There are several reasons for its freedom from silt. To begin with, the rivers of the northeastern U. S., from New England down to Chesapeake Bay, are practically clear and discharge little or no sediment into the ocean. Chesapeake Bay itself traps much of the sediment carried by the muddy Susquehanna, James and other rivers entering it. Nonetheless considerable mud does escape from the bay into the Atlantic, as is demonstrated by the color of the outflowing tide between Cape Charles and Cape Henry, and a great deal more is washed into the ocean by the muddy rivers south of Chesapeake, notably the Savannah and the Santee. It does not stay on the shelf, however; practically all of it is swept off the platform and deposited on the steep outer slope plunging into the deep ocean basin. Probably the reason is that the Atlantic has swifter bottom currents than the Gulf. Its tidal currents must be stronger, because of the greater range of the tides (roughly four to five feet at the Delaware breakwater, as compared with a foot and a half at Galveston).

Storm waves and swells have longer periods in the wide Atlantic than in the Gulf, and therefore can move sedimentary material at greater depths. And the swift, turbulent Gulf Stream also plays a part in sweeping sediment from the face of the Atlantic terrace south of Cape Hatteras. Indeed, the Atlantic currents not only are washing the shelf clean of mud but are reworking and redistributing sediments deposited in an earlier era.

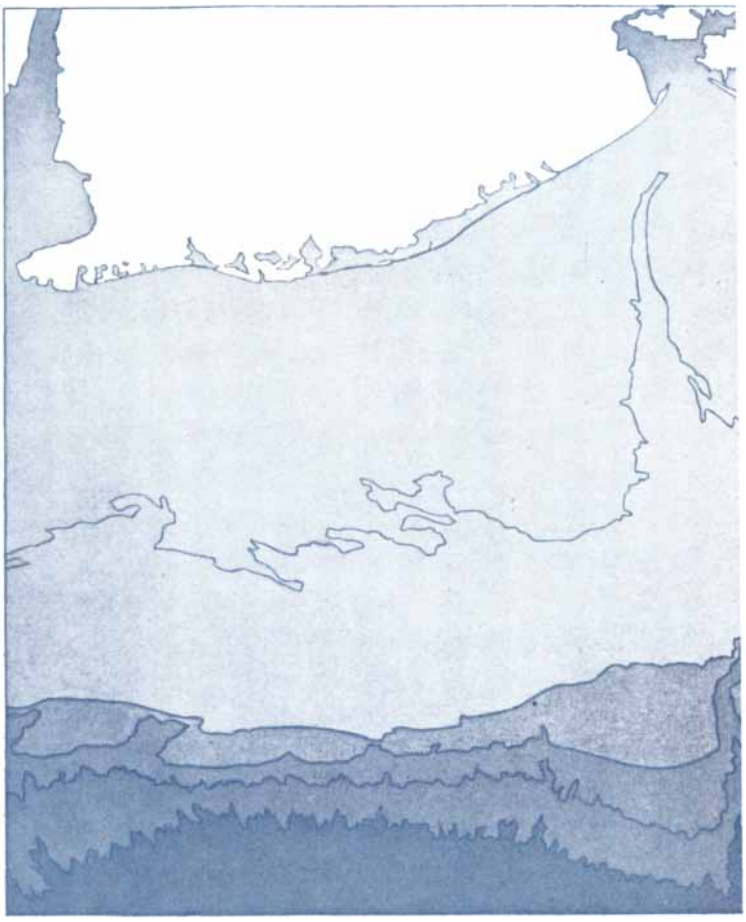
As a result of the differences in deposit and erosion, the Atlantic terrace is not nearly so thick as the sedimentary wedge in the Gulf. As logged in an oil well drilled at Cape Hatteras, the Atlantic wedge at the present shore line is only about 10,000 feet thick, compared with the more than 40,000-foot thickness at the Gulf shore. Offshore the Atlantic



CONTINENTAL SHELF off part of the coast of North America is traced by these contours. The lightest colored tone represents the bottom from sea level to 600 feet below it; the next darkest tone, the bottom from 600 to 6,000 feet; the darkest tone, the bottom below 6,000 feet. The line from Cairo, Ill., to Houma, La., indicates the path of the section at the bottom of the next two pages.



OFF THE GULF COAST the continental shelf is characterized by ridges and basins. The tones from light to dark gray represent the contours of the bottom at 2,400, 4,800, 7,200 and 9,600 feet.



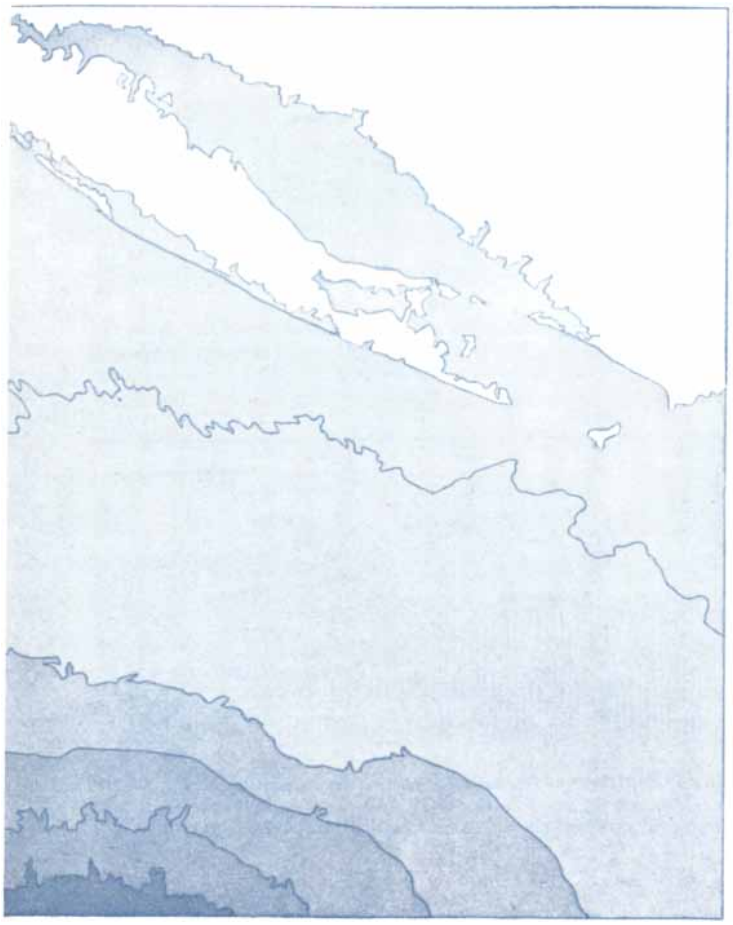
OFF THE ATLANTIC COAST the continental shelf is cut by deep canyons. The first contour within the lightest tone represents the bottom at 150 feet; the second, the bottom at 300

terrace is 16,000 feet thick or more, according to seismic measurements.

From cores drilled through the Gulf and Atlantic terraces we can read the record of each advance and retreat of the sea. Piled on the underlying basement, which has been subsiding, is a huge series of overlapping lenses of sediments. The sea flooded the continental margin many times, and this resulted in alternating deposition and erosion. When the sea advanced, under the simplest conditions the new deposits overlapped the older in a shoreward direction—a process called onlap. In strata formed at such a time the near-shore sediments are sandy or gravelly, while the offshore deposits are muddy. This eventually results in an overlapping of shales on sandstones. It is a time of continuous accumulation of sediment in a deepening sea, and the continental shelf grows in thickness as well as in width. Conversely, when the sea level falls, the new deposits overlap the older in a seaward direction; this is known as offlap. Some of the coarser deposits of the shoal-water zone are washed seaward over the older and finer muds previously laid down in deeper water. The surface of the shelf is undergoing erosion; the strata deposited near shore during the previous onlap are shaved down or removed entirely. Though the shelf is reduced in thickness, it continues to grow in width, because the eroded material is deposited on the steep seaward slope.

Through all the oscillations of the shore line, indeed even when the sea level remained constant, the face of the slope progressed steadily seaward into deeper water. As we have seen, the Gulf

ENTIRE CONTINENTAL TERRACE extends far inland from the Gulf of Mexico. The sediments (*horizontal bands*) in this cross section reach beyond Cairo, Ill., to the high-water mark of the seas during the Cretaceous Period. The black band of sediment was

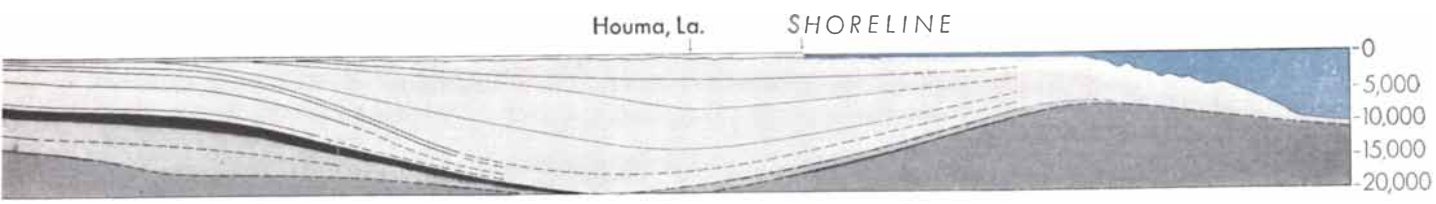


feet. The remainder of the tones from light to dark represent the bottom at 600, 3,000, 6,000 and below 6,000 feet. The deep cleft of the Hudson River canyon is visible at the left center.

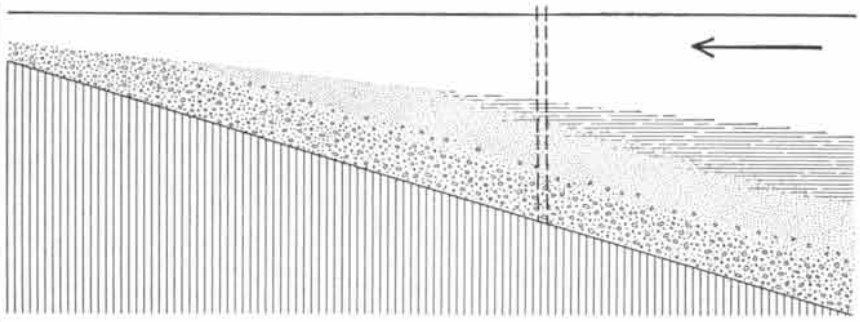
OFF THE CALIFORNIA COAST the continental shelf has a topography resembling that of the land. The tones from light to dark gray represent the bottom at 3,000, 6,000, 9,000 and 12,000 feet.

terrace is now some 700 miles wide; the Atlantic wedge at its widest (at the latitude of Cape May) measures about 175 miles from the fall line to the offshore break.

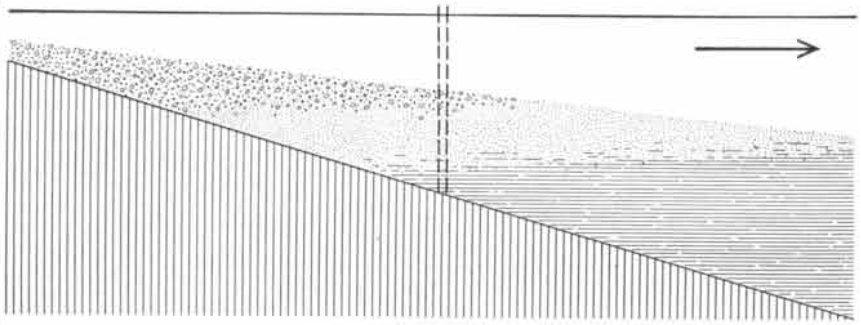
The Atlantic terrace is gashed by many canyons, like the valleys of rivers with their tributaries. Some of them, notably the undersea extension of the Hudson River, are of considerable size. These spectacular submarine valleys are still an enigma to geologists. In trying to explain them the geologist is truly on the horns of a dilemma. If he chooses to believe that they were cut by conventional rivers across dry land, he must assume that the continental margins once stood thousands of feet above the present sea level [see "Submarine Canyons," by Francis P. Shepard; SCIENTIFIC AMERICAN, April, 1949]. This is more than most geologists will admit is probable. In the last few years many have leaned to a new theory: that the canyons were carved by submarine streams heavily loaded with silt and clay. Flows of this type, known as turbidity currents, have never been observed in the ocean, but gentle turbidity currents are known to flow along the bottom the whole length of man-made Lake Mead, where the muddy Colorado River plunges beneath the clear waters of that lake. They have also been observed in some glacial lakes such as Geneva, where from an overlooking mountain one can clearly see the Rhone River drop beneath the lake waters. Yet there is no proof that turbidity currents could have cut the great canyons in the continental terraces. The canyons represent an enormous amount of very recent erosion, and



laid down during the Upper Cretaceous. The sediments below it were laid down earlier; the sediments above it were laid down later. The depth of the sediment is given in feet by the scales at left and right. The vertical scale is 10 times larger than the horizontal.



ONLAP PROCESS occurs when the sea is advancing. The sediments nearest the shore are gravelly; those farther out are sandy; those still farther out are muddy. Eventually the sediments become sandstone and shale. Their sequence is determined by borings (*dotted lines*).



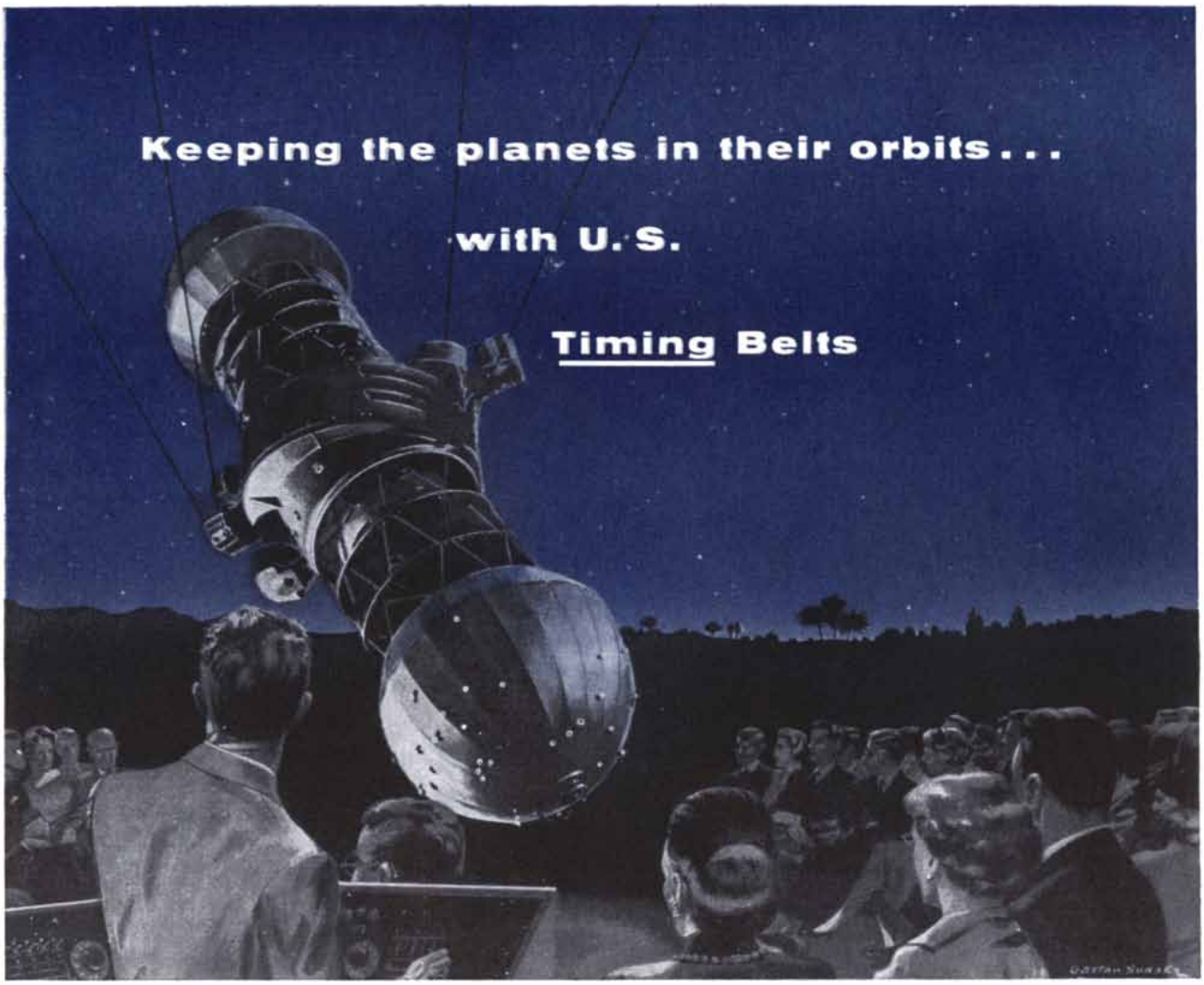
OFFLAP PROCESS occurs when the sea is retreating. Some of the gravelly and sandy sediments are washed out over the muddy ones. In the onlap process the shales lie on top of the sandstones. In the offlap process the reverse is true: the sandstones lie on top of shales.

the turbidity current theory is difficult to evaluate quantitatively.

The seaward bank of the terrace in the Gulf of Mexico presents another puzzle. Along the western half the upper part of this steep slope is marked by a succession of ridges and basins, some of them closed, while a number of deep channels slice downward across the lower sections of the slope. This rough topography is not too difficult to explain if we accept the theory that the continental terrace was built by the slow accumulation of muddy sediments. At the edge of the terrace the stress of gravity may well cause the unstable sediments to shear and slide down the steep slope. Such shearing is familiar on a small scale on earth slopes and in failures of earth dams, and it has been observed that they produce a hummocky slope like that of the terrace bank in the Gulf. Of course slumps and mudflows also may play a part in furrowing the slope, and perhaps turbidity currents as well. If ever there was a locale favorable for the operation of turbidity currents, it is the western Gulf slope.

There is another phenomenon which at first sight may seem to throw doubt on the theory that the steep face of the continental terrace is built simply by the piling up of sediments which slowly push the bank seaward. In the eastern and western Gulf and in many places off California the continent ends in sharp cliffs of the kind known as fault scarps. Such a cliff is created by a shift or upheaval of the earth's crust. But its existence at the edge of a continental terrace does not necessarily invalidate the sedimentary hypothesis. It may mean simply that the sedimentary platform is building across a zone of crustal movement. If, in building outward from the continent, the terrace reaches a cliff separating the continental block from the ocean floor, it can build no farther. Very possibly the truncated sections of the terrace in the Gulf have reached such a "land's end."

The continental shelves and slopes around the world differ greatly from one another; those off Norway and California, for example, are very unlike the ones in the Gulf of Mexico and off the U. S. eastern coast. Terraces go through a series of evolutionary changes in the course of geologic time, and some have had a more complex history than others. The Atlantic and Gulf terraces can be regarded as being in the primitive stage, although they date from the Cretaceous and are relatively old. They have been modified little by geologic upheavals. This is fortunate for geologists, because they give us an almost unique opportunity to study a continental terrace still in process of formation.



Planetarium constructed by Spitz Laboratories, Inc., Elkton, Md., for the city of Montevideo, Uruguay, showing the heavens as seen looking southward from Montevideo.

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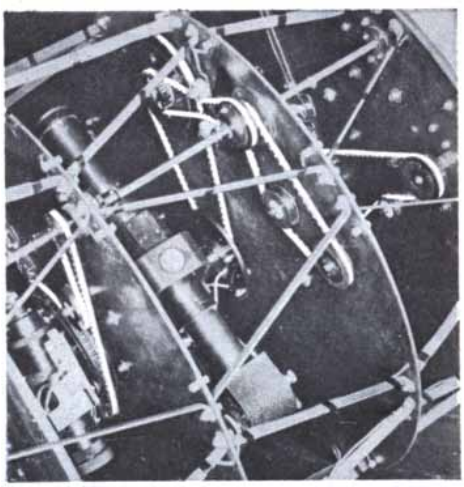

Close-up section of Spitz Planetarium showing some of the U. S. PowerGrip *Timing* Belts.

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BIRDS AS FLYING MACHINES

A sequel to the article on the aerodynamics of birds in the April, 1952, issue of this magazine. Among the remarkable adaptations birds have made to life in the air are high power and light weight

by Carl Welty

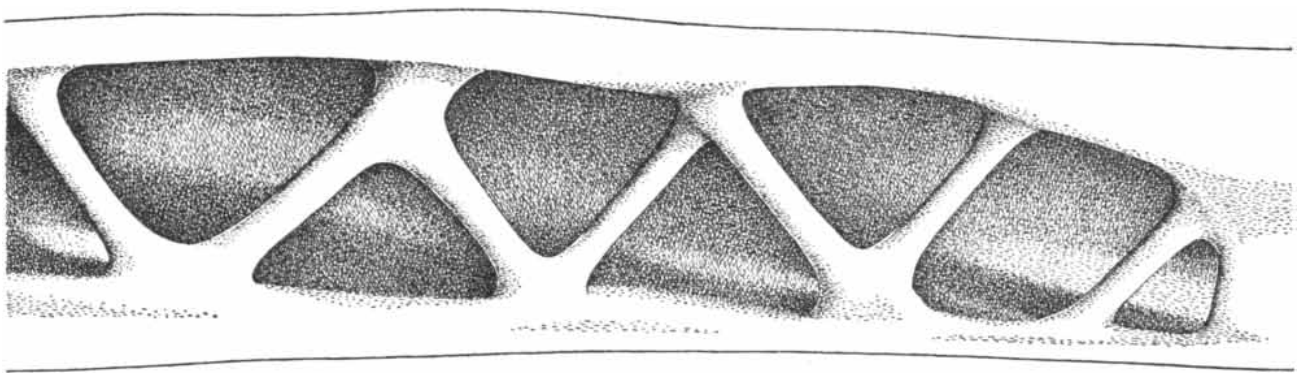
The great struggle in most animals' lives is to avoid change. A chickadee clinging to a piece of suet on a bitter winter day is doing its unconscious best to maintain its internal status quo. Physiological constancy is the first biological commandment. An animal must eternally strive to keep itself warm, moist and supplied with oxygen, sugar, protein, salts, vitamins and the like, often within precise limits. Too great a change in its internal economy means death.

The spectacular flying performances of birds—spanning oceans, deserts and whole continents—tend to obscure the more important fact that the ability to fly confers on them a remarkably useful mechanism to preserve their internal stability, or homeostasis. Through flight birds can search out the external conditions and substances they need to keep their internal fires burning clean and steady. A bird's wide search for specific foods and habitats makes sense only when considered in the light of this persistent, urgent need for constancy.

The power of flight opens up to birds an enormous gaseous ocean, the atmosphere, and a means of quick, direct access to almost any spot on earth. They can eat in almost any "restaurant"; they have an almost infinite choice of sites to build their homes. As a result birds are, numerically at least, the most successful vertebrates on earth. They number roughly 25,000 species and subspecies, as compared with 15,000 mammals and 15,000 fishes.

At first glance birds appear to be quite variable. They differ considerably in size, body proportions, color, song and ability to fly. But a deeper look shows that they are far more uniform than, say, mammals. The largest living bird, a 125-pound ostrich, is about 20,000 times heavier than the smallest bird, a hummingbird weighing only one tenth of an ounce. However, the largest mammal, a 200,000-pound blue whale, weighs some 22 million times as much as the smallest mammal, the one-seventh-ounce masked shrew. Mammals, in other words, vary in mass more than a thousand times as much as birds. In body architecture, the comparative uniformity of birds is even more striking. Mammals may be as fat as a walrus or as slim as a weasel, furry as a musk ox or hairless as a desert rat, long as a whale or short as a mole. They may be built to swim, crawl, burrow, run or climb. But the design of nearly all species of birds is tailored to and dictated by one pre-eminent activity—flying. Their structure, outside and inside, constitutes a solution to the problems imposed by flight. Their uniformity has been thrust on them by the drastic demands that determine the design of any flying machine. Birds simply dare not deviate widely from sound aerodynamic design. Nature liquidates deviationists much more consistently and drastically than does any totalitarian dictator.

Birds were able to become flying machines largely through the evolutionary gifts of feathers, wings, hollow bones, warm-bloodedness, a remarkable system of respiration, a strong, large heart and powerful breast muscles. These adaptations all boil down to the two prime requirements for any flying machine: high power and low weight. Birds have thrown all excess baggage overboard. To keep their weight low and feathers dry they forego the luxury of sweat glands. They have even reduced



INTERNAL STRUCTURE of the metacarpal bone of a vulture's wing is shown in this drawing of a longitudinal section. The braces within the bone are almost identical in geometry with those of the Warren truss commonly used as a steel structural member.

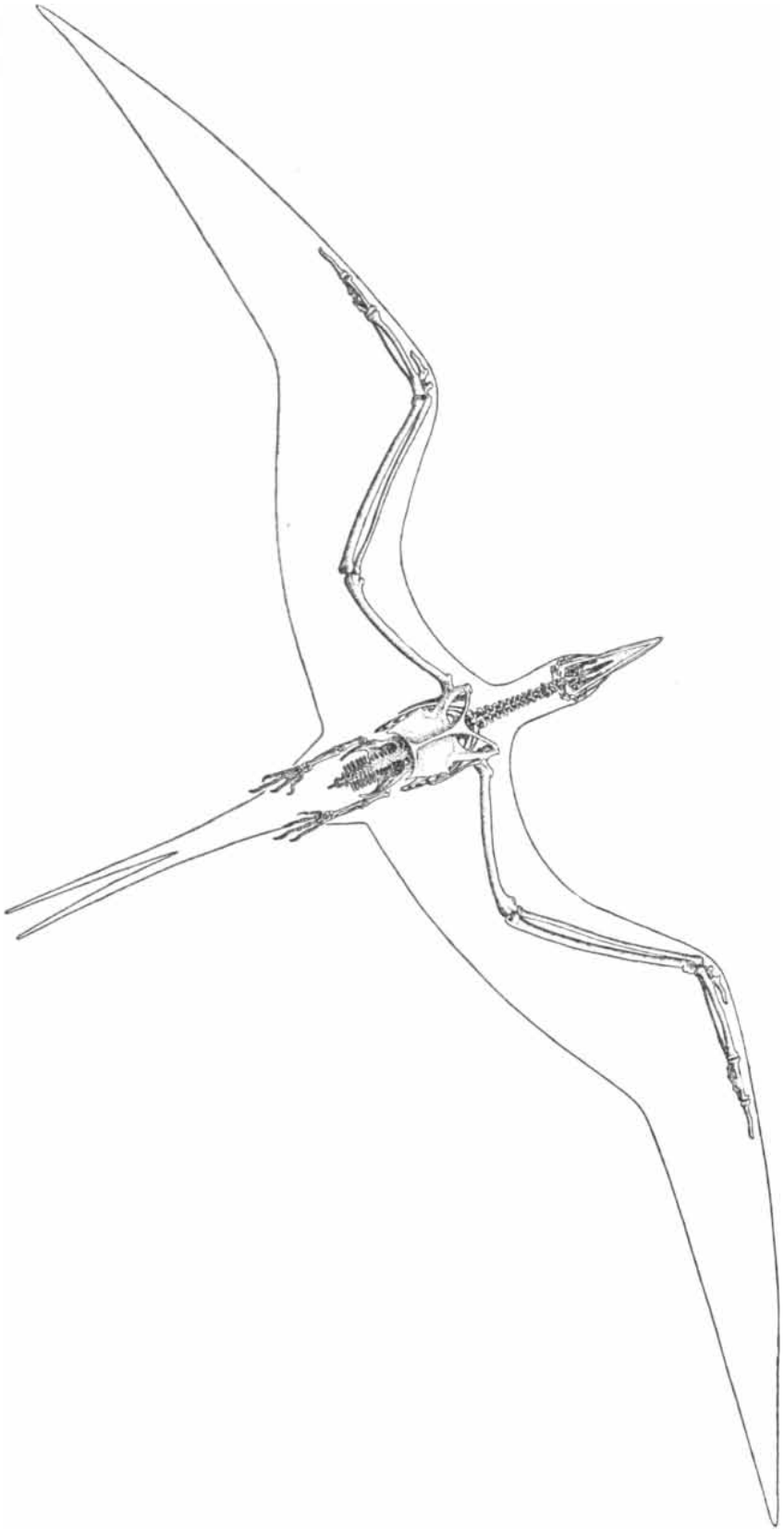
their reproductive organs to a minimum. The female has only one ovary, and during the nonbreeding season the sex organs of both males and females atrophy. T. H. Bissonette, the well-known investigator of birds and photoperiodicity, found that in starlings the organs weigh 1,500 times as much during the breeding season as during the rest of the year.

As early as 1679 the Italian physicist Giovanni Borelli, in his *De motu animalium*, noted some of the weight-saving features of bird anatomy: ". . . the body of a Bird is disproportionately lighter than that of man or of any quadruped . . . since the bones of birds are porous, hollowed out to extreme thinness like the roots of the feathers, and the shoulder bones, ribs and wing bones are of little substance; the breast and abdomen contain large cavities filled with air; while the feathers and the down are of exceeding lightness."

The skeleton of a pigeon accounts for only 4.4 per cent of its total body weight, whereas in a comparable mammal such as a white rat it amounts to 5.6 per cent. This in spite of the fact that the bird must have larger and stronger breast bones for the muscles powering its wings and larger pelvic bones to support its locomotion on two legs. The ornithologist Robert Cushman Murphy has reported that the skeleton of a frigate bird with a seven-foot wingspread weighed only four ounces, which was less than the weight of its feathers!

Although a bird's skeleton is extremely light, it is also very strong and elastic—necessary characteristics in an air frame subjected to the great and sudden stresses of aerial acrobatics. This combination of lightness and strength depends mainly on the evolution of hollow, thin bones coupled with a considerable fusion of bones which ordinarily are separate in other vertebrates. The bones of a bird's sacrum and hip girdle, for example, are molded together into a thin, tube-like structure—strong but phenomenally light. Its hollow finger bones are fused together, and in large soaring birds some of these bones have internal trusslike supports, very like the struts inside airplane wings. Similar struts sometimes are seen in the hollow larger bones of the wings and legs.

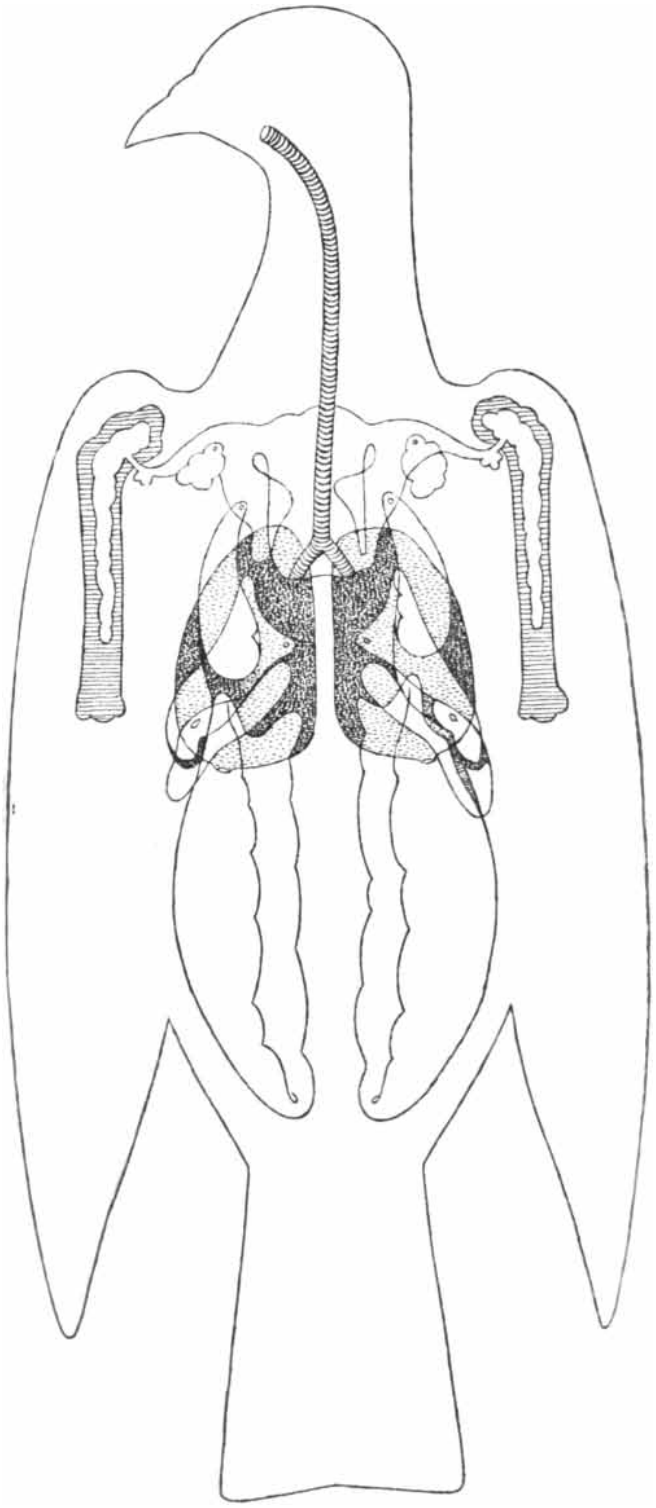
To "trim ship" further, birds have evolved heads which are very light in proportion to the rest of the body. This has been accomplished through the simple device of eliminating teeth and the accompanying heavy jaws and jaw muscles. A pigeon's skull weighs about



FRIGATE BIRD has a seven-foot wing span, but its skeleton weighs only four ounces. This is less than the weight of its feathers. The skeleton is shown against the outline of the bird.

one sixth as much, proportionately, as that of a rat; its skull represents only one fifth of 1 per cent of its total body weight. In birds the function of the teeth has been taken over largely by the gizzard, located near the bird's center of gravity. The thin, hollow bones of a bird's skull have a remarkably strong reinforced construction [*see photograph on page 92*]. Elliott Coues, the 19th-century U. S. ornithologist, referred to the beautifully adapted avian skull as a "poem in bone."

The long, lizard-like tail that birds inherited from their reptilian ancestors has been reduced to a small plate of bone at the end of the vertebrae. The ribs of a bird are elegantly long, flat, thin and jointed; they allow extensive movement for breathing and flying, yet are light and strong. Each rib overlaps its neighbor—an arrangement which gives the kind of resilient strength achieved by a woven splint basket.



AIR SACS connected to the lungs of a pigeon not only lighten the bird but also add to the efficiency of its respiration and cooling. The lungs are indicated by the two dark areas in the center. Two of the air sacs are within the large bones of the bird's upper "arm."

Feathers, the bird's most distinctive and remarkable acquisition, are magnificently adapted for fanning the air, for insulation against the weather and for reduction of weight. It has been claimed that for their weight they are stronger than any wing structure devised by man. Their flexibility allows the broad trailing edge of each large wing-feather to bend upward with each downstroke of the wing. This produces the equivalent of pitch in a propeller blade, so that each wingbeat provides both lift and forward propulsion. When a bird is landing or taking off, its strong wingbeats separate the large primary wing feathers at their tips, thus forming wing-slots which help prevent stalling. It seems remarkable that man took so long to learn some of the fundamentals of airplane design which even the lowliest English sparrow demonstrates to perfection [see "Bird Aerodynamics," by John H. Storer; SCIENTIFIC AMERICAN, April, 1952].

Besides all this, feathers cloak birds with an extraordinarily effective insulation—so effective that they can live in parts of the Antarctic too cold for any other animal.

The streamlining of birds of course is the envy of all aircraft designers. The bird's awkwardly angular body is trimmed with a set of large quill, or contour, feathers which shape it to the utmost in sleekness. A bird has no ear lobes sticking out of its head. It commonly retracts its "landing gear" (legs) while in flight. As a result birds are far and away the fastest creatures on our planet. The smoothly streamlined peregrine falcon is reputed to dive on its prey at speeds up to 180 miles per hour. (Some rapid fliers have baffles in their nostrils to protect their lungs and air sacs from excessive air pressures.) Even in the water, birds are among the swiftest of animals: Murphy once timed an Antarctic penguin swimming under water at an estimated speed of about 22 miles per hour.

A basic law of chemistry holds that the velocity of any chemical reaction roughly doubles with each rise of 10 degrees centigrade in temperature. In nature the race often goes to the metabolically swift. And birds have evolved the highest operating temperatures of all animals. Man, with his conservative 98.6

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MICROWAVE TUBES—Tube Development and Manufacture (Traveling Wave—Backward Wave)		H	H	H			H	H			H	H
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COMPUTERS (ANALOG AND DIGITAL)—Systems—Advanced Development—Circuitry—Assembly Design—Mechanisms			M C			M C			M C			
COMMUNICATIONS—Microwave—Aviation—Specialized Military Systems			M C			M C			M C			
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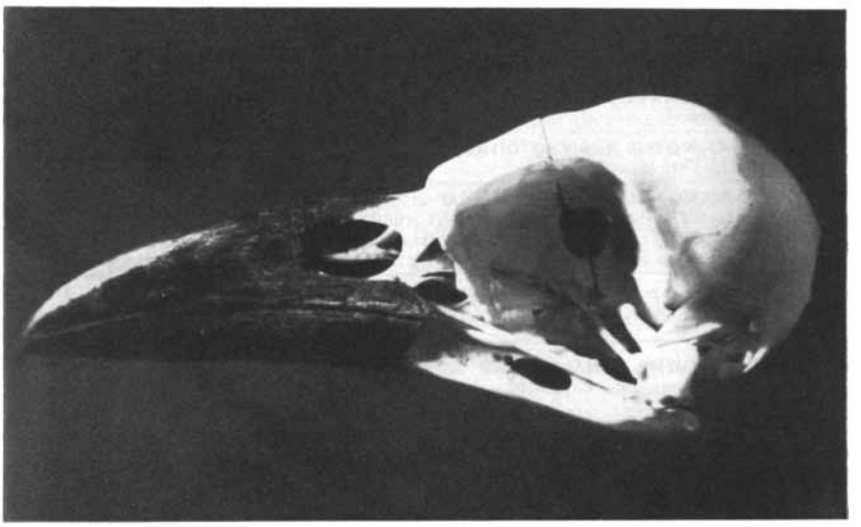
degrees Fahrenheit, is a metabolic slowpoke compared with sparrows (107 degrees) or some thrushes (113 degrees). Birds burn their metabolic candles at both ends, and as a result live short but intense lives. The average wild songbird survives less than two years.

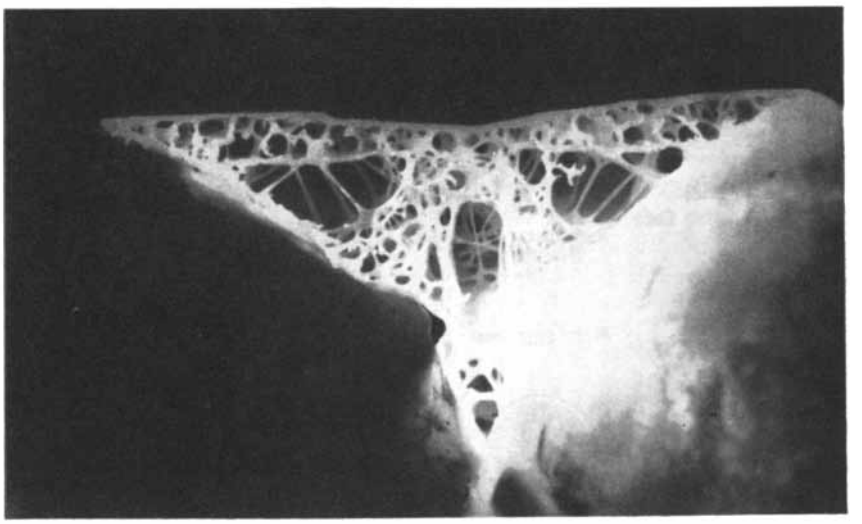
Behind this high temperature in birds lie some interesting circulatory and respiratory refinements. Birds, like mammals, have a four-chambered heart which allows a double circulation, that is, the blood makes a side trip through the lungs for purification before it is circulated through the body again. A bird's heart is large, powerful and rapid-beating [*see table of comparisons on page 96*]. In both mammals and birds the heart rate, and the size of the heart in proportion to the total body, increases as the animals get smaller. But the increases seem significantly greater in birds than in mammals. Any man with a weak heart knows that climbing stairs puts a heavy strain on his pumping system. Birds do a lot of "climbing," and their circulatory systems are built for it.

The blood of birds is not significantly richer in hemoglobin than that of mammals. The pigeon and the mallard have about 15 grams of hemoglobin per 100 cubic centimeters of blood—the same as man. However, the concentration of sugar in their blood averages about twice as high as in mammals. And their blood pressure, as one would expect, also is somewhat higher: in the pigeon it averages 145 millimeters of mercury; in the chicken, 180 millimeters; in the rat, 106 millimeters; in man, 120 millimeters.

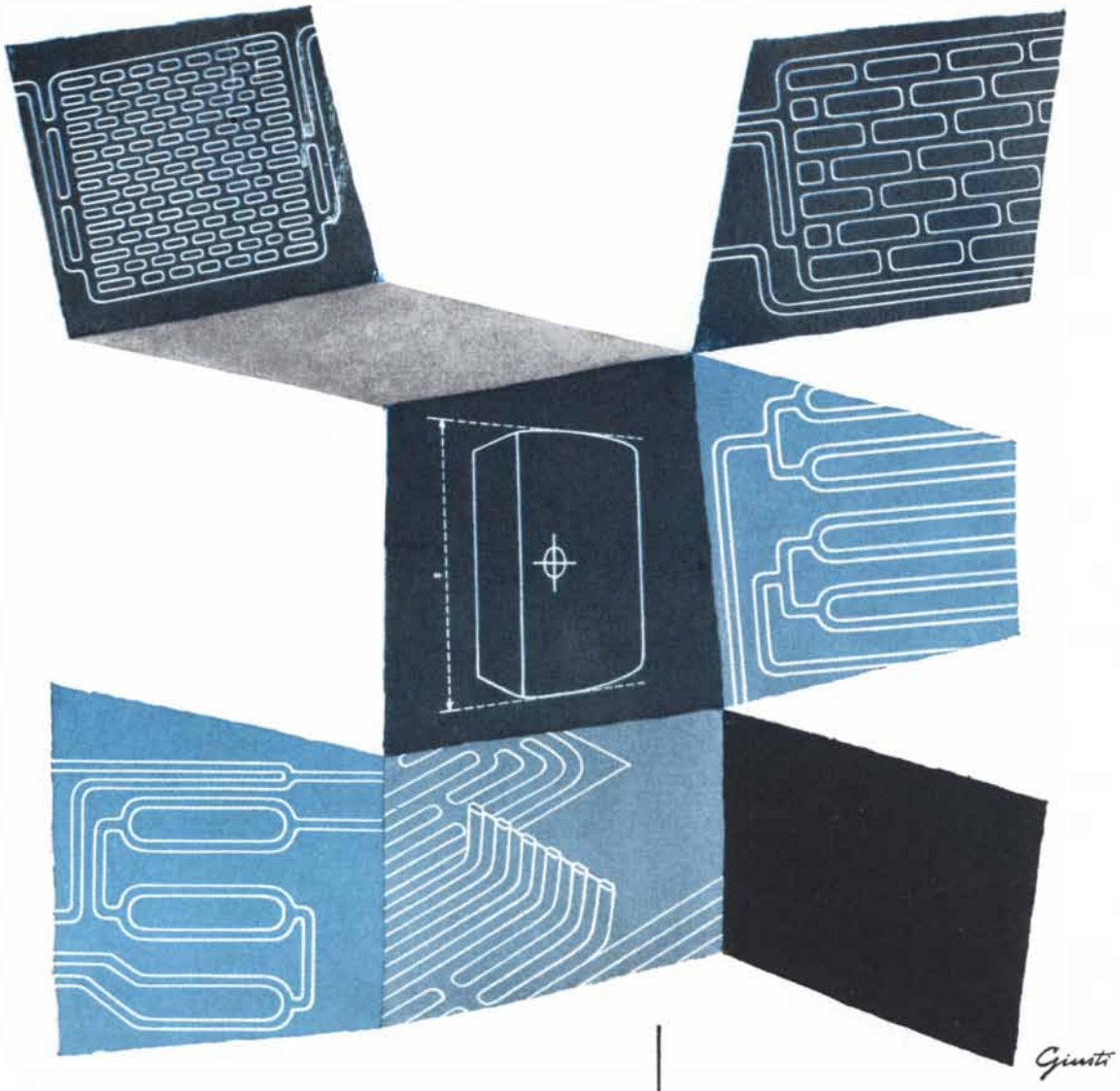
In addition to conventional lungs, birds possess an accessory system of five



SKULL OF A CROW achieves the desirable aerodynamic result of making the bird light in the head. Heavy jaws are sacrificed. Their work is largely taken over by the gizzard.



FRONTAL BONE in the skull of a crow is cut through to show its hollow and braced internal construction. The skull of the bird accounts for less than 1 per cent of its total weight.



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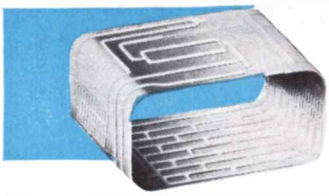

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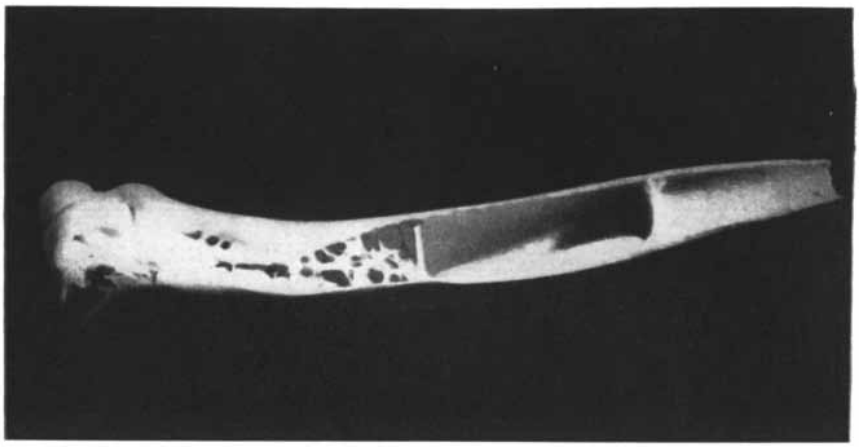

UPPER ARM BONE, or humerus, of a golden eagle also is cut through to show its construction. The hollow spaces not only make the bone light but also serve as respiratory air sacs.

or more pairs of air sacs, connected with the lungs, that ramify widely throughout the body. Branches of these sacs extend into the hollow bones, sometimes even into the small toe bones. The air-sac system not only contributes to the birds' lightness of weight but also supplements the lungs as a supercharger (adding to the efficiency of respiration) and serves as a cooling system for the birds' speedy, hot metabolism. It has been estimated that a flying pigeon uses one fourth of its air intake for breathing and three fourths for cooling.

The lungs of man constitute about 5 per cent of his body volume; the respiratory system of a duck, in contrast, makes up 20 per cent of the body volume (2 per cent lungs and 18 per cent air sacs). The anatomical connections of the lungs and air sacs in birds seem to provide a one-way traffic of air through most of the system, bringing in a constant stream of unmixed fresh air, whereas in the lungs of mammals stale air is mixed inefficiently with the fresh. It seems odd that natural selection has never produced a stale air outlet for animals. The air sacs of birds apparently approach this ideal more closely than any other vertebrate adaptation.

Even in the foods they select to feed their engines birds conserve weight. They burn "high-octane gasoline." Their foods are rich in caloric energy—seeds, fruits, worms, insects, rodents, fish and so on. They eat no low-calorie foods such as leaves or grass; a wood-burning engine has no place in a flying machine. Furthermore, the food birds eat is burned quickly and efficiently. Fruit fed to a young cedar waxwing passes through its digestive tract in an average time of 27 minutes. A thrush that is fed blackberries will excrete the seeds 45 minutes later. Young bluejays take between 55 and 105 minutes to pass food through their bodies. Moreover, birds utilize a greater portion of the food they eat than do mammals. A three-weeks-old stork, eating a pound of food (fish, frogs and other animals), gains about a third of a pound in weight. This 33 per cent utilization of food compares roughly with an average figure of about 10 per cent in a growing mammal.

The breast muscles of a bird are the engine that drives its propellers or wings. In a strong flier, such as the pigeon, these muscles may account for as much as one half the total body weight. On the other hand, some species—*e.g.*, the albatross—fly largely on updrafts of air, as a glider does. In such birds the breast muscles are greatly reduced, and there are well-developed wing tendons and ligaments which enable the bird to hold its wings in the soaring position with little or no effort.

A bird may have strong breast muscles and still be incapable of sustained flight because of an inadequate blood supply to these muscles. This condition is shown in the color of the muscles; that is the explanation of the "white meat" of the chicken and the turkey—their breast muscles have so few blood vessels that they cannot get far off the ground. The dark meat of their legs, on the other hand, indicates a good blood supply and an ability to run a considerable distance without tiring.

After a ruffed grouse has been flushed four times in rapid succession, its breast muscles become so fatigued that it can be picked up by hand. The blood supply is simply inadequate to bring in fuel and carry away waste products fast enough. Xenophon's *Anabasis* relates the capture of bustards in exactly this manner: "But as for the Bustards, anyone can catch them by starting them up quickly; for they fly only a short distance like the

Compact new attack bomber,

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continues trend to

"more plane per pound"

—the U. S. Navy's Douglas A4D Skyhawk

Continuing a growing trend, the Douglas A4D attains maximum efficiency—at lower production cost—through highly simplified design.

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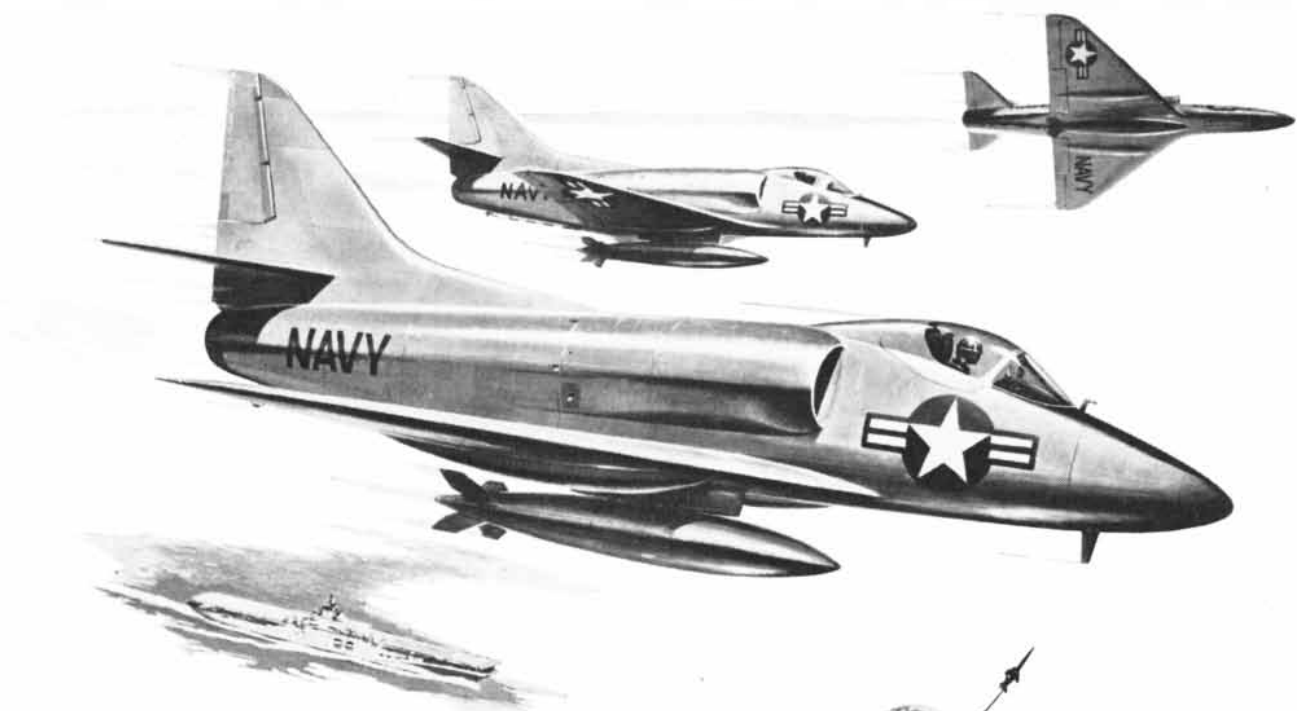
Performance of A4D shows Douglas leadership in aviation. Planes that can be built in quantity to *fly farther and faster with a bigger payload* are a basic rule of Douglas design.



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HEART	PERCENT OF BODY WEIGHT	HEART BEATS PER MINUTE
FROG	.57	22
MAN	42	72
PIGEON	1.71	135
CANARY	1.68	514
HUMMINGBIRD	2.37	615

HEART WEIGHT and pulse rate are compared for a number of animals. The hearts of birds are relatively large for body size.

partridge and soon tire. And their flesh was very sweet."

In birds the active phase of the breathing cycle is not in inhaling but exhaling. Their wing strokes compress the rib case to expel the air. Thus instead of "running out of breath" birds "fly into breath."

Probably the fastest metabolizing vertebrate on earth is the tiny Allen's hummingbird [see "The Metabolism of Hummingbirds," by Oliver P. Pearson; SCIENTIFIC AMERICAN, January, 1953]. While hovering it consumes about 80 cubic centimeters of oxygen per gram of body weight per hour. Even at rest its metabolic rate is more than 50 times as fast as man's. Interestingly enough, the hovering hummingbird uses energy at about the same proportionate rate as a hovering helicopter. This does not mean that man has equalled nature in the efficiency of energy yield from fuel. To hover the hummingbird requires a great deal more energy, because of the aerodynamic inefficiency of its small wings and its very high loss of energy as dissipated heat. The tiny wings of a hummingbird impose on the bird an almost incredible expenditure of effort. Its breast muscles are estimated to be approximately four times as large, proportionately, as those of a pigeon. This great muscle burden is one price a hummingbird pays for being small.

A more obvious index of the efficiency of bird's fuel consumption is the high mileage of the golden plover. In the fall the plover fattens itself on bayberries in Labrador and then strikes off across the open ocean on a nonstop flight of 2,400 miles to South America. It arrives there weighing some two ounces less than it did on its departure. This is the equivalent of flying a 1,000-pound airplane 20 miles on a pint of gasoline rather than the usual gallon. Man still has far to go to approach such efficiency.

Advances in Applied Radiation

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

HIGH VOLTAGE PIONEERS LINEAR ACCELERATORS

HIGH VOLTAGE, sole manufacturer of Van de Graaff particle accelerators, has just announced the first microwave linear accelerator offered commercially in this country.

The initial model of a new line of linear accelerators to be manufactured by HIGH VOLTAGE is a radiation-producing machine designed especially for operation in the 4 to 7-million-volt range. The company will soon introduce several models of this accelerator for cancer therapy, scientific research, industrial radiography, electron-beam sterilization and radiation processing of plastics and other chemical products.

This seven-million-volt atom-smasher has been undergoing an exhaustive test program at HIGH VOLTAGE's plant for several months. Excellent performance is reported by the company's physicists and engineers. Its introduction will fill a long-felt need for a compact, flexible radiation machine capable of operating efficiently in this particular high energy range. Adapted to cancer therapy, it will supplement the 2-million-volt Van de Graaff x-ray generator also made by HIGH VOLTAGE, nearly a score of which are now in use in hospitals both in this country and abroad.

The powerful beam of electrons produced can be used directly in the treatment of biological or chemical systems, or it can be fired onto a gold target with x-rays being produced in the collision. These x-rays have far greater penetrating power than x-rays normally used in medical therapy and industrial radiography. As an x-ray source, the new linear accelerator will produce several hundred roentgens of radiation at one meter while operating at 6 to 7 million volts. Electron beam power is approximately one kilowatt in the range from 4 to 6 million volts.

Compactness is a most important feature of the new accelerator, allowing it to be flexibly mounted at considerable distance from its radar frequency power supply and controls, and to be operated in a relatively small treatment room. This compactness and the flexibility it makes possible, together with the very high energy of the x-rays it produces, make the linear accelerator a valuable new tool, both for industry and for the battle against deep-seated cancer.

Van de Graaff Components for Britain

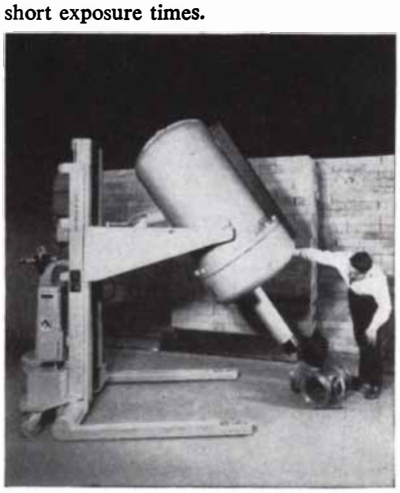
HIGH VOLTAGE has recently contracted to supply all the vital components of a huge 6-million-volt Van de Graaff accelerator soon to be located at the Imperial College, Kensington, England. The heavy metal components, including the pressure tank, will be purchased in Britain and the machine assembled there. It will be used in a program of fundamental nuclear research conducted by Prof. Samuel Devons. The 6-MeV machine will be similar to those built by HIGH VOLTAGE for Oak Ridge National Laboratory, Rice Institute and to another now under construction for Columbia University.

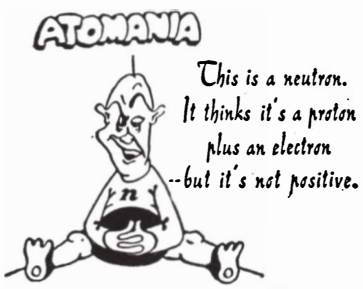
Cancer Therapy Unit to Cleveland

A two-million-volt Van de Graaff for cancer therapy will be delivered this month to University Hospitals, Cleveland, Ohio, where it will mark the first step in the expansion of the radiology department to two or three times its present size. Dr. Hymer L. Friedell, director of Radiology, will use the machine for rotational therapy, in which the patient is placed in a rotating chair and the powerful x-ray beam precisely focused on the axis of the tumor. In this way, the tumor is continuously subjected to radiation, while dosage to the skin and surrounding tissue is minimized.

Radiographic Machine Gets New Mount

The unique one-million-volt Van de Graaff x-ray generator for industrial radiography recently introduced by HIGH VOLTAGE has now been fitted with a new mount which accentuates this supervoltage machine's portability. The Lewis-Shepard Company of Watertown, Mass., has designed and built a new version of its Jack-Stacker especially for use as a carriage for this compact x-ray source. With the new mount, the machine can be moved to any part of a plant, used at any angle from horizontal to vertical, and made operative simply by plugging in a power cable. This radiographic unit is the smallest (its tank is only six feet long and 36 inches in diameter), the lightest (it weighs only 2,500 pounds) and the lowest-priced one-million-volt x-ray generator made. Its ¾ millimeter focal spot makes possible radiographs of remarkable clarity through metal sections up to five inches thick with short exposure times.





History of a Dig

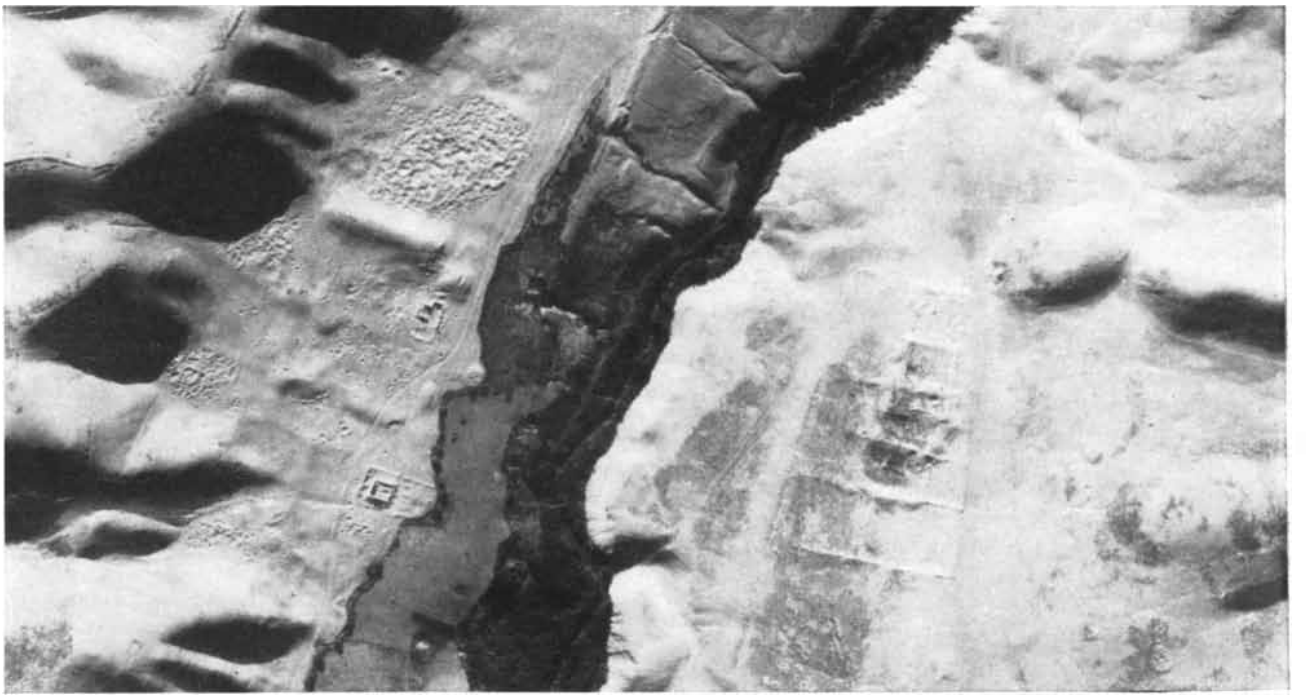
How does an archaeologist decide where to excavate, and exactly how does his work proceed? These questions are answered in terms of the digging at a single site: Cerro Culebra on the coast of Peru

by Louis M. Stumer

Each year parties of archaeologists stick their spades into a few dozen sites in more or less deserted corners of the earth to dig for man's buried past. When their needle-in-a-haystack search is rewarded with some dramatic new find—the treasures of a vanished civilization, the tools of early men long obliterated by geological time—we are apt to think of the discovery as a stroke of luck. Any dig of course is a gamble, but discoveries come often enough to keep archaeologists interested in their profession. A modern archaeological expedition is not undertaken lightly: it takes money, equipment and a great many man-hours. How do archaeologists select a site and carry out their exploration?

This article will try to answer the question by giving an account of excavations made at a site in Peru in 1952 and 1953. Like most archaeological field work, these excavations yielded some unexpected finds, some disappointments and some leads for further digging.

Readers of SCIENTIFIC AMERICAN should be well acquainted with the history of Peru, for excavations there have been reported in several articles in this magazine [see especially "The History of a Peruvian Valley," by James A. Ford, August, 1954, and "The Lost Cities of Peru," by Richard P. Schaedel, August, 1951]. Archaeological work in Peru has been guided primarily by the peculiar geography of the country—a country divided into many separate communities by the great ranges of the Andes and by deserts. The long coastal desert of Peru, below the towering Andes, is cut into many valleys by rivers flowing across the strip from the mountains to the Pacific Ocean. In the prehistory of Peru small settlements in these valleys grew into valley states; the valley states were united by conquest into kingdoms, and the kingdoms eventually combined in the great Inca Empire, which was ended by the Spanish Conquest in 1532. It is in the coastal valleys that archaeologists



AERIAL PHOTOGRAPH was one of many studied to find a pre-Tiahuanaco site. The photograph shows Cerro Culebra, the site discussed in this article. The trapezoidal structure at right center is the temple enclosure. The small pits at left are looted graves.

have done most of their digging for information on the early history of Peru.

Our expedition wished to investigate the culture of the Peruvian Central Coast in the period just before the valleys were overrun by a mountain people (associated with a site known as Tiahuanaco) from the Andes. The period in which we were interested is estimated to date roughly from the time of Christ to A.D. 500.

Finding a site of this era was not easy, because its settlements were few and scattered. Fortunately the Peruvian Air Force had a complete set of aerial photographs of our region and generously made them available to us. The value of aerial photos to archaeologists cannot be overemphasized. Not only do they make possible a quick survey of sites that are most difficult to reach on foot, but often it is much easier to identify sand-covered ruins from the air than on the ground.

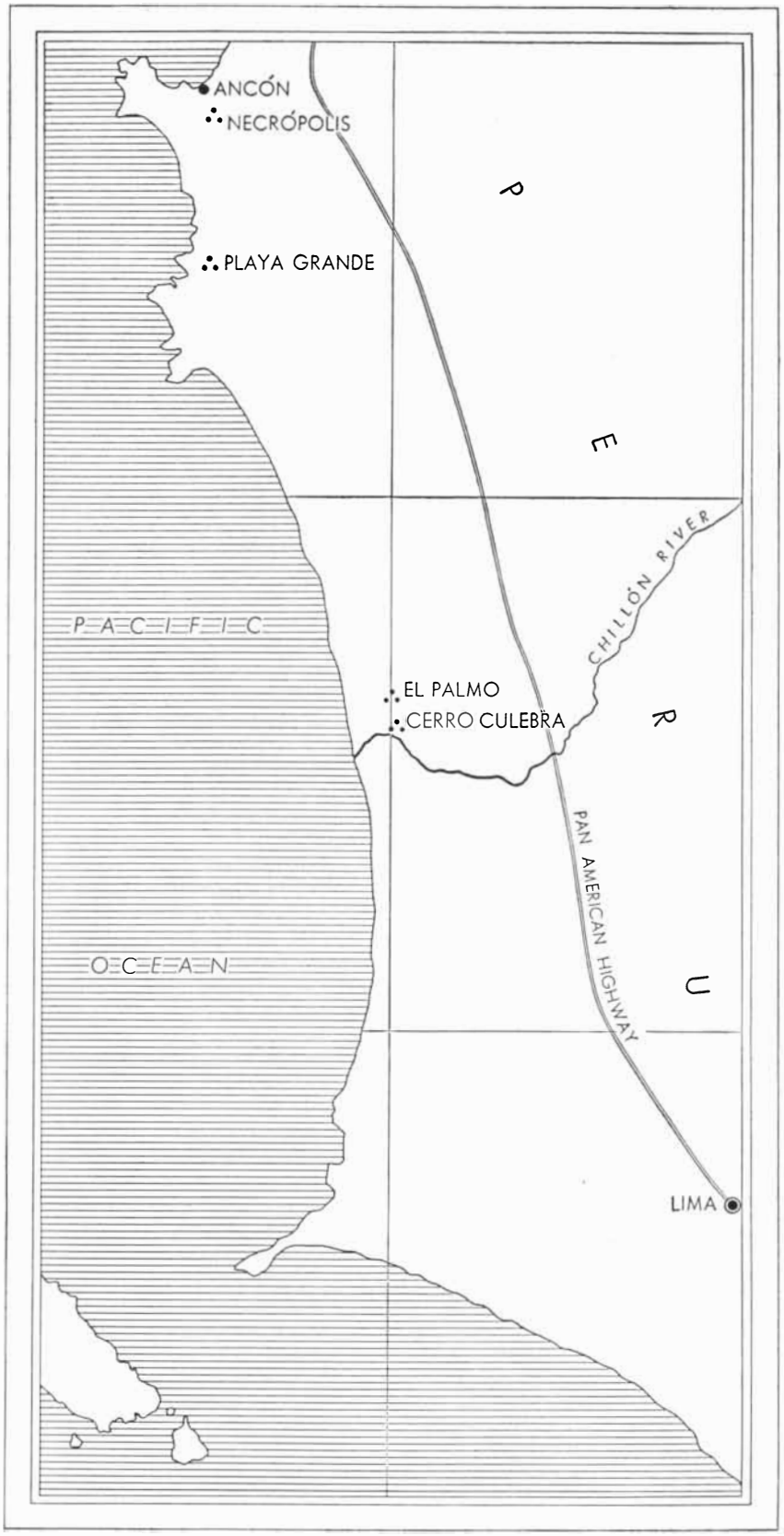
We surveyed the photographs and studied carefully enlargements of those that contained ruins. The settlements of each epoch in Peru had a characteristic pattern or ground plan; thus from inspection of the photographs we were able to narrow our search to the sites most likely to be of the period we wished to study. We then visited and made a thorough examination of each of these sites, including an analysis of pottery fragments found on the surface. After three months of reconnaissance we finally chose a site known as Cerro Culebra (meaning the hill of the serpent) at the mouth of the Chillon River some 10 miles northwest of Lima. Cerro Culebra showed a high concentration of excellent pottery fragments of the pre-Tiahuanaco periods; it was uncomplicated by later reoccupations; it had suffered little from the attentions of grave robbers; there was an imposing ceremonial pyramid as well as an extensive living area, and there was good evidence of fairly large and undisturbed cemeteries.

During the reconnaissance we had been acquiring the tools and equipment we needed for the dig. It is no longer necessary to import a great deal of archaeological equipment to Peru, as practically everything needed can be purchased locally at prices which compare favorably with those in the U. S. We also arranged for storage and laboratory space at the Museo de la Cultura Peruana with its cooperative director, Luis E. Valcarcel, one of Peru's outstanding archaeologists. When we had chosen the site for digging, we applied to the Peruvian Government for an excavation

LARGE DWELLING of the Playa Grande culture is excavated at Cerro Culebra. The post at upper right is one of those that supported a loggia. The wall at top is made of poured adobe.

CHILD'S GRAVE is opened at Cerro Culebra. At the left is a large pottery vessel. At the right is a wooden plaque on which the photograph is identified for later research purposes.

ADULT BURIAL at Cerro Culebra is completely excavated. Although the body is remarkably well preserved, it is not mummified. Its preservation is due to the dryness of the soil.



SITES mentioned in this article are located on a map showing a small part of Peru. Cerro Culebra is near the mouth of the Chillón River about 10 miles northwest of Lima. The expedition to Cerro Culebra also excavated El Palmo. Playa Grande lent its name to one of the cultures at Cerro Culebra. Ancón Necrópolis was a famous site excavated earlier.

permit. It was readily forthcoming, for Peru's Director of Archaeology, Jorge C. Muelle, is an enthusiastic archaeologist, with a lively desire for the furtherance of scientific field research and the solution of the many problems of the pre-Conquest civilizations. We were fortunate enough to obtain the services of two of Peru's most experienced archaeological workmen to take charge of the digging; they were available at once because the government had just suspended its long excavations at the famous site of Ancón Necrópolis. Skilled and knowledgeable labor is of the highest importance in any archaeological excavation; it is remarkable how much more scientific work can be accomplished when the expedition does not have to supervise closely the removal of every shovel load or worry about the breakage and fiascoes that almost invariably bedevil a dig begun with inexperienced workmen.

The most important work is the excavation of the ancient refuse heaps, called middens, on which archaeologists rely for establishing the sequence of cultures at a site—that is, the history and cultural development of the peoples who inhabited it. In Peru the chief index of relative chronology is pottery style. A midden is carefully peeled layer by layer (usually 10 or 20 inches at a time), and the pottery fragments and other human remains at each level are screened and analyzed. Great care must be taken to make sure that the refuse heap used for dating has not been disturbed, because the ancient Peruvians had a tendency to use midden material as fill for building house foundations and their temple pyramids, thus providing a reverse stratigraphy for the unwary!

At Cerro Culebra we began by exploring, with our two workmen, a small cemetery adjoining the ruins of the ancient settlement's houses. We excavated eight graves, of which the first five turned out to be those of children. In them were found some excellent ceramics, some extraordinarily well preserved basketware dolls and two urn burials. The culture proved to be the one named Playa Grande, after another site nearby. It is identified by an interlocking fish or serpent motif which appears on most of the pottery and textiles. Remains of the Playa Grande culture have been found at various points over a 50-mile stretch along the Central Coast of Peru. It appears to have been primarily a fishing and agricultural civilization, but also to have attained a high degree of artistic

elegance for its comparatively early time.

After this first small grave plot was exhausted, we moved on to a large mound some 500 yards from the center of the settlement. Here we encountered the first of the surprises that were in store for us. I had expected this mound to be a large midden, because there was quite a bit of organic refuse on it. But the first half day's digging showed it was not a midden at all; the mound covered the remains of the most imposing dwelling of the period ever found.

We spent six weeks excavating this ancient house—an elaborate affair of painted clay cornices, patios, outdoor loggias and inside and outside hearths. Near the inside hearth were several circular storage pits abundantly stocked with fish, corn, peanuts, yucca and lima beans. There was also a stone pen for keeping guinea pigs—still a staple of the Indian diet in the Andes. The construction of the house was rather complex. The outer walls were made of poured adobe, the partitions of handmade adobe bricks and the roof and loggia were supported by a frame of large willow logs. The roof itself was constructed of heavy cane crossbeams, over which were laid several layers of lighter canes lashed together. In the almost rainless climate of coastal Peru this type of roof provided all the shelter needed, and the space between the adobe walls and the roof-supporting willow logs provided air circulation during the hot summer months. All in all, the house was very well planned and must have been most comfortable for its time.

Further digging disclosed that the main patio contained 23 graves, and that the house overlay another of an earlier phase of the same culture, also with its own family burial plot. This rather conclusively confirmed a tentative theory we had formulated in previous excavations at Playa Grande: that burials of this period generally occurred in small family groups and that the practice of interment in general cemetery areas did not take hold until somewhat later. We encountered a strange sight, however, in the upper house: in three of its doorways lay the bodies of infants wrapped for burial. The meaning of this unsanitary ceremony remains obscure.

We excavated only a portion of the underlying house, as total excavation would have entailed destruction of the later dwelling above. What we uncovered showed that the earlier building had walls of small adobe bricks and guinea pig pens made of canes rather than stone. Below the lower house we found only sterile sand.

WALL PAINTINGS of the Cerro Culebra temple may be seen on the side of the trench in the foreground. The canes and adobe fragments at the right are remnants of the roof.

Our next excavation was the clearing of a cemetery plot adjoining a small cluster of simple dwellings. As might have been expected, the burials were simple—poverty-stricken might be a better word—but in sufficient number to provide a representative sample for analysis of the physical build of the people of this period. We were particularly pleased to find a high percentage of adults for measurement, because up to this excavation infant mortality among the burials had been running around 40 per cent!

At the conclusion of this rather dull phase of the excavations, we proceeded to the pyramid temple—the heart of the Cerro Culebra settlement. The temple has a trapezoidal central pyramid surrounded by a quadrangular wall, also in the form of a trapezoid, measuring 820 feet on its longest side. The pyramid itself is some 50 feet tall at its highest point. It was the largest Playa Grande structure yet encountered.

We began our digging in the central quadrangle on top of the pyramid. It quickly became apparent that here, as on the large house site, there were two distinct periods. The first builders had erected the mound and the walled quadrangle; its architectural style showed that it had been built during the period of the upper house I have described. Later a massive structure of poured adobe and a broad ceremonial stairway had been added on top of this. Pieces of pottery found at this upper level identified it with what is known as the Maranga culture, which followed the Playa Grande era and came just before the Tiahuanaco period. Thus this superposition gave us most of the culture sequence we were seeking—a fortunate circumstance, because the refuse heaps found at Cerro Culebra cover only the Playa Grande period and do not connect with other epochs.

However, the very superposition that

Pottery was used to date the excavations. These decorated vessels of the Playa Grande culture were taken from

aided us in our chronological problem hindered us in our study of the temple, for we could not explore the lower part thoroughly without demolishing the upper part, and the Peruvian Government frowns on the destruction of prehistoric architecture.

One day, in my annoyance with the architectural situation, I kicked at the sand in front of one of the walls of the original quadrangle, which projected only an inch or so above the windblown sand and rubble. The furrow where I had kicked the sand away exposed brilliant flashes of red, black and white on the wall! I quickly summoned the workmen, who were busy clearing the great staircase, and we eagerly dug along the top of the wall to a depth of some six inches. This shallow cut showed enough to make us certain that we had come upon the best preserved and most extensive series of wall paintings yet found on the central coast of Peru. The paintings apparently extended the entire length of the temple mound. The only feasible method of uncovering them without destroying the overlying construction was to sink a narrow trench along the whole length of the wall.

We engaged extra diggers at once and went anxiously to work. During the next weeks we uncovered six distinct panels of wall paintings, all but one of them in excellent shape. Some were painted in as many as nine colors. The panels occupied the middle 85 feet of the wall, and some were more than six and a half feet high. Beyond the ends of the panels the wall was painted a clear, brilliant yellow. It had originally been topped with a cane and clay roof, also brilliantly painted, but this and the top of the wall had been destroyed in the building of the upper structure. It was possible, however, to get a mental picture of how the complete section must have looked from the many roof fragments found on the floor of our trench, which was, incidentally, the clay floor of the original temple itself.

The colors were of vegetable origin and had been applied over a fine yellow clay coating with a technique surprisingly similar to that of true fresco. The panels represented deities or demons and were executed in a most effective geometric style. They had a prominent motif of serpents, similar in design to those found on ceramics and textiles of the Playa Grande period. Perhaps these paintings explain the name Cerro Culebra (hill of the serpent), because the only serpents we ever saw at this site were those on the frescoes.

Aside from the paintings' artistic and archaeological value, they suggested a completely new line of exploration. Several of the motifs, as well as the concept and execution of the serpents, are remarkably similar to those appearing on pottery and stone sculpture found in the Callejón de Huaylas, a basin in the Andes more than 200 miles northeast of the Cerro Culebra site. Somewhere on the long route between these points there must be traces of the travels of people from one place to the other. Hence a thorough survey of the territory between the upper part of the Callejón de Huaylas and the Chillon Valley is definitely in order and has high possibilities of being archaeologically productive. It is not being overoptimistic, I feel, to think that there may well be one or more sites in this area equal in importance to Cerro Culebra.

We cleared the entire painted portion of the south wall of the inner quadrangle, checked the north wall at several points, where we also determined both the earlier and final pyramid construction, penetrated to and through the temple floor in the inner and outer quadrangles, cleared a portion of the main stairway and temple approaches, and made cuts in several refuse heaps in the temple. This intense activity was made possible by the cooperation of Richard P. Schaedel, whose archaeological ability and knowledge of pre-Columbian architecture enabled me to concentrate on the wall paintings and location of refuse deposits with the serene knowledge that the architectural examinations were being carried on with a great deal more competence than I myself could muster.

After devoting some six weeks to this work we were reluctantly forced to move on, as time was growing short and our major task was the examination of grave contents and stratigraphy. We finished our field work with excavation of a number of burials at El Palmo cemetery near Cerro Culebra. Here surface reconnaissance had given rise to high hopes that we might be able to establish at least the beginnings of an uninterrupted culture sequence from the Maranga culture straight through the Tiahuanacoid periods and well into the epoch of kingdoms and confederations which immediately preceded the Inca Empire. Our hopes were dashed when actual digging demonstrated that El Palmo's earliest graves apparently went no farther back than the Tiahuanacoid. However, our work was not wasted, as sufficient cases of grave superposition were found to give us the first solid culture sequence for the Chillon Valley from the begin-

graves at Cerro Culebra

ning of the Tiahuanacoid to the Inca epoch. A goodly amount of information was also gleaned about the spread of local cultures. In addition, El Palmo graves yielded good examples of the pottery and other artifacts of the later periods of central coast prehistory.

At the conclusion of this phase of the work, the laborers were dismissed and we proceeded to our laboratory at the museum for analysis of our Cerro Culebra finds. We expect to get from this work a fairly conclusive typing of the Playa Grande pottery style, especially when we correlate it with the material obtained from the excavations at Playa Grande itself. As for the objects unearthed from the graves, they have already provided a great deal of insight into the social classes of the Playa Grande civilization, the trade between the Peruvian coast and the Amazon River region in early prehistoric times, and the metallurgy, bone work and textiles of the Playa Grande culture, which were more highly skilled than has been thought up to now.

During this period of evaluation in the lab at Lima we have also catalogued, cleaned and packed all the excavated material to preserve it from the high humidity of Lima's foggy winter months, have photographed all the significant items and have examined numerous mummies of children removed from the graves. During the actual dig daily field notes were made and many photographs taken. At the end of a dig there is usually a good deal of work putting all this field material in convenient form for detailed study, and the Cerro Culebra excavations were no exception to the rule. It should be pointed out that in practically

all archaeological field work there are many, many days which are extremely dull and unproductive and during which the taking of field notes and photographs proceeds in an orderly and sometimes almost drowsy way. At other times, however—when, for instance, an important tomb is being opened—everyone is so busy that order must perforce go by the board and it requires an able field assistant to catch and appreciate the significance of the many remarks that are made during the course of the action. We were fortunate in having the services of Patricia Fry in this capacity, and her enthusiasm and grasp of the work resulted in our records being in eminently satisfactory condition.

The last stage of a dig is the preparation and publication of the final report. This involves research into accounts of all prior work that might have a bearing upon the subject, description and classification of the data, consultation of specialists on such topics as textiles, plant remains, architecture and physical anthropology, and evaluation of the results.

At this stage the field work itself becomes a pleasurable memory, and the archaeologist, attempting to fit the dead remains together into a meaningful picture at his desk in an office or library, dreams longingly of days on the hot desert with the wind blowing sand in his face!

This, then, is the history of a dig, being in part the actual account of a series of excavations which only recently came to an end, and in part a foretaste of what the author is now going through and what is necessary before any archaeological work can have any real value. It requires many months of evaluation, research and writing.

On emerging from the field archaeologists are apt to swear that wild horses will never drag them back, and that all they want is to spend the rest of their days in the comfortable surroundings of a museum or campus. After some months of having their wish, a certain restiveness begins to be noticeable. Conversations begin to turn to field projects, usually in areas in which six months before they would not have been found dead! Plans for a new expedition crystallize, and soon the archaeologist is booking passage on an airline or steamship. As this article goes to the editor, the writer is on his way back to Peru. [Last month Dr. Stumer discovered, at a site 15 miles up the Chillon Valley from Cerro Culebra, the ruins of a larger settlement which seems to have been the capital city of the Playa Grande culture.—Ed.]

To physicists and engineers with broad analytical ability

An address by R. P. Buschmann, Department Manager of Company Studies, on "Planning for the Best Airplanes" is available to interested scientists. It shows the approach Operations Research takes to various problems. Address inquiries to Mr. Buschmann.

Operations Research experience is not necessary to join the department. A high degree of scientific ability and proven analytical traits are primary requirements. Those interested are invited to write E. W. Des Lauriers, Dept. O-12-3.

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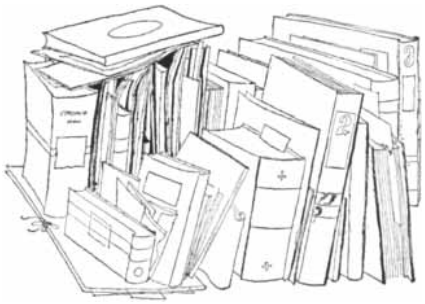

BOOKS

The role in mathematics of "plausible" reasoning, e. g., induction and analogy

by Morris Kline

MATHEMATICS AND PLAUSIBLE REASONING, by George Polya. Princeton University Press ($9.00).

Mathematics has been called the science that draws necessary conclusions, because its proofs are based on deductive reasoning. But before a mathematician formulates his final, thoroughly rigorous proof, many rehearsals take place, and in these it is not deductive reasoning but plausible reasoning that is practiced. Deductive reasoning becomes useful only when we know what to prove and how to prove it. Plausible reasoning is the logic of discovery. In his two-volume work on the subject Polya, emeritus professor of mathematics at Stanford University, does a masterful job of showing just how plausible reasoning is used in mathematics.

What are the basic methods of plausible reasoning? Briefly stated, they are induction, analogy, generalization and specialization. Let us, following Polya, examine these methods and their application to mathematics. In his first volume, entitled *Induction and Analogy in Mathematics*, he illustrates the methods with examples.

Induction, as is well known, is the process of inferring a general conclusion from a number of special cases which are observed to be true. How does induction proceed in mathematics? Suppose that a mathematician, observing that 2, 4, 6 and 8 are each the sum of two prime numbers, concludes inductively that *every* even number is a sum of two primes. He has arrived at a conjecture, a possible theorem. The mathematician could not prove his conjecture by continuing to examine even numbers, because one cannot test all of the infinite set of even numbers. But he has at least discovered what to prove.

Analogy, a second method of plausible reasoning, proceeds on the basis of similarity between two situations. If the similarity is close enough, one may conjecture that a conclusion which holds in one situation should hold in the other. For example, from theorems on polynomials (expressions containing more than one term) one might tentatively derive analogous theorems for a power series, which is a polynomial of an infinite number of terms.

Induction and analogy are the most conspicuous forms of plausible reasoning. But less conspicuous ones, such as generalization, are highly useful. In this process one passes from a given class of objects to a more inclusive, larger class. For example, theorems about triangles, which are polygons of three sides, often suggest theorems about polygons of any number of sides.

In the process of specialization, the fourth method, one passes from a given set of objects to a subset. For instance, to obtain a theorem about all triangles one might start by examining equilateral triangles.

Though for clarity the methods of plausible reasoning have been separately described, in practice they are not so sharply distinguishable. For example, the method of generalization certainly has much in common with induction. To pass from knowledge of second- and third-degree equations to the nth-degree equation is as much induction as generalization. Properties of the ellipse may hold for the hyperbola because they are both conic sections. Hence analogy is involved. But by a slight change in point of view one may argue that a property of the ellipse should by generalization hold for all the conic sections and therefore hold for the hyperbola in particular. What matters, however, is that the patterns exist and can be employed separately or collectively.

The simple instances of plausible reasoning given above do not do justice to the variety, depth and fascination of the examples chosen by Polya. They range from elementary algebra and plane geometry to advanced portions of analysis.

Besides the many examples of methods of plausible reasoning the first of Polya's two volumes deals with other valuable topics, including a chapter showing how natural phenomena suggest mathematical problems and methods of solution. Nature—father and mother to mathematics—rarely deceives its offspring, and then only to instruct it. The solutions that nature suggests are more than plausible.

In Volume II, entitled *Patterns of Plausible Inference*, Polya goes on to delineate the patterns of plausible reasoning in general terms. Suppose that we have some reason to believe in the truth of proposition A and that proposition A implies a second proposition, B. Now if we discover that B is true, A gains in credibility. If B, though true, happens to be a very improbable proposition, we have all the more reason for confidence in A, which implies it. Polya treats this pattern and others as types of inductive reasoning, but he fails to deal with the important, basic pattern of induction that involves inferring a proposition, A, from special cases. A person might examine even numbers for months and never notice the inductive conclusion that every even number is the sum of two primes. Apparently this kind of conjecture requires some process which is not covered by the recognized principles or patterns of reasoning. I shall return to this point presently in connection with mathematical creation.

After induction Polya considers in similar fashion the patterns of the other kinds of plausible inference—analogy, generalization and so on. Suppose that we wish to establish proposition A and we note that A is analogous to B and that B is true. A thereby becomes more credible. If B is merely credible, we gain some confidence in A but not as much as when B is true. Suppose, again, that a proposition, B, implies A, but B is found on testing to be false. Then A becomes less credible. Conversely, a proposition which is incompatible with B gains in credibility if B is found to be false. A more complicated pattern is: C implies both A and B. If B is found to be true,

C becomes more credible, and so does A, because C implies A.

One of the many fine features of Polya's presentation is that he utilizes nonmathematical examples to make the patterns clearer. Suppose that a person is accused of blowing up a yacht with dynamite. Let us call the assumption that he is guilty proposition A. We learn that the defendant possessed some dynamite; call this fact proposition B. Our knowledge that B is true does not prove A (the defendant's guilt). However, it certainly renders A more credible, since A implies B. In a law court this plausible inference often persuades the jury to convict. In mathematics A is never established until it is proved deductively.

Polya introduces in his second volume the mode of plausible reasoning based on mathematical probability. Basically the mathematical theory of probability enables us to infer likely conclusions about random mass phenomena. To take a simple example, the theory of probability asserts that if we throw a pair of true dice 600 times, say, we may expect a seven to appear about 100 times; it is far from certain, but it is likely.

The theory of probability is commonly used to test statistical hypotheses. Suppose we wish to test the hypothesis that boy and girl births are equally likely, and as the test we examine the records of 1,000 births at random. Say the records show that 525 were boys and 475 girls. We would apply the theory of probability to determine the likelihood that in 1,000 births a deviation of 25 from the expected number might occur by chance. If this probability is not too small—say no smaller than 1/50—the hypothesis of equal births is acceptable. If, however, the probability of a chance deviation of this size is only 1/1,000, we should reject the hypothesis. In other words, "the actual occurrence of an event to which a certain statistical hypothesis attributes a small probability is an argument against that hypothesis, and the smaller the probability, the stronger is the argument" against the hypothesis.

The theory of probability can be used to test the credibility of a physical theory. To use one of Polya's nontechnical examples, suppose that three out of four cuckoo clocks in a store window are observed to agree within two minutes of each other. Can one rely upon the time they show? The hypothesis we wish to test here is that all the clocks were set to the correct time and that three have kept nearly accurate time, while the fourth, being truly cuckoo, has wandered. We begin by considering the possibility that all four clocks were set going at random and three of them now happen to agree by chance; that is, running at different rates, they have caught up with one another at this moment. To test the possibility that chance alone accounts for the agreement of the three clocks, we adopt the hypothesis that all four clocks are equally likely to record a given time, and we calculate the probability that in a 720-minute period (12 hours) three out of four clocks would chance to agree within two minutes. This probability turns out to be so small that we prefer to believe our original theory, namely, that the clocks were set to the correct time and one is functioning inaccurately.

One might apply the same reasoning to check a bank balance. If the bank's statement agrees with my book balance, it does not follow indisputably that the balance is correct. However, the probability in this case is overwhelmingly in favor of the hypothesis (which we may call a physical theory) that the bank and I are accurate in our arithmetic. Assuming that the balance is a five-figure number (pennies included, since this is a professor's bank account), the probability that the two balances would agree purely by chance (allowing the possibility of any number from 00000 to 99999) is only 1/100,000.

Polya's discussion of the use of the theory of probability shows how conjectures, possible theorems, physical theories and statistical hypotheses can be either supported or discredited. The theory is therefore a method of plausible reasoning. However, it also serves another purpose in this book. Polya demonstrates that probability theory may be applied to give a rough indication of the degree of reliability of conclusions arrived at by other methods of plausible reasoning, though, as he points out, it is impossible ever to attain an exact numerical measure of the credibility of a proposition.

In mathematics plausible reasoning, as we noted at the outset, is only the prelude to deductive proof. How does a mathematician proceed from one to the other? On this crucial point Polya's discussion is forced and unsatisfying. He presents some obvious truths and suggestions, noting among other things that the inductive process itself sometimes suggests the deductive proof or at least gives insight into the problem. But he has little to say about how mathematicians discover a method of proof when it is not apparent.

This omission brings to focus the one weakness of Polya's book. His argument suggests that the two essential steps in mathematics—discovering what to prove and devising a method of deductive proof—depend entirely upon plausible reasoning. Polya says, in fact: "Anything new that we learn about the world involves plausible reasoning." But there is another indispensable element—the creative act of the human mind. Flashes of illumination or insight, spontaneous strokes of genius, ideas suddenly reemerging from the storage places of the unconscious—these often disclose the theorem or the method of proof. The greatest mathematicians recognized this phenomenon. Gauss and Helmholtz spoke of flashes of lightning. Poincaré stressed the role of the unconscious in mathematical invention. Additional testimony can be found in Jacques Hadamard's *The Psychology of Invention in the Mathematical Field.*

The creative act owes little to logic or reason. In their accounts of the circumstances under which big ideas occurred to them, mathematicians have often mentioned that the inspiration had no relation to the work they happened to be doing. Sometimes it came while they were traveling, shaving or thinking about other matters. The creative process cannot be summoned at will or even cajoled by sacrificial offering. Indeed, it seems to occur most readily when the mind is relaxed and the imagination roaming freely. In creation "rest is the condition of work." Almost everyone has had the happy experience of awaking with new ideas after sleeping on a problem.

In the early stages of work on a problem the methods of plausible reasoning may at least eliminate nonsense and direct the mind toward a reasonable conjecture or method of proof. Likewise, after the conjecture or possible plan of proof has occurred, plausible reasoning may do much to refine the conjecture or method or to redirect the mind. But in between there is mystery. It has been said that the shortest way between two real truths passes through the imaginary domain. Unless we admit that there are processes of discovery which do not adhere to a logic of discovery, we cannot account for failures on the part of competent professionals. Hundreds of great mathematicians failed in their attack on the problem of the parallel postulate before Gauss, Bolyai and Lobachevski succeeded. One cannot lay genius aside.

Polya may have omitted discussion of the role of the subconscious in creation simply because it is so elusive and indescribable. Certainly it cannot be reduced to a pattern. Perhaps, too, Polya believes that God will favor those who

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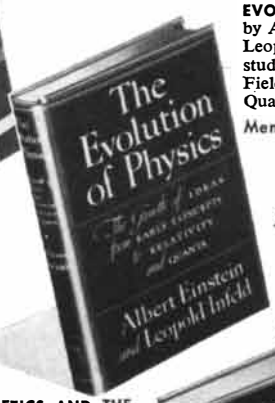

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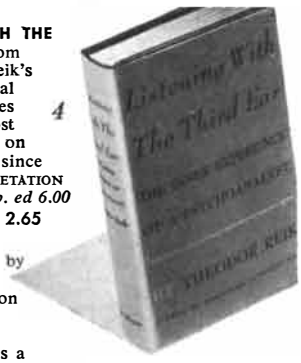

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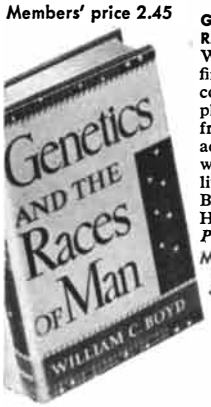

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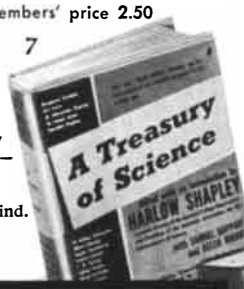

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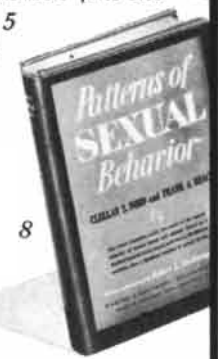

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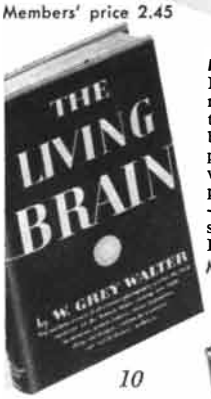

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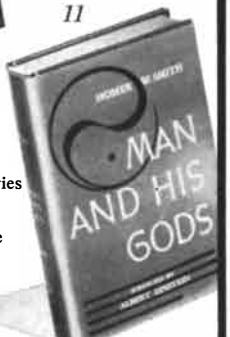

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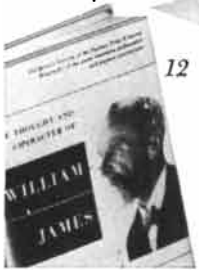

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help themselves by employing the patterns of plausible reasoning. Nonetheless, some mention of this creative element in mathematical discovery would have avoided giving the wrong impression about the process.

Polya's main thesis remains an extremely valuable contribution. The methods or patterns of plausible reasoning can be analyzed and are systematic guides to the discovery of new truths. He has shown by examples and quotations just how the great mathematicians used these methods. In doing so he has let nonmathematicians in on aspects of the creative process which are never mentioned in books or classrooms, where students are given only the pat final results. Polya wishes to aid students who would like to invade the seemingly impregnable domains of mathematics, to help them attain the delight of discovery and the thrill of creation. He would have teachers and textbook writers show the students how theorems and proofs are arrived at. As he points out, mathematicians are rarely satisfied with the mere presentation of a cold and rigorous proof; they insist upon seeing the heuristic and intuitive basis for the proof. Teachers have presented the formal science of mathematics; Polya would have them present the vitality and the art.

His book is addressed primarily to students desiring to develop their ability in mathematics and secondarily to teachers. But a lay reader will also learn much about the creation of mathematics and about plausible reasoning. The first volume presupposes some knowledge of mathematics, but the second is largely nontechnical. The material in both volumes is fresh and highly original; the presentation is stimulating, informal and occasionally humorous; examples from science, legal reasoning and daily life make the arguments clear even to a nonspecialist. Polya's book is a rare event among the hundreds of mechanical, unilluminating books on mathematics published every year.

Short Reviews

A STUDY OF HISTORY, Volumes VII to X, by Arnold J. Toynbee. Oxford University Press ($35.00). These four volumes complete Professor Toynbee's edifice, begun 33 years ago. In the first six volumes he presented a natural history of 21 different civilizations (nine others, by his count, either were hung up at the wire or failed to run a full course). He described how 20 of them began, flourished, aged and expired and how ours, the 21st, though not yet extinct, shows "authentic symptoms of breakdown and disintegration." In this final installment Toynbee examines in detail some of the institutions of modern society and ranges over many diverse topics. He also turns seer and religious prophet. He considers world government inevitable but doubts it will come in time to save our civilization. He regards its disintegration, however, as not an unmixed calamity, for out of the ashes will emerge at some future time a better kind of society, man making his "mysterious spiritual ascent on the wings of material catastrophe." Professional historians have not taken kindly to Toynbee's historical methods, much less to his visions, but the general reading public has evidently embraced both. *A Study of History* comprises 3,150,000 words, 6,290 pages and 19,000 footnotes. This incontinence has had no effect upon sales. Six thousand sets of the first six volumes have been sold in the U. S. alone. When completed, these sets (the publisher says) will make a stack, if piled one on another, six times the height of the Empire State Building. Some critics would regard this statistic as better proof than any adduced by Toynbee that our civilization is getting out of hand.

OUR AMERICAN WEATHER, by George H. T. Kimble. McGraw-Hill Book Company, Inc. ($4.75). The U. S. has lots of weather of all kinds every month of the year. On the Keweenaw Peninsula of upper Michigan 115 inches of snow fell in January, 1950; in the western Sierras 400 inches a year is common, and at Tamarack, Calif., there is at least one authenticated fall of 800 inches in a single season. The groundhog is a bust as far as weather prediction is concerned; you might better rely on the reports from your sinuses or rheumatic knee. March is the windiest month. There are plenty of frosts in April but not every frost is a killer. May has the most tornadoes. A druggist in Potter, Neb., made an affidavit in which deponent swore that on July 6, 1928, hailstones 17 inches in circumference fell in his town. Florida has the largest mean summer rainfall of any state, but it rains more on Mount Washington in New Hampshire. Death Valley holds the U. S. heat record (134 degrees), but in Tripoli it gets hotter, and Washington, D. C., has recorded 118 degrees—a fact which invites charity for politicians. In Fort Yukon, Alaska, the temperature in the shade has gone as high as 100, and the Russians avow they once measured the air temperature to be 88 on an ice floe crossing the North Pole. September,

though it has hurricanes, is a good time to vacation on Cape Cod. New Jersey is a terrible spot for hay fever. October is a forest-fire month; November abounds in fogs and smogs. A professor at Tufts College measures temperature by counting the chirps per minute of a katydid, subtracting 40, dividing by 4 and adding 60. And if you wish to know the cause of wind and weather you can scarcely do better than read Caxton's translation of the *Image du Monde* by an unknown French author of the 13th century who said that "Wynde is none other Thyng but Ayer that is Meuyd [moved] so longe tyl his force be beten down with the stroke. Thus come ofte clowdes, raynes, thondres and lygthnings." Dr. Kimble's chatty almanac is full of such details, but it also has its share of solid information on what the weather is like when, where and why.

ASIA, EAST BY SOUTH, by J. E. Spencer. John Wiley & Sons, Inc. ($8.50). Professor Spencer, a geographer at the University of California, has had extensive experience in Far Eastern affairs, including eight years' service, beginning in 1932, with the Chinese Nationalist Government as an official in the Salt Administration. His knowledgeable and objective book deals with the cultural geography of India, Thailand, the East Indies, Malaya, the Philippines, China, Manchuria, Korea and Japan. It presents information on landscapes, climate, mineral resources, soils, plants and plant cultures, marine life and animals, the geography of health and disease, languages, religions, legal and social institutions. It is a most useful volume, with maps, charts, statistical tables and an excellent bibliography.

EPILEPSY AND THE FUNCTIONAL ANATOMY OF THE HUMAN BRAIN, by Wilder Penfield and Herbert Jasper. Little, Brown & Company ($16.00). In this splendid monograph two leaders in research on the brain—Penfield is a neurosurgeon and Jasper a neurophysiologist—have brought together knowledge from their respective specialties bearing on epilepsy. The authors advance fresh opinions on the mechanisms of cerebral seizures, on brain function and the seat of consciousness, on the medical management of epileptic patients. While devoting a good deal of their study to surgical attack on focal epilepsy, Penfield and Jasper express the hope "that the day will come when operation is no longer necessary, when the gray matter, being better understood, will be corrected by some form of specific medica-

tion." The book is a distinguished contribution to the understanding of an ancient and terrifying affliction.

CLIMATIC CHANGES, edited by Harlow Shapley. Harvard University Press ($6.00). The causes and effects of weather change are here discussed in a symposium. The unusually interesting and varied articles cover climate and race, climate and civilization, the causes of the ice ages, solar variation as an explanation of climate change, polar motion and changes in the earth's orbit, climatic changes and radioisotope dating, tree-ring evidence for climatic changes, atmospheric circulation patterns, cyclical aspects of climate. The book makes it evident that climatology is a lively, growing science whose problems appeal to imaginative investigators.

MARKETING: THE 1954 YEARBOOK OF AGRICULTURE. U. S. Government Printing Office ($1.75). The 1954 edition is a pretty dull affair compared with some of its predecessors, but it has its uses. It discusses how farmers sell their produce, how food is transported, stored, processed and graded. Among other things it covers farm cooperatives, pricing formulas and price supports, waste and spoilage, the efficient use of farm labor. Maps, charts and a marketing atlas.

EXPLORING OUR NATIONAL PARKS AND MONUMENTS, by Devereux Butcher. Houghton Mifflin Company ($4.00). This is the fourth edition of a helpful guidebook to 26 major national parks and to other places of natural and archaeological interest. The book contains maps, many halftone illustrations and 16 fuzzy color plates which look as if they had been printed by an absent-minded amateur in his basement.

THE DISTRIBUTION AND ABUNDANCE OF ANIMALS, by H. G. Andrewartha and L. C. Birch. The University of Chicago Press ($15.00). This exhaustive 800-page monograph deals with animals' survival and increase. Among the topics considered are the innate capacity for increase in numbers, the genetic aspects of ecology, the factors causing animals to disperse and the effects of weather, other organisms and various kinds of food on habitat and population size. A most impressive book, presenting a new theory for specialists in biology.

THE ODYSSEY OF AN ANIMAL COLLECTOR, by Cecil S. Webb. Longmans, Green and Co. ($6.50). This agreeable

volume presents the relaxed memoirs of an easygoing naturalist who spent more than 40 years collecting for museums shrikes, anteaters, chimpanzees, elephants, bare-throated francolins, frogs, hornbills, platypuses, hoatzins, hippos, wood nymphs, lesser kudus, ringtailed opossums, sloths, wallabies and other wild creatures. Webb enjoyed every moment of every field trip, no matter how discomforting or how dangerous. He is now superintendent of the Dublin Zoo and is probably as happy as a koala bear in a eucalyptus tree.

THE PSYCHOANALYTIC STUDY OF THE CHILD, Vol. IX, edited by Ruth S. Eissler and others. International Universities Press, Inc. ($7.50). The latest volume of this annual includes articles by Anna Freud on psychoanalysis and education, Edith Buxbaum on technique of child therapy and Emma N. Plank and Robert Plank on "emotional components in arithmetical learning." It also contains the record of a conference on problems of infantile neurosis.

HAMMOND'S AMBASSADOR WORLD ATLAS. C. S. Hammond & Company ($12.50). This is a reasonably priced general reference atlas containing 326 maps, of which 241 are in color, and a full-color wall map, three by four feet, which is inserted in a pocket. Special features include maps of congested and important areas; distribution maps of continents, showing vegetation, temperature, rainfall, population and the like; resource maps; transportation route charts; a useful gazetteer, and tables of social and economic data.

THE GEOMETRY OF MENTAL MEASUREMENT, by Sir Godfrey H. Thomson. The University of London Press Ltd. (Six shillings and sixpence). The primary purpose of this book, based on lectures to psychology students, is "to describe a geometrical model from which can be deduced most of the formulas used in the factorial analysis of human ability." An interesting, intuitive approach to psychometric problems.

RUSSIA'S SOVIET ECONOMY, by Harry Schwartz. Prentice-Hall, Inc. ($9.00). This is the second edition of a study of the Soviet economy by the New York *Times* specialist on Soviet affairs. It adds material dealing with developments from mid-1950 to mid-1954, as well as other data pertaining to earlier periods, not available when the first edition was written. The author obviously follows the field very carefully, but there

are great gaps in his book; for example, it has disappointingly little on Russian mineral resources and only a skimpy treatment of atomic energy, much of it based on U. S. popular magazines as authorities.

A HISTORY OF MEDICINE, by Ralph H. Major. Charles C. Thomas ($14.50). This abundantly illustrated survey in two volumes by the professor of medicine and of the history of medicine at the University of Kansas is "written primarily for the medical student and the medical practitioner." Dr. Major gives a straightforward account of the main developments of medical thought and practice and biographical details about the leading physicians of all ages. He advances no novel interpretations but rather follows along the lines of the leading authorities. Despite its modest disclaimer, this is a book a specialist can read with profit and a general reader will find immensely instructive.

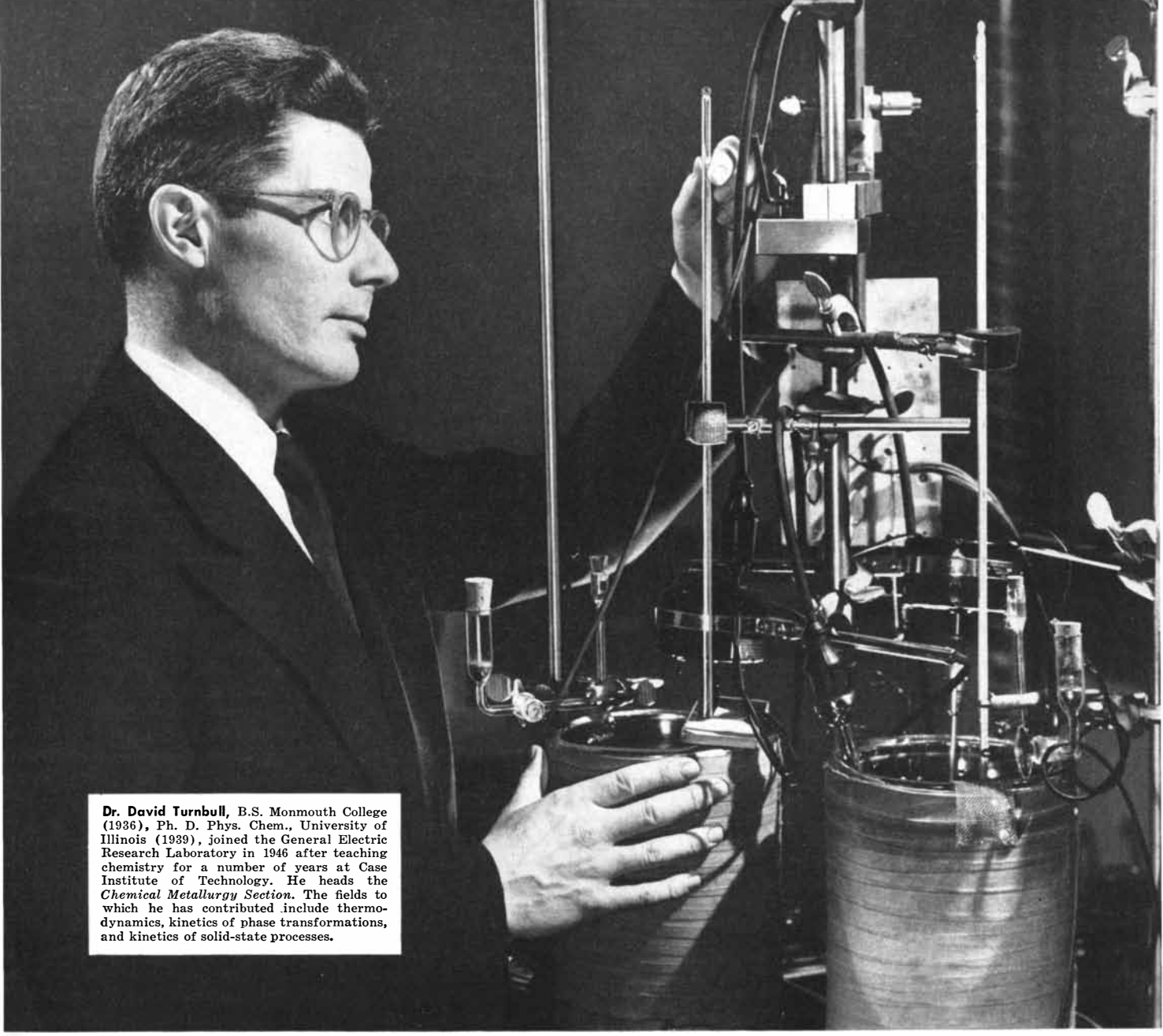
STUTTERING, by Dominick A. Barbara. The Julian Press, Inc. ($5.00). Dr. Barbara, aided by his past experience as a stutterer and his psychiatric experience in working with stutterers, has drawn together and critically examined the information on the subject. He believes that stuttering derives from a deep unconscious conflict and represents an attempt to unify the warring aspects of an individual. He holds that treatment of the difficulty must include not only speech therapy and suggestion but also investigation of the whole personality. This is a valuable book for psychiatric workers, teachers, speech therapists and the 1 per cent of the U. S. population who have the misfortune to be stutterers.

Notes

THE MACMILLAN WORLD GAZETTEER AND GEOGRAPHICAL DICTIONARY, edited by T. C. Collocott and J. O. Thorne. The Macmillan Company ($6.95). A sound, handy, desk-size reference book.

NUCLEAR GEOLOGY, edited by Henry Faul. John Wiley & Sons, Inc. ($7.00). Some 26 scientists contribute to a symposium on topics ranging from detection of radioactivity to the origin of the earth. For graduate students and professional geologists.

TELEVISION, by V. K. Zworykin and G. A. Morton. John Wiley and Sons, Inc. ($17.50). In this massive, authoritative handbook the authors explain everything about television except the programs.



Dr. David Turnbull, B.S. Monmouth College (1936), Ph. D. Phys. Chem., University of Illinois (1939), joined the General Electric Research Laboratory in 1946 after teaching chemistry for a number of years at Case Institute of Technology. He heads the *Chemical Metallurgy Section.* The fields to which he has contributed include thermodynamics, kinetics of phase transformations, and kinetics of solid-state processes.

How atoms behave in alloys

Dr. David Turnbull of the General Electric Research Laboratory demonstrates importance of crystal defects in structure changes

New understanding of the mechanisms responsible for the formation of alloy structures has been achieved by Dr. David Turnbull and his colleagues in General Electric's *Chemical Metallurgy Section.*

They discovered that crystal imperfections and foreign particles play a decisive role in controlling structure development. For example, precipitation in age-hardening alloys often takes place millions of times faster than can be explained by known rates of diffusion in single crystals. Dr. Turnbull showed that this rapid precipitation is due to the "short circuiting" of diffusion by certain crystal defects.

Because microstructure determines some of the most important qualities of alloys, including strength and certain magnetic properties, this new knowledge will be valuable in the development of stronger, more versatile materials for tomorrow's technology.

Progress Is Our Most Important Product

GENERAL ELECTRIC

THE AMATEUR SCIENTIST

About little computers that solve puzzles and an experiment on the "gyroscopic eye"

Conducted by Albert G. Ingalls

Some of our acquaintances have been having a great deal of fun with a new solution for the old problem of entertaining tongue-tied guests. They call their invention "pircuits," short for puzzle circuits—electrical switching systems which play a game or help solve a puzzle. "Just hand your silent friends a pircuit," say the enthusiasts, "and they will retire in delight to a corner for the rest of the evening."

A growing band of amateurs is becoming interested in making these puzzle circuits. The devices are greatly simplified digital computers, made with a few relays, signal lamps and other simple elements. The necessary batteries, wiring and so on are enclosed in a small box, and on it is an array of switches, push buttons and lights with which you play a game or solve a given puzzle.

A pircuit differs from the more elaborate computer chiefly in the way information is fed into the machine and processed. Instead of getting its information from a perforated tape and carrying out the subsequent computations automatically, the pircuit has the information built in, and the player directs its operations by manipulating keys or buttons.

Designing and building these entertaining gadgets combines the age-old fascination of puzzle solving with that of performing electrical experiments. Those who have taken to the new hobby are quick to point out, however, that its satisfactions go beyond the mere production of ingenious playthings. You gain an insight into the nature of games and puzzles which acts as a powerful stimulus to the imagination. The theory of equations, probability, topology, the infinitesimal calculus—all these, as Edward Kasner and James R. Newman pointed out in their book *Mathematics and the Imagination*, have grown out of problems first expressed in puzzle form.

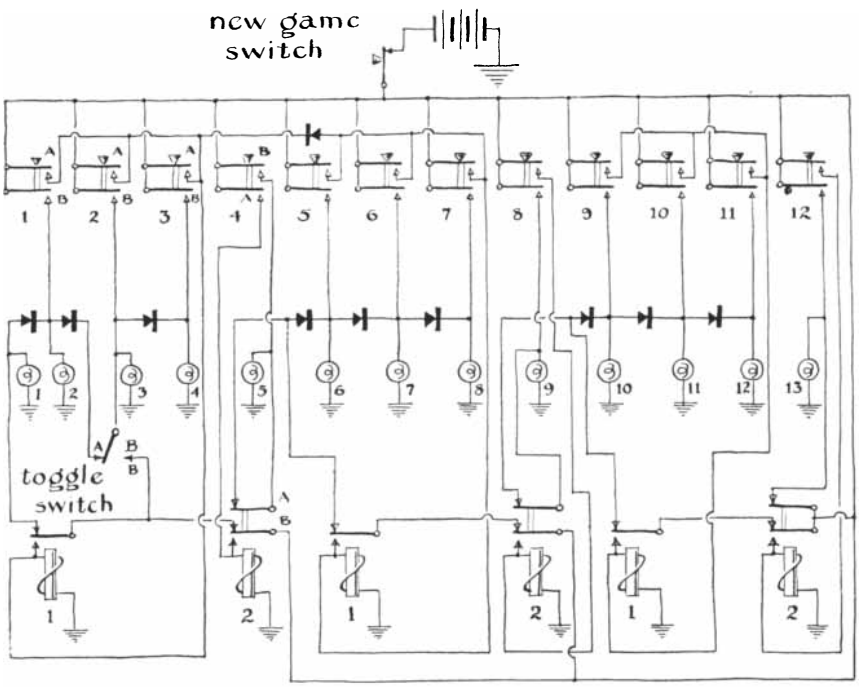
Pircuit making does not require an extensive background in mathematics, although a knowledge of the elementary principles of symbolic logic comes in handy. Essentially puzzle solving involves discovering a logical relationship among terms which has been buried beneath an ingenious pattern of rhetorical statements. The solution can be made easier by restating the puzzle in simple language. When this is done, certain key words generally stand out. These include: "and," "or," "yes," "no," "either but not both," "but not" and others [see "Symbolic Logic," by John E. Pfeiffer; SCIENTIFIC AMERICAN, December, 1950]. Such words can be represented by patterns of electrical keys, relays, diodes and related parts common to switching systems. The first steps in designing a pircuit, therefore, consist in restating the puzzle in simple terms, arranging the elements in logical sequence and substituting electrical counterparts for the key words.

An avid pircuit-maker is Harry Rudloe, a 16-year-old high-school boy of Brooklyn, N. Y. He writes:

"The first project I attempted was the design of a circuit to represent the 'battle of numbers' game. As this game is usually played, opponents take turns picking up matches from a pile of 13. A player may pick up one, two or three matches at a time, and the one forced to pick up the last match loses.

"In my machine a row of 13 signal lamps is substituted for the matches [*see illustration at left*]. Push-button keys control the lamps. At the beginning of a game all 13 lamps are lighted. The machine's opponent opens the game by flipping a toggle switch which gives either himself or the machine the first move. The player makes his move by depressing the key which turns off the number of lights he chooses, that is, the one he presses and all those to the left. When he releases the key, the machine registers its move.

"An analysis of the game discloses that a win can be forced by the player who



A circuit for the "battle of numbers" game

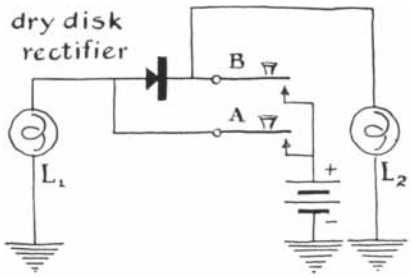
moves second. Consider the first 12 lamps (left to right) as consisting of three groups of four lamps each. If, after the first player has put out one, two or three lamps, the second player puts out the remainder in each group, he cannot fail to win, because only the 13th lamp will remain lighted after all lamps in the three groups have been extinguished in this sequence. Thus, if the machine is designed with built-in instructions to follow this strategy, it will always win when the opponent elects the first move. It will also win even when it is required to make the first move if the opponent fails to figure out the winning strategy and carry it out without a mistake; if any lamps in a group remain lighted after the opponent has made his move, the machine will invariably seize the advantage. The opponent can win only by electing to make the second move and playing a perfect game.

"Each group of four lamps is controlled by a circuit identical with the others. The diagram here denotes by the letters A and B some of the possible opening moves. Consider first a game in which the machine wins. The toggle switch has been thrown to position A, indicating that the machine's opponent moves first. He can put out one, two or three lamps by operating the first, second or third key, respectively. Contact spring A on the operated key transmits an impulse to relay 1 (associated with group 1). The relay locks down, because its winding receives power through the lower contact from its spring (connected to the battery through the upper contact and spring of relay 2 of group 1). This cuts off power to some of the lamps in the first group of four. The lamp associated with the key and those to its left will go out—but not those to the right of the key. Observe that 'but-not' elements (diodes) are inserted between each pair of lamps in each group. Contact B of the key now transmits power to the lamps at the right of the key but not to those at its left. This completes the opponent's play. He now releases the key—which initiates the machine's play. Contact B opens, cutting off power from the alternate 'but-not' circuit to all remaining lamps of the group. This registers the machine's move.

"Now consider a game in which the machine has the losing side. The toggle switch is operated to position B. This cuts off power to the first two lamps and constitutes the machine's first move. The opponent gains the advantage by depressing key 4 and thus extinguishing the remaining lamps in this group. The contact spring A on this key transmits an impulse to the winding of relay 2 in group 1, and the relay locks down through its bottom contact (by means of power supplied through spring B). Spring B of relay 2 acts as an 'either-or' element, supplying power either to the first group of four lamps or to its lock-down contact. This prevents power from entering the first group of lamps for the remainder of the game. Spring A on relay 2 cuts out the first lamp in the second group of four. Contact B on key 4 continues to supply this lamp with power, however, until the key is released. The machine could be designed so that this play would put out either the first, second or third lamps of group 2. It could not, however, capture the advantage by any of these plays. Hence in the interest of keeping the circuit as simple as possible I confined the machine's choice of play to the first lamp. This tactic also gives the opponent the maximum choice of plays—and the maximum opportunity for making an error! The opponent can now preserve his advantage by operating key 8. This extinguishes the remaining lamps in the second group. The machine will reply by putting out lamp 9. The opponent then operates key 12, putting out the remaining lamps in the final group and forcing the machine to lose by putting out lamp 13. None of my friends has yet discovered the simple winning strategy of this game, although a few have won by accident.

"My second machine was designed around a simple ancient puzzle of the permutational variety. This puzzle generally takes the form of confronting a person with the problem of ferrying himself and his possessions across a river under frustrating circumstances. Its original author is supposed to have been the 8th-century scholar Alcuin, a friend of Charlemagne.

"Take the case of the farmer who wants to ferry a wolf, a goat and a head of cabbage across a river in a small boat which can hold only himself and one of his possessions. For obvious reasons, he must never leave the wolf and the goat alone, or the goat and the cabbage alone. The problem involves three key words: 'either,' 'and' and 'or.' We can symbolize the conditions of the puzzle by a circuit with four toggle switches [*see diagram at top of the next page*]. Analysis of the puzzle shows that a trouble situation occurs when the farmer is on the opposite side from the goat and either the wolf or the cabbage is on the same side as the goat. The function of the machine is to signal trouble (by flashing a light) so that the player can switch it off and start again;



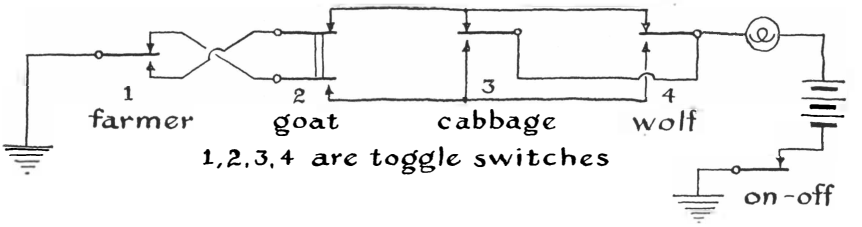
"And–but not" circuit

he wins if he gets all four items across the river without a 'trouble' signal.

"This pircuit is a nice project for the beginner, because it can be wired up in a single evening from materials that cost less than $5 if purchased new and as little as 75 cents on the war-surplus market. The circuitry for the puzzle was fully described and discussed in this department in the issue of May, 1953.

"In the 16th century Niccolò Tartaglia, the Italian mathematician and inventor, suggested a somewhat more elaborate version of the same puzzle. Three lovely brides and their jealous husbands must cross the proverbial river in the small boat, holding only two people. Each husband insists that the crossing must be so arranged that his wife is never in the company of another man unless he, the husband, also is present.

"A circuit representing this situation is developed by following the same elementary rules of symbolic logic as in the simpler farmer problem. Your friends will find the machine more interesting if you install signal lamps to indicate the location of each character as play progresses. A convenient circuit for accomplishing this employs a relay equipped with front and back contacts (an 'either-or' arrangement) and a pair of double-pole, single-throw keys. This 'transfer' circuit is identical for all characters in this as well as in other puzzles. The diagram at the bottom of the next page shows the circuit for one character. All the contact springs are assumed to be connected to the battery unless otherwise indicated. Operation of the 'cross' key closes the bottom contact of the relay and thus energizes the relay's coil. The armature accordingly locks down through the bottom contact of the 'return' key. In effect the arrangement constitutes a memory circuit and relieves the player of the need to keep account of his moves or reconstruct them by inspecting the position of the toggle switches (or relays, whichever are used for constructing the trouble circuit). Operation of the return key releases the



The puzzle of the farmer, the goat, the cabbage and the wolf

memory relay. The 'break' contacts of all keys are wired in series and supply power to the trouble circuit. When the player wishes to send a pair of characters across the river, he operates the key representing one character and, before releasing it, operates the other key. Power is thus prevented from entering the trouble circuit until the move is completed.

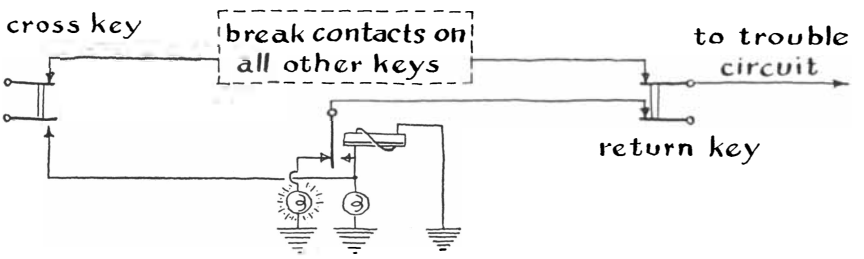
"As in the farmer problem, the trouble signal operates whenever any husband is on the opposite side of the river from his wife and she is in the presence of either or both of the other husbands. The trouble circuit is shown at the bottom of the opposite page. Although the diagram omits mechanical linkages, it is understood that all the switches associated with the same character, H_1, for example, operate in unison and in the same direction. They may be linked mechanically (toggle switches) or electromagnetically (relays). For simplicity relay coils have been omitted from the diagram of the trouble circuit.

"In a still more complex version of this puzzle, the husbands and wives become missionaries and cannibals—three of each. Same river, same two-passenger boat. All the missionaries can row. Only one cannibal can row. If the cannibals on either side of the river outnumber the missionaries at any time—into the stewpot go the missionaries!

"Outnumbering may occur in these combinations: three to two, three to one and two to one. The complete trouble circuit is shown at the top of page 120. Its action is easier to follow if you divide the circuit into three parts [*see page 121*] and examine them one at a time. The missionary configuration [*top*] will register trouble if proper cannibal circuits are closed when any two missionaries are opposite the third missionary. Circuit 1 [*middle*] conducts when any two or three cannibals are on one side of the river. It also shows which side they are on. Circuit 2 [*bottom*] similarly indicates when all three cannibals are on the same side of the river and which side they are on. In combination, the three configurations register all the possible trouble situations: (1) when all three cannibals are on the same side with just two, any two, missionaries, (2) when any two or three cannibals are on the same side with a lone missionary.

"After constructing a variety of games and puzzles with built-in 'intelligence,' I became interested in the problem of designing a machine with the ability to learn from experience and apply its acquired knowledge in avoiding future mistakes. Claude Shannon's famous 'mouse,' which investigates a maze and learns how to avoid blind passages by trial and error, fascinated me and I decided to have one of my own.

"His mouse is a simple bar magnet enclosed in a mouse-shaped covering and equipped with copper whiskers which 'ground' the mouse upon contacting the brass walls of the maze. It is moved by

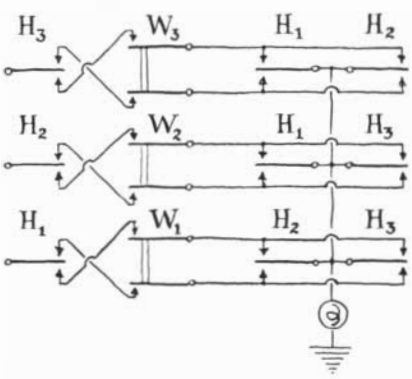


Part of the circuit for the puzzle of the three brides and their jealous husbands

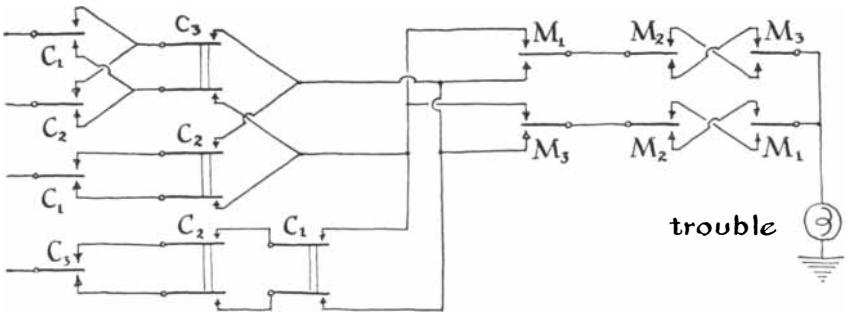
other magnets concealed beneath the maze. Its 'brain' is located outside the maze. I wanted a self-contained mouse—even if that meant building him the size of a jack rabbit.

"I could not find any published circuit information on Shannon's mouse, but after consulting a few books on switching systems I finally succeeded in designing and constructing a mouse which can learn any maze with the following properties: (1) the correct passage leads to a fork; (2) every fork leads into two passages, one of which is a dead end; (3) there are no more than three forks and dead-end passages. This last limitation was imposed by the size of my pocketbook, for the cost goes up with the complexity of the maze and the necessary increase in the mouse's memory capacity. Cost also prevented my mouse from being completely self-contained; its power supply and brain are located outside the maze.

"The mouse is powered by two motors, each driving a front wheel. Its rear is supported by two contact shoes which slide over a pair of electrically independent metal strips fastened to the floor of the maze. One strip serves as a ground return. The other strip supplies juice to one of the motors; the second motor gets its power by way of a trolley fastened to the ceiling of the maze. Information is transmitted from the brain to these motor 'muscles' through the conducting strips. Steering is accomplished by cutting off power to one or the other of the driving wheels, as in the case of tread-equipped tractors and bulldozers. Friction against the sides or walls of the maze is reduced by mounting rubber wheels on each side of the mouse. They also help the mouse negotiate dead-end passages. These dead ends terminate in circular or 'cheesebox' walls which force the mouse through a 270-degree turn. By pivoting an additional 90 degrees the mouse can leave the



Detail of the foregoing puzzle



The puzzle of the missionaries and the cannibals

dead-end passage and continue to the next fork without reversing its motors.

"If it is to profit from experience, the mouse must be fitted with some means of sensing its environment, of storing this information and of drawing upon it for subsequent use. As a minimum, the creature must be able to count the forks as it proceeds through the maze and remember where it went wrong in the sequence; for instance, if a right turn at fork 2 led to a dead end during the exploratory run, it must remember and go left at the same fork the next time.

"This information is sensed by means of three 'organs,' all composed of microswitches. The first group of microswitches is distributed along the ceiling of the maze—one at the entrance of each fork. This sequence of switches advises the brain whenever the mouse comes to a fork. The second set of switches, mounted on the walls, signals the mouse whenever it arrives at a dead end. The third group of switches, also wall-mounted at the entrance to each straightaway passage, informs the brain that power should be restored to both motors. All switches of each group are wired in parallel.

"The mouse's brain consists of three basic elements: 'neurons' for remembering (in the form of two relays for each fork), an associative device (a stepping switch) and an element enabling the mouse to choose a fork at random when it does not know which is correct. The heart of the latter element is a motor-driven rotary switch which is alternately conducting and nonconducting.

"When the mouse first enters the maze, both of its driving motors receive power through a master relay. The mouse accordingly proceeds to the first fork. Here an impulse from the fork sensor signals the brain. As a result: (1) the master relay cuts off power to the motors; (2) a secondary relay then supplies power to one or the other of the motors, depending upon the position of the rotary switch at the moment; (3) the stepping switch advances to the first set of contacts through which the memory relays are actuated. The mouse, powered by one motor, turns to the right or the left as the chance position of the rotary motor has selected. Now the straightaway sensors advise that a straight passage lies ahead, actuate the master relay and restore power to both motors. The mouse proceeds through the passage.

"If the mouse reaches a fork at the end of the passage, the cycle of operations repeats. The mouse has learned nothing. If the passage leads to a dead end, however, the memory relays come into action. The dead-end sensor transmits a pulse through the appropriate spring of the stepping switch and thus locks down either a 'right-turn' or 'left-turn' memory relay. With this information stored, the mouse negotiates the circular wall of the dead end and proceeds to the next fork. The mouse thus learns only from *hard* experience. Chance may lead it through the maze successfully on the very first run. In that case the mouse emerges from the experience as ignorant as though the run had not been made. On the other hand, chance may cause it to explore every dead end in the course of a single run. If it does, the mouse has learned all there is to know: it will never make a mistake again!

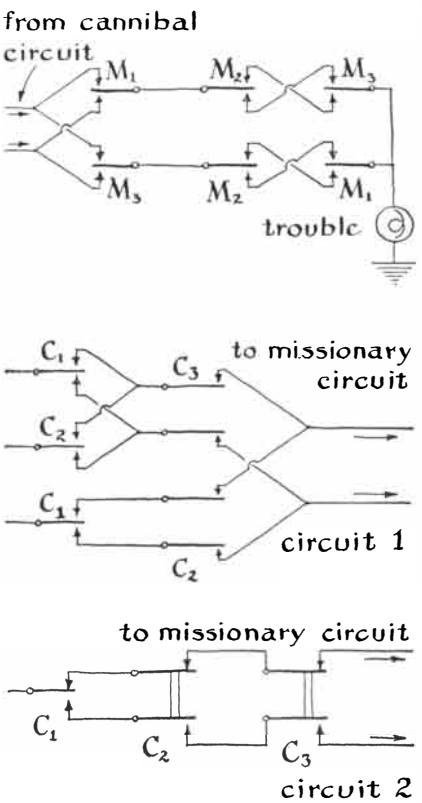
"The mouse's memory works this way: When it reaches the first fork on a second run, the fork sensor transmits an impulse which advances the stepping switch to the first set of contacts and trips the master relay, cutting power to both motors. If neither relay is locked down, the mouse chooses at random. But if one relay is locked, its break contact inactivates the random-choice circuit, and a set of 'make' contacts on the same relay feeds power to the motor that turns the mouse in the correct direction."

Rudloe's mouse can scarcely be called a "thinking" creature. Yet it demonstrates that with a few hand tools and junk parts an amateur can design and

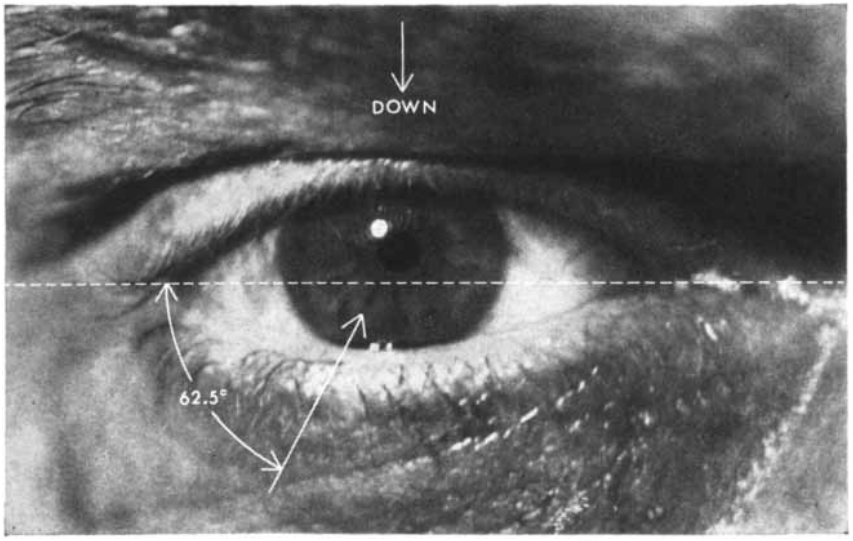
build a machine endowed with the ability to exercise free choice, learn from experience and apply its knowledge. The schematic diagram of Rudloe's mouse could not be fitted into the space of these columns, but a copy of it and a detailed analysis of its circuitry will be mailed to anyone who requests it and sends a stamped, self-addressed envelope.

Last November Henri Morgenroth, a consulting engineer of Santa Barbara, Calif., suggested an interesting research project to readers of this department which he thought might be within the capabilities of amateurs. The project was inspired by the article in this department of March, 1954, on the gyroscopic (self-leveling) eye of the copperhead snake. Morgenroth, who had confirmed this phenomenon not only in snakes but also in fish and turtles, wondered why these animals need "gyroscopic eyeballs" when other creatures do not, "or if others have them, which species do—and why?" What sort of evolutionary adaptation, Morgenroth wondered, had freed the higher-order vertebrates from the necessity of eyes with freedom of movement in three dimensions? He suggested that amateur zoologists make a start on the puzzle by observing eye movements.

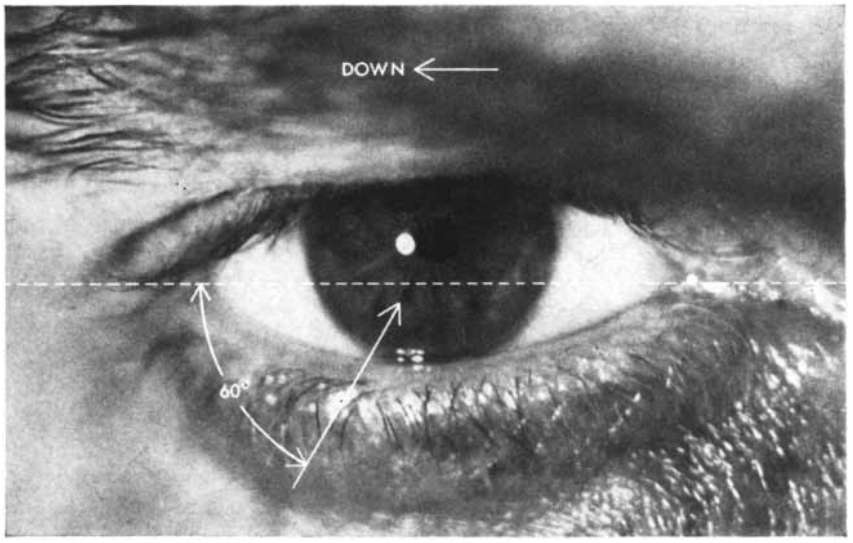
Much to Morgenroth's astonishment,



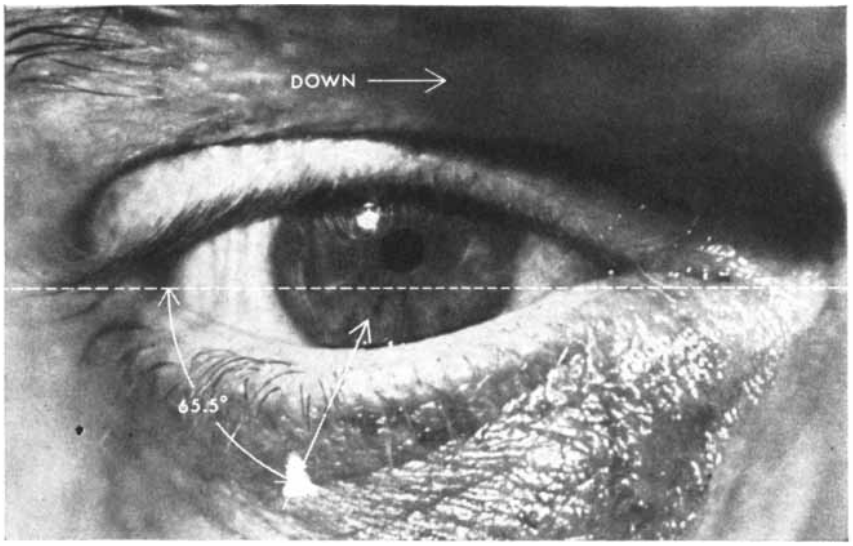
Details of the foregoing puzzle



The eye with the head in its normal upright position



The eye with the head rotated sideways 90 degrees



The eye with the head rotated 90 degrees in the other direction

letters immediately poured in from critical readers—some from prominent physiologists. All denied that the eyes of vertebrates could rotate only in two dimensions! "I hate to spoil the fun," wrote one, "but you have no problem to investigate. All vertebrates have 3F eyes." Wrote another: "This rotation can easily be observed by looking into a mirror. If one picks a portion of the iris pattern as a point of reference and tilts his head from side to side he will see his eye rotate about its visual axis a distance of 70 to 80 degrees." A third remarked: "It would be cruel and destructive to perform a step-by-step dissection on the 'gyro-eye' article. Actually Mr. Morgenroth writes in a very interesting and scholarly manner. We can only wish that the discussion did not depend entirely on the conclusion that the eyes of higher animals do not rotate when they tilt their heads."

In support of their criticisms most of the correspondents referred Morgenroth to the book *Physiological Optics*, by A. von Tschermak-Seysenegg.

During the course of his investigation Morgenroth had looked not only into books but also into a mirror. He had found that his own eyes showed so little cyclorotation when he turned his head sideways that they could be considered 2F (rotating only in two dimensions).

To find out whether Morgenroth's eyes were unique, we consulted a number of physiologists who study eye movements outside books and the dissection theater. None had made an exhaustive investigation of cyclorotation. So we invited some 50 friends to cooperate in an experiment. The subjects were strapped one at a time to a steel framework which could tilt them to a horizontal position on either side. Rigidly fixed to the frame was a 35-millimeter motion-picture camera. The camera could be focused, close up, on either of the subject's eyes. Starting from the upright position, pictures were made as the subject was rotated slowly sideways, first 90 degrees to the right, then 90 degrees to the left. Any rotation of the subject's eye could be measured by a change of position of natural markings on the pupil.

Measurements of the resulting photographs showed that the eye rarely rotated more than two degrees to the side and never more than six degrees—notwithstanding the authorities who speak of 70- to 80-degree movement! The amount of eye rotation did not increase even when subjects were kept in a horizontal position for as long as 10 minutes. A typical set of these photographs is reproduced at the left.

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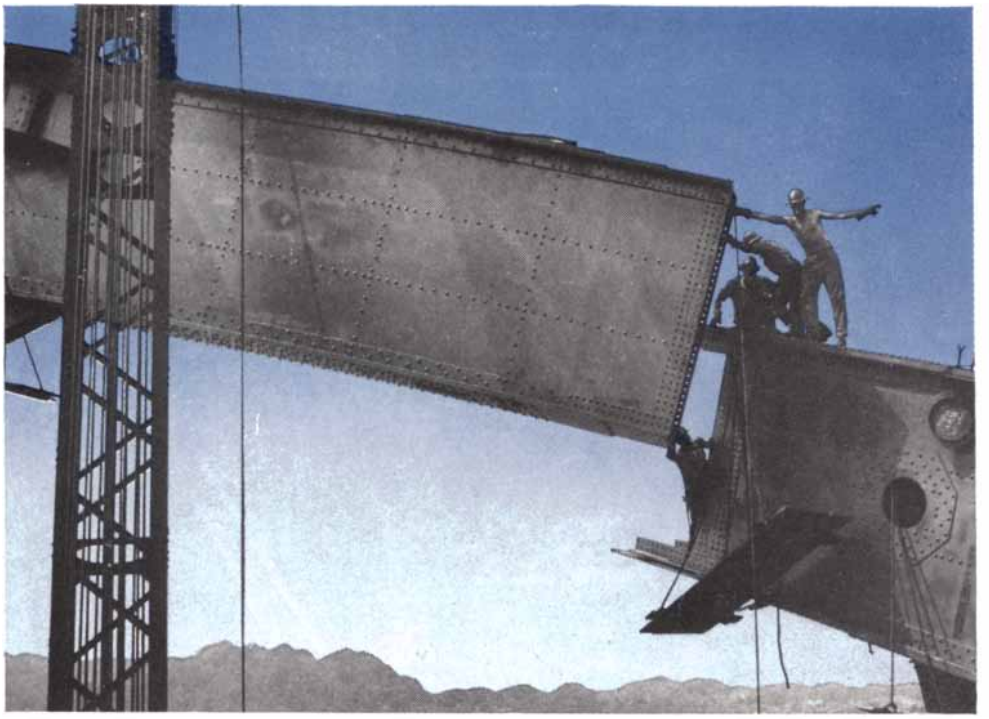

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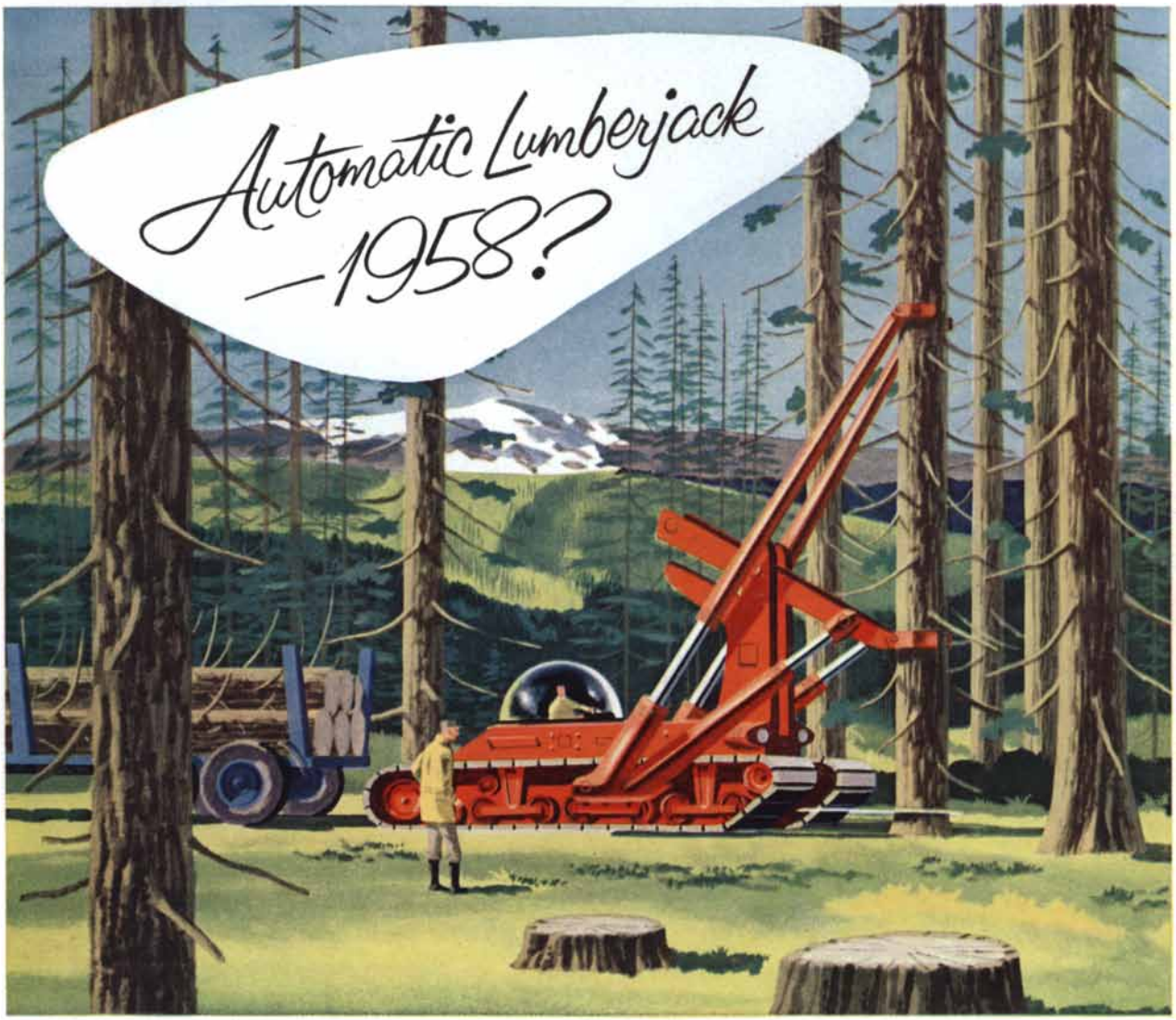

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