SCIENTIFIC AMERICAN

SUSPENSION BRIDGE

FIFTY CENTS

November 1954

The metal that makes time stand still

Thanks to chromium, steel now serves you with strength and beauty that lasts a lifetime

In time, one of man's most useful materials—steel—is often the victim of such destructive forces as rust, corrosion, heat, or wear.

THESE NATURAL ENEMIES of steel now are mastered by the metal called chromium. When the right amount of chromium is added to molten steel, the result is strong, lustrous stainless steel that defies the ravages of time.

IN HOMES, TODAY, stainless steel is a shining symbol of modern living. It brings us care-free sinks, gleaming tableware and kitchen utensils—all with beauty that lasts a lifetime.

IN INDUSTRY—Food is prepared in super-sanitary stainless steel equipment. Streamlined trains and buses are made of this wonder metal. Vital parts of jet planes that must withstand both blazing heat and sub-zero cold are made of tough, enduring stainless steel.

SERVING STEEL... AND YOU—The people of Union Carbide produce alloys of chromium for America's steelmakers. This is another of the many ways in which UCC transforms the elements of nature for the benefit of everyone.

FREE: *For the full story of the everyday miracles made possible by alloying metals such as chromium, write for the illustrated booklet, "Hot-Metal Magic." Ask for booklet G.*

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LETTERS

Sirs:

May I add a postscript to my article "The Supergalaxy" [SCIENTIFIC AMERICAN, July] to the effect that the first sign of radio-frequency radiation from the Virgo cluster of galaxies was obtained by Grote Reber in 1946 and 1947 during a survey of "cosmic static" at 480 megacycles per second (*Proceedings of the Institute of Radio Engineers,* Vol. 36, pages 1215-1218; 1948).

Reber noted: "A few traces showed some faint disturbance to be present near right ascension 12 hours between declination 0 degrees and –20 degrees."

In a letter Reber adds: "Actually these traces could be followed down to –32 degrees (the limit of the apparatus) and up to +35 degrees. The energy seemed to be over an area about an hour wide and varied between 12 and 13 hours right ascension."

It is only proper to put on record this early detection of radio radiation from the supergalaxy by one of the pioneers of radio astronomy.

G. DE VAUCOULEURS

Mount Stromlo
Canberra, Australia

Sirs:

In Fred Hoyle's article "Ultrahigh Temperatures" [SCIENTIFIC AMERICAN,

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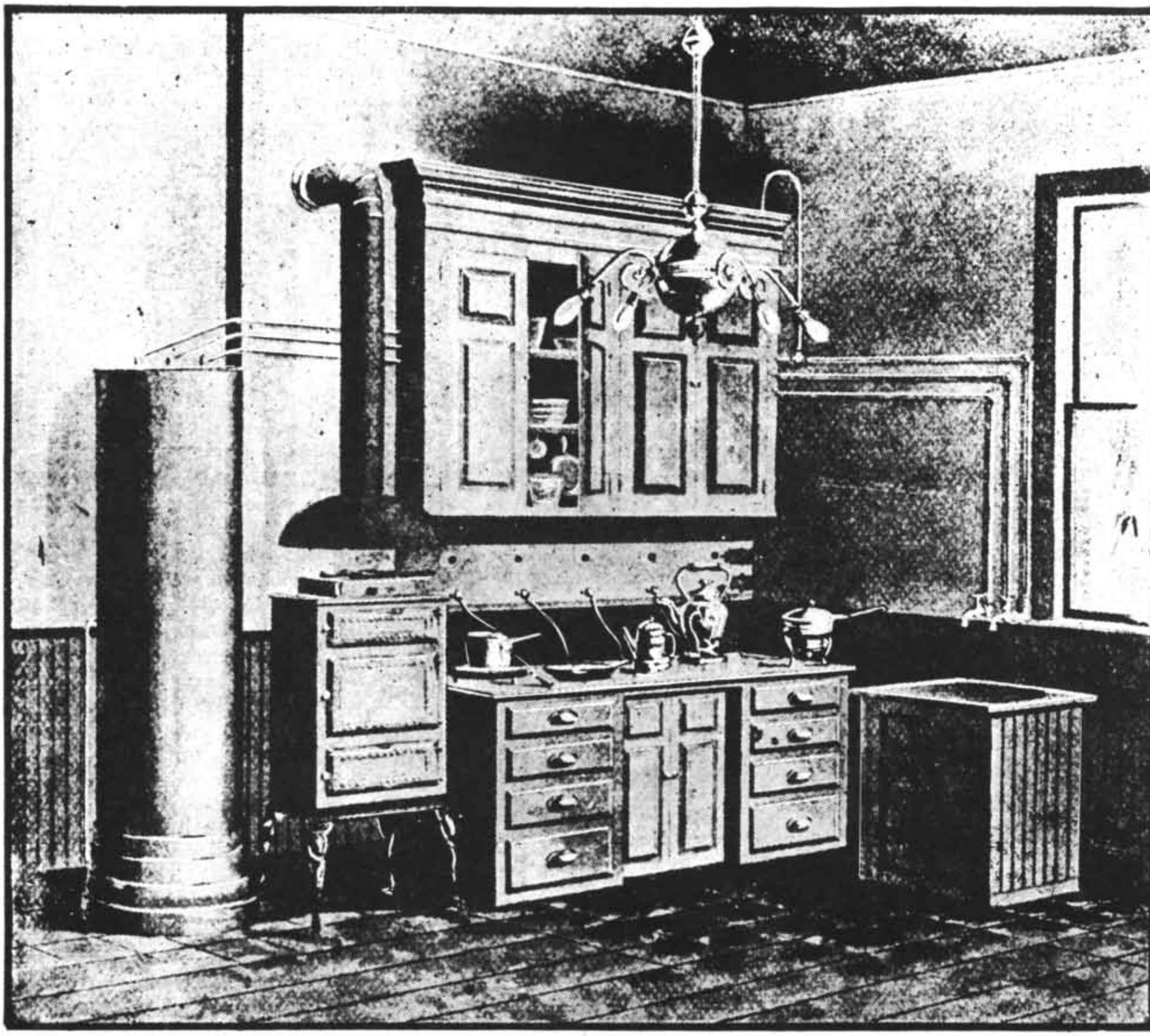

Living was slower paced in 1893, the year this electric kitchen made headlines at the Columbian Exposition. *But even 40 years later...*

Your 3-minute egg took 30 minutes!

Imagine waiting half an hour for water to come to a boil on an electric range!

It used to take that long. As you might expect, this slowness didn't help sell ranges.

Early heating units wasted electricity. Their open coils were easily shorted or damaged. They were devilish things to keep clean. And they kept burning out.

The first hope of making electric cooking really practical came with the development of a durable resistance alloy of nickel and chromium. It used electricity efficiently and is still standard on today's electric range. (And on all other types of modern electric heating appliances.)

But even this new wire had to be encased in a heavy insulated covering. And the covering soaked up heat, slowed up cooking. It got rusty and scaly with use. It often warped, sometimes cracked.

When range manufacturers heard the news of Inconel®, they came to International Nickel. Was there an outside chance that this Inco Nickel Alloy might hold the key to their problem?

There was. And it did. Used as a protective sheathing, Inconel immediately opened the way to higher temperatures and fast cooking. Stretched the life of electric range heating units. Did away with oxidation. Wasn't bothered by spillovers. Ended cracking, breakage and high temperature corrosion.

Next time you pass through the kitchen, take another look at those heating units. You may get an idea from that glowing example of how an Inco Nickel Alloy (Inconel or its heat resisting companion Incoloy) solved a practical problem of high temperatures.

Perhaps nickel or an Inco Nickel Alloy is the metal needed to get one of your products out of the doldrums, too. If you are up against *any* problem that a metal might solve, talk it over with us. We may be able to help you.

The INTERNATIONAL NICKEL COMPANY, Inc.
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INCO TRADE MARK **Nickel Alloys**

MONEL® • "R"® MONEL • "K"® MONEL
"KR"® MONEL • "S"® MONEL • INCONEL®
INCONEL "X"® • INCONEL "W"® • INCOLOY®
NIMONIC® ALLOYS • NICKEL
LOW CARBON NICKEL • DURANICKEL®

September] there was a slight mistake in the caption under the color-luminosity diagram for the globular cluster Messier 3. This diagram is credited to Allan R. Sandage and to me. Although I have worked on diagrams of other globular clusters, the credit for the excellent Messier 3 diagram belongs to Sandage alone.

HALTON C. ARP

Mount Wilson Observatory
Mount Wilson, Calif.

Sirs:

It is often true that it is not only the time but also the man that shapes destiny. I could not help thinking this as I read Samuel Tolansky's article "A Topographic Microscope" [SCIENTIFIC AMERICAN, August] since we in medicine have observed and used Dr. Tolansky's expressed ideas for many years, though only on the macroscopic level. Yet none of us has ever given a thought to its use on a microscopic plane.

In using the opthalmoscope for detecting evidence of papilledema (swelling of the optic disk often due to an increased intracranial pressure) we frequently cast the shadow of a line on the disk and by its configuration we can determine the elevation of the disk or in certain conditions (such as glaucoma) the depression of the disk. In fact, by changing focus from the shadow line on the base retina to the shadow line on the plateau of the disk we can determine, in diopters, the height of the disk from the normal retinal base. . . .

RONALD M. LAWRENCE

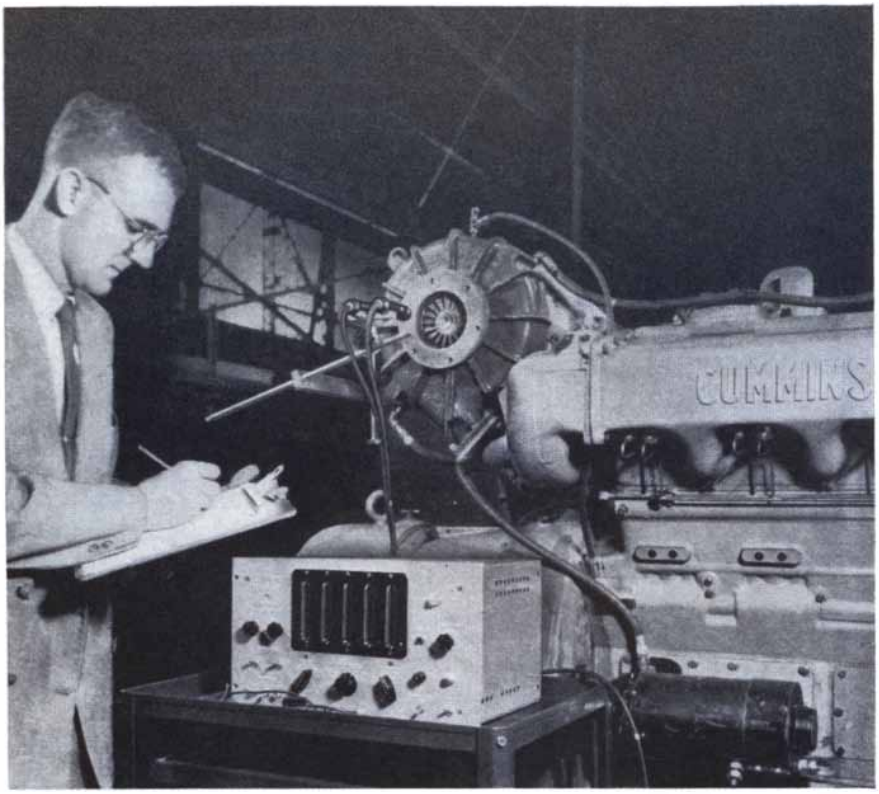
Laurel Canyon Medical Center
North Hollywood, Calif.

Sirs:

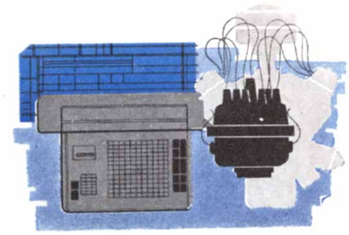
The article by J. W. Westwater on the boiling of liquids [SCIENTIFIC AMERICAN, June] would appear to be in a relatively unexplored area of scientific interest. In that article a Japanese scholar, Shiro Nukiyama, was credited with having done important pioneering work in this deceptively prosaic subject. To a specialist in Far Eastern culture it would seem quite possible that the empirical observations of the *Chajin*, or Tea-Masters of Pre-Restoration Japan, may easily have motivated Nukiyama to follow up a lead that they had provided him.

Almost concurrently with reading Westwater's article the writer's atten-

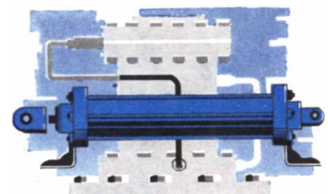
Your business is in the Age of Electronics



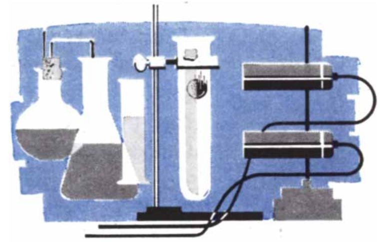
Cummins Engine Company, Inc. employs *-hp-* electronic counters in numerous ways. One is precision measurement of R. P. M. in new diesel engine turbo supercharger. The *-hp-* counter will measure accurately to 6,000,000 R. P. M.



Time interval. Time measurement of extreme accuracy is required in design and manufacture of automotive electrical systems, calculation equipment, automatic devices, etc. *-hp-* electronic counters measure intervals as microscopic as 1/1,000,000 second, as long as 100 days.



Pressure. In hydraulic and pneumatic equipment, pressures must be known exactly. Together with a simple transducer converting pressure to electric signals, *-hp-* counters read even most minute pressures directly, instantly; determine pressures at remote or hazardous points.



Viscosity. *-hp-* electronic counters and *-hp-* photo tubes work as a team to give instant viscosity data. Measurements are made by reading time of fall of free object through liquid under test. Counter reads time directly in seconds or milliseconds. Velocity measurements are also made this easy, accurate way.

Electronic Counters—new, easy way industry makes precision measurements better, faster

Pressure, flow, velocity, r.p.m., quantity, viscosity, time interval—these are but a few production and research measurements new electronic counters make with hitherto unattainable speed and accuracy.

You do not need highly trained technicians to operate *-hp-* electronic counters. Nor is an elaborate and expensive instrument setup required. Reading an *-hp-* counter is like reading numbers on a license plate. Results appear in direct numerical form, complete even to automatic illuminated decimal.

-hp- 522B Electronic Counter shown here is but one of 10 *-hp-* counters, scalers or converters for research and industrial use, and one of over 250 different electronic test instruments Hewlett-Packard builds. Throughout industry and science, men are finding these instruments a better, faster way of obtaining engineering and manufacturing information.

Correct application is of course of first importance; and this is where your *-hp-* field engineer can help most. If there are measurements you would like made more swiftly, simply or accurately, please write us about them.

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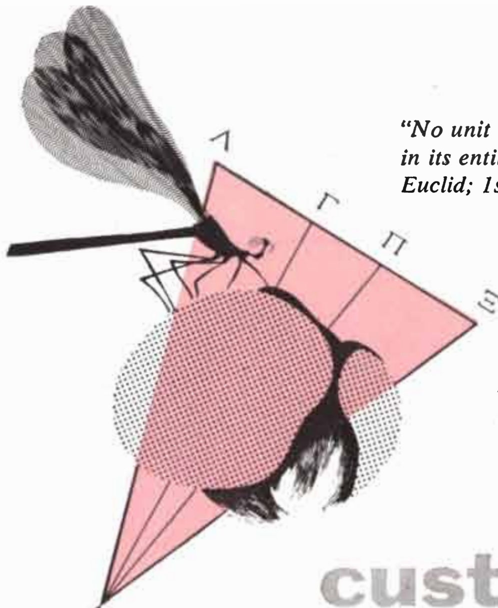
tion was drawn to a pertinent statement in *Japan: Its History, Arts and Literature*, by Captain F. Brinkley. This statement indicated the considerable data that the accomplished tea devotees of medieval Japan had gathered concerning the boiling of water. In this source Westwater would find understandable and reasonably accurate the following description of the boiling of water, as the observations of Japanese Tea-Masters are cited:

[In the Tea Ceremony] "minute attention must be paid to the temperature of the water. A brisk fire should be used. The water gives the first indication of heat by a low, intermittent singing, and by the appearance of large, slowly rising bubbles known as 'fish eyes.' The next stage is marked by agitation like the seething of a hot spring, accompanied by a constant succession of rapidly ascending bubbles. In the next stage waves appear upon the surface, and these finally subsiding, all appearance of steam is lost. The water has now attained the condition of maturity: it is 'aged hot water.' If the fire is good and well sustained, all these stages can be distinctly noted. . . ."

There can be little doubt that the sophisticated *Chajin* recognized clearly in their esthetic ritual all the stages of boiling recently described by Westwater. During the long ritual of *Cha-no-uy*, the Tea Ceremony, the tea was brewed before the guests, the pot being brought to and maintained at the vigorous boiling stage over a hearth in the room. The participants had hours in which to meditate under conditions highly conducive to an awareness of their immediate environment, and the best of form could only be followed by commenting upon all equipment used and everything that took place. The state of boiling identified as "nuclear," which takes place at the lowest temperature of the heating solid, is described from the Japanese sources as occurring at the beginning of the process when the water first commences boiling, and both U. S. and Japanese sources mention the separateness of the individual bubbles rising in the liquid at this time. "Transition" boiling is described in both sources as visually producing a marked agitation of the surface. From this point on, however, the ability to halt rapid movement by pictures taken at a millionth of a second gives the advantage to modern science.

ROBIN A. DREWS

Michigan State College
East Lansing, Mich.



"No unit can be seen simultaneously in its entirety."
Euclid; 1st. theorem of optics.

2076 eyes

custom optics in quantity

Lenses ready for coating

It doubtless took ages to develop the Dragonfly's many faceted eye. Today, at Kollsman, highly complex optical systems such as photoelectric trackers, periscopic sextants, telescopes for radar bombing systems, and others, are not only designed expeditiously, but are produced in quantity.

Kollsman represents something new in optics. This is because the Kollsman Optical Department, established in 1940, grew up within a company devoted for over 25 years to designing and producing some of the most complex instruments and controls in the aviation industry. Aviation moves as fast as tomorrow's guided missile. It is this quality of up-to-dateness you will find in our entire optical operation.

Here we have the finest talents and tools to be found anywhere for the solution of your optical problems. Consult us without obligation on any or all phases of

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- Cones and rods for ranging devices
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- Drift sights • Periscopic sextants (used in aircraft)
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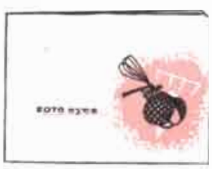
- Anti-aircraft fire control sights (used in the famous Skysweeper)
- Photoelectric sextants
- Astrocompasses • Photoelectric trackers



WRITE for our new brochure "2076 Eyes"

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TYPICAL PROPERTIES OF DU PONT "TEFLON"

CHEMICAL: | **METHOD**

Resistant to: All chemicals except molten alkali metals and fluorine at elevated temperatures and pressures.

MECHANICAL:

Tensile strength, 73°F.	1,800	LB./SQ. IN.	D638-49T
170°F.	1,100	LB./SQ. IN.	D638-49T
Elongation, 73°F.	110	%	D638-49T
170°F.	600	%	D638-49T
Modulus of elasticity, 77°F.	58,000	LB./SQ. IN.	D638-49T
Shear strength	3,800	LB./SQ. IN.	D732-46
Impact strength, Izod, —40°F.	2.0	FT.-LB./IN.	D256-47T
73°F.	4.0	FT.-LB./IN.	D256-47T
Stiffness, 73°F.	60,000	LB./SQ. IN.	D747-48T
Flexural strength, 73°F.	did not break		D790-49T
Compressive stress at 1% deformation	670	LB./SQ. IN.	D695-49T
Creep in flexure	67		*
Hardness, Rockwell	D55		**

THERMAL:

Coefficient of linear thermal expansion per °F.	5.5x10-5		D696-44
Thermal conductivity	1.7	B.T.U./hr./sq. ft./°F./in.	***
Specific heat	0.25		—
Deformation under load, 122°F., 2000 lb/sq. in.	25	%	D621-48T
Heat-distortion temperature, 264 lb/sq. in.	140	°F.	D648-45T
66 lb/sq. in.	270	°F.	D648-45T

ELECTRICAL: | **METHOD**

Dielectric strength, short-time	480	V/MIL	D149-44
step by step	430	V/MIL	D149-44
Volume resistivity	> 10^{15}	OHM-CM.	D257-49T
Dielectric constant, 60 cycles	2.0		D150-47T
10^3 cycles	2.0		D150-47T
10^6 cycles	2.0		D150-47T
10^8 cycles	2.0		D150-47T
Power factor, 60 cycles	< 0.0005		D150-47T
10^3 cycles	< 0.0005		D150-47T
10^6 cycles	< 0.0005		D150-47T
10^8 cycles	< 0.0005		D150-47T

OPTICAL:

Index of refraction	1.35	n_D	D542-42

MISCELLANEOUS:

Water absorption	0.0	%	D570-42
Flammability	nonflammable		D635-44
Specific gravity	2.1-2.3		D792-48T
Resistance to weathering	excellent		
Basic color	light opaque		

*Term "creep in flexure" is a measure of the deformation under a prolonged standard load. Results here represent mils deflection in 24 hrs. of a ⅛" x ½" bar, 4" span, center-loaded flatwise to 1,000 lb./sq. in., minus the initial deflection.

**Hardness of "Teflon" determined by Shore durometer, A.S.T.M. method D676-49T.

***Thermal conductivity measured by Cenco-Fitch apparatus.

Note: This table shows the typical property data for Du Pont "Teflon" 1.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

NOVEMBER, 1904: "One of the most remarkable recent communications to the British Association was that of Mr. R. A. Hadfield, who described Dr. Heusler's magnetic alloys made from non-magnetic materials. When copper is alloyed with manganese and aluminium, a substance is obtained which possesses high permeability. For a given percentage of manganese, the best results are obtained when the percentage of aluminium is, roughly, half that of manganese; this corresponds to one atom of aluminium to one of manganese. An alloy containing 60 per cent of copper, 26 per cent of manganese, and 14 per cent of aluminium is practically as magnetic as cast iron; unfortunately the alloy is very brittle, and cannot be drawn or forged. It used to be thought the magnetic properties of iron were due to some peculiarities of the iron atom, a conclusion to which it was hard to subscribe, owing to the circumstance that at high temperatures iron is non-magnetic. It now appears that the magnetic properties of a substance are due to some peculiarity in the grouping of the atoms within the molecule, or perhaps within the more complex aggregates in which atoms arrange themselves in solids."

"The success of the experiment of introducing the Guatemala ant to combat the cotton-boll weevil, which has been undertaken by the United States government, was threatened by an effort to have the courts interfere. A large Texas plantation owner named Ross took the matter into court, to have the importer enjoined from bringing these ants into this country, on the ground that they would in all likelihood become a greater nuisance and a more serious menace than the weevil. He claimed that the ant was very ferocious, and would make it so disagreeable for the cotton pickers that it would be difficult to get them to go into the fields. The court refused to entertain this view of the matter."

"A very ingenious experiment has been made by Joly, as regards constancy

Bell's new Telephone Answering Set. In use, the machine tells the caller when to start talking, and when his time—thirty seconds—is up.

He's out . . .
but he's answering his telephone!

This newly designed Bell Telephone Answering Set makes it possible for you to go out—but leave your voice behind.

Before you leave you twist a knob, dictate a message into your telephone, then switch the machine to "Automatic Answer." When somebody calls, the machine starts up and the caller hears your voice telling who you are, requesting his name and telephone number, repeating whatever you have said. The reply is recorded too. On your return you play back all the calls that have come in, as often as you please.

The new machine features "talking rubber," a Laboratories-developed recording medium made of rubber-like plastic and iron oxide which can be used over and over again millions of times. It is another example of how Bell Laboratories research works to help your local Bell Telephone Company serve you.

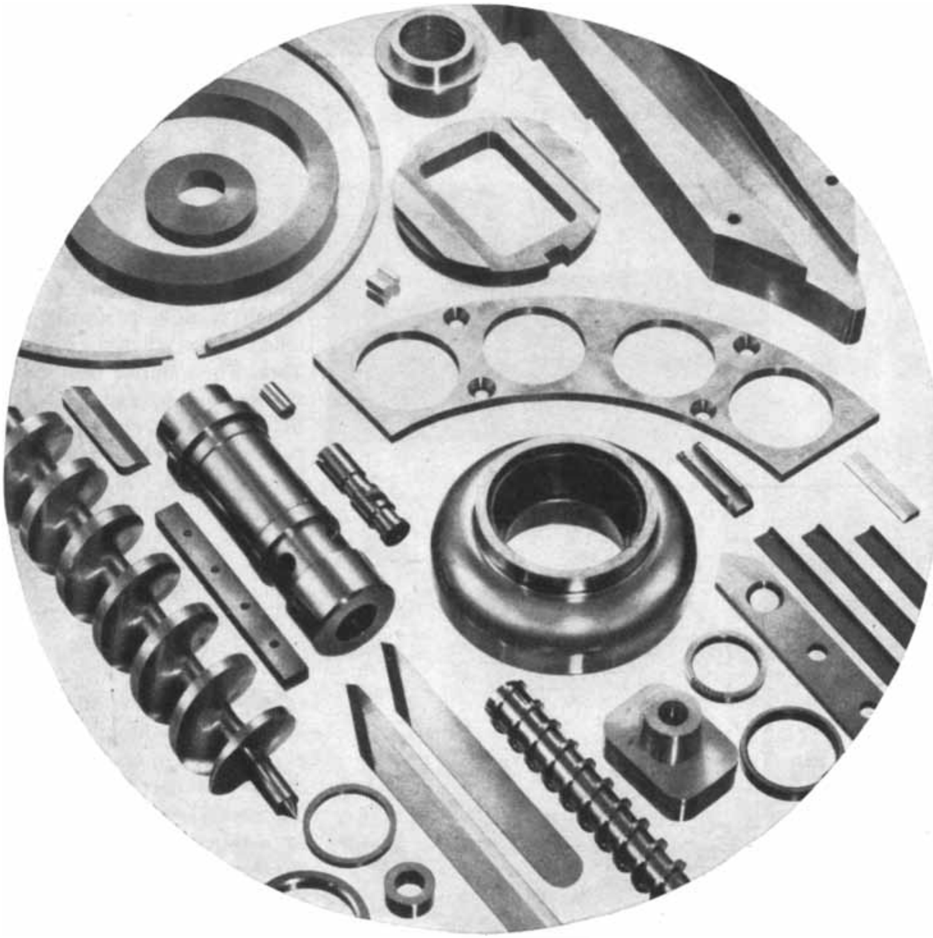
Bell Telephone Laboratories

Improving telephone service for America provides careers for men in scientific and technical fields of weight in a chemical reaction. It was designed to try whether any change of mass occurs on mixing two reacting bodies, for which purpose the inertia of the substances to be mixed was suspended to the arm of a torsion balance, the arm of which was at right angles to the direction of motion of the earth, which is known to be at the rate of about 30 miles a second through space. If matter had been created during the chemical change, then the created matter would not partake of the earth's velocity, and a retardation—made manifest by the rotation of the arms of the torsion balance in one direction—would have been observed; and if, on the other hand, matter had been destroyed, an acceleration would have shown itself. A variation in weight or in inertia was not observed; hence it may be concluded that no change in mass is produced by a chemical reaction."

"Some very alarming statements have been made as to the small amount of oxygen and large amount of poisonous gases that are to be found in the New York Subway, even at this early stage of its operation. That conditions are anything like as bad as has been suggested is, however, quite out of the question. A careful observation of conditions since the opening of the road seems to prove that the theory of the engineers as to ventilation is to a certain degree correct. It was believed that the moving trains would induce sufficient drafts in the Subway, and movements of the air as a body, to maintain a thorough circulation and renewal. In the course of a trip over the whole length of the line, made with a view to special observation of this feature, a member of our staff noted that the local trains carried into the station ahead of them a body of air that moved at a considerable velocity, and that while standing on the local platform twenty feet away from the express tracks, the wave of air carried ahead of the expresses as they swept through the station was distinctly discernible."

SCIENTIFIC AMERICAN

NOVEMBER, 1854: "At the recent annual meeting of the British Association for the Advancement of Science, held in Liverpool, J. Scott Russell read a paper on the advantage of increasing the size of ships. The Eastern Steam Navigation Company got their charter for the pur-



Some typical parts produced from H*AYNES alloys*

Custom Tailored to cut maintenance costs

Alloys for Every Wear Condition Shaped to Your Specifications

HAYNES alloys are available in a wide range of properties. They can be supplied as castings, forgings, stampings, or fabricated parts finished to close tolerances and with a mirror-like finish where required.

Some HAYNES alloys are extremely hard—to resist severe abrasion. Some are tough and ductile, designed for use where mechanical shock or repeated stress cause ordinary metal parts to crack and splinter. Some resist the corrosive action of acids, alkalies, and molten metals. Erosion from steam or liquids, the softening effects of high-temperatures, seizing and galling from metal to metal contact, are other severe conditions that can be effectively controlled through the use of HAYNES alloys.

Send us a blueprint of one of your wearing parts and tell us about the conditions under which the part must operate. We are sure we can supply you with a HAYNES alloy part "custom tailored" to solve your problem.

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Chicago • Cleveland • Detroit • Houston • Los Angeles • New York • San Francisco • Tulsa pose of improving upon the existing state of ocean steam navigation, and the first question they asked of shipbuilders was, 'How can we make steamships go faster?' One said, 'Put more power into them,' but they found that that alone would not do, and at last Mr. Brunel drew out plans for the great vessel now building. Brunel was the first person who designed a steamship large enough to cross the Atlantic with regularity and speed; this was the *Great Western*, which is now performing services as efficiently as when she first went to New York. The monster new ship is to carry six thousand tuns of goods, five hundred first-class and one thousand steerage passengers, and is to reach Australia in about 33 days. We really wait with some intensity of feeling the completion and trial of this monster steamer. When loaded, she will draw about 60 feet of water, and is the grandest nautical enterprise on record."

"The common cramps of wagons and carriages consist simply of strips of metal nailed to the bottom of the box or body of the vehicle, to prevent the wearing of the wooden part where the wheels come into contact with it in the act of turning. As a superior mode to this, Samuel T. Sanford, of Fall River, Mass., has made an improvement by constructing the cramps with anti-friction rollers, so arranged that when the wheel comes into contact with the rollers, they obviate the great friction of the common cramp, and at the same time prevent the vehicle from being overturned."

"It is scarcely possible to appreciate the vast internal resources of the United States. Our bituminous coal fields embrace an area of 133,132 square miles, whilst those of all Europe amount to only 17,504 miles. It is a singular fact that the coal trade of our country commenced with 365 tuns in the year 1820, which were sent to Philadelphia by the Lehigh Coal and Navigation Company. We may safely set down the amount of all kinds of coal now consumed in our country at 10,000,000 tuns per annum. This is certainly a great amount, but when we consider that Great Britain produces 31,500,000 tuns per annum, we have some efforts to make yet before we reach that figure. But it will not require many years to accomplish this. As the anthracite region of Pennsylvania embraces an area of but 437 square miles, only a 304th part of our bituminous coal area, we can form some conception of what the coal trade will yet attain to in the future history of our country."

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in pressure and temperature measurement

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ELECTROSYN's exceptionally high output signal, electrically transmitted, makes possible accurate remote readings of temperature and pressure without complex electronic circuits.

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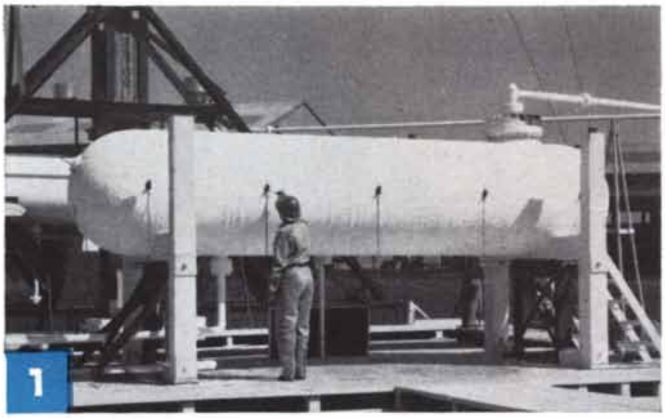
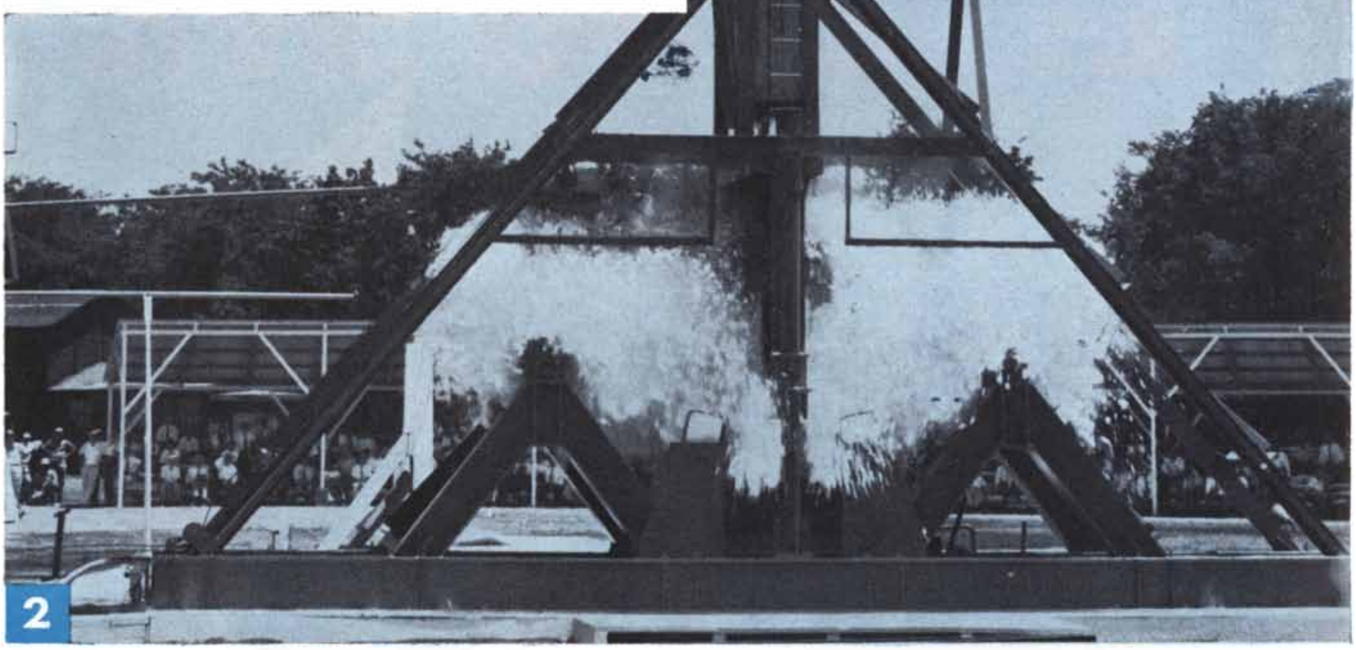
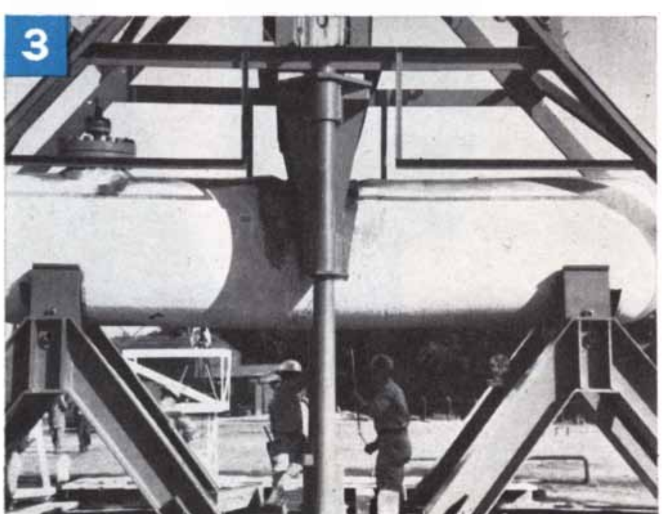
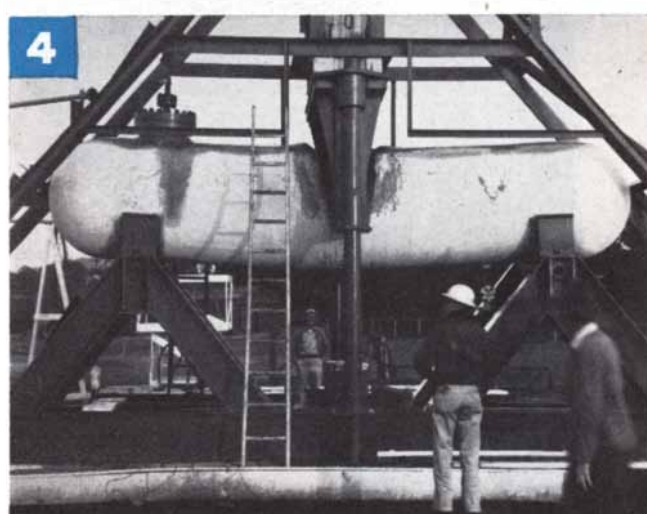
FROZEN STEEL









THE AUTHORS

DAVID F. CAVERS ("The Atomic Energy Act of 1954") is Lessenden Professor of Law and associate dean of the Harvard Law School. After graduating from the University of Pennsylvania and getting his law degree at Harvard in 1926, he practiced for three years in New York City, then taught law successively at Harvard, the University of West Virginia, Duke University and finally Harvard again. At Duke he established and for 10 years edited the quarterly *Law and Contemporary Problems*. During the war he was an associate general counsel to the Office of Price Administration. At Harvard Dean Cavers has been concerned primarily with the development of the Law School's research activities and its postwar program in international legal studies.

S. FRED SINGER ("The Origin of Meteorites") is associate professor of physics at the University of Maryland. He graduated in electrical engineering from Ohio State University and took a Ph.D. in physics at Princeton University. After two years in the U. S. Navy working on mines and digital computers, he went into high-altitude research. He twice went to the Arctic to sound cosmic radiation with balloons. From 1950 to 1953 he was in London as scientific liaison officer with the Office of Naval Research.

N. TINBERGEN ("The Courtship of Animals") is lecturer in animal behavior at the University of Oxford. He has been a naturalist ever since his boyhood days in Holland, and has studied everything from birds to flowers. Since 1937 he has worked closely with the noted naturalist Konrad Lorenz. Tinbergen's lectures at the University of Leiden had long been famous, and he was invited at the end of World War II to conduct the same sort of program at Oxford, where he now has many pupils. In his recent book, *The Herring Gull's World*, he wrote: "I know people often wonder whether it is worth while to spend so much time and energy in watching the ways of wild birds while there are so many urgent problems of human sociology to be solved. I am convinced it is. The utilitarian might be convinced when we remind him of the practical value this kind of work will have for human psychology and sociology. . . . But even if . . . I myself could not see any use in watching

gulls, I am afraid I would not leave them alone."

DAVID B. STEINMAN ("Bridges") is one of the world's foremost bridge-builders. A graduate *summa cum laude* of the College of the City of New York (1906), he took a Ph.D. at Columbia University and taught civil engineering at the University of Idaho and at City College. Since 1920 he has devoted himself to designing bridges, pausing only to accept honorary degrees from universities in various parts of the world. The recognition he has gained is reflected in *Who's Who*, where he occupies more space than Presidents Eisenhower and Truman combined. More direct evidence of his eminence in his field is supplied by the 300 or so bridges on which he has left his mark. Notable among these are the Triborough and Henry Hudson Bridges, as well as several mentioned in his article. He is now at work on what will be the most gigantic bridge in the world—across the Straits of Messina between Sicily and the tip of Italy's boot.

SIR MACFARLANE BURNET ("How Antibodies Are Made") is, in a virus-minded age, one of those who have done the most to advance the laboratory study of these elusive organisms. Born and educated in Australia, he is the director of the Walter and Eliza Hall Institute of Medical Research at Melbourne. He has previously contributed to SCIENTIFIC AMERICAN articles on viruses in general (May, 1951) and the influenza virus in particular (April, 1953).

P. LE CORBEILLER ("The Curvature of Space") is professor of general education and applied physics at Harvard University. Born in Paris, he is a product of France's Ecole Polytechnique, a military school which has turned out some of France's leading mathematicians. He took his doctorate in mathematics at the Sorbonne in 1926 and spent the 1920s and 1930s as a communications engineer in the service of the French Government. Under this rather conventional civil service career he harbored hopes of a quite different order. In 1938 he took a leave of absence from his job to obtain a *licence* (the French M.A.) in philosophy. Three years later he came to the U. S., to which he had long been attracted and where he had met his Chicago-born wife during a French Government mission. He joined the faculty at Harvard, where he is now teaching graduate courses in ap-

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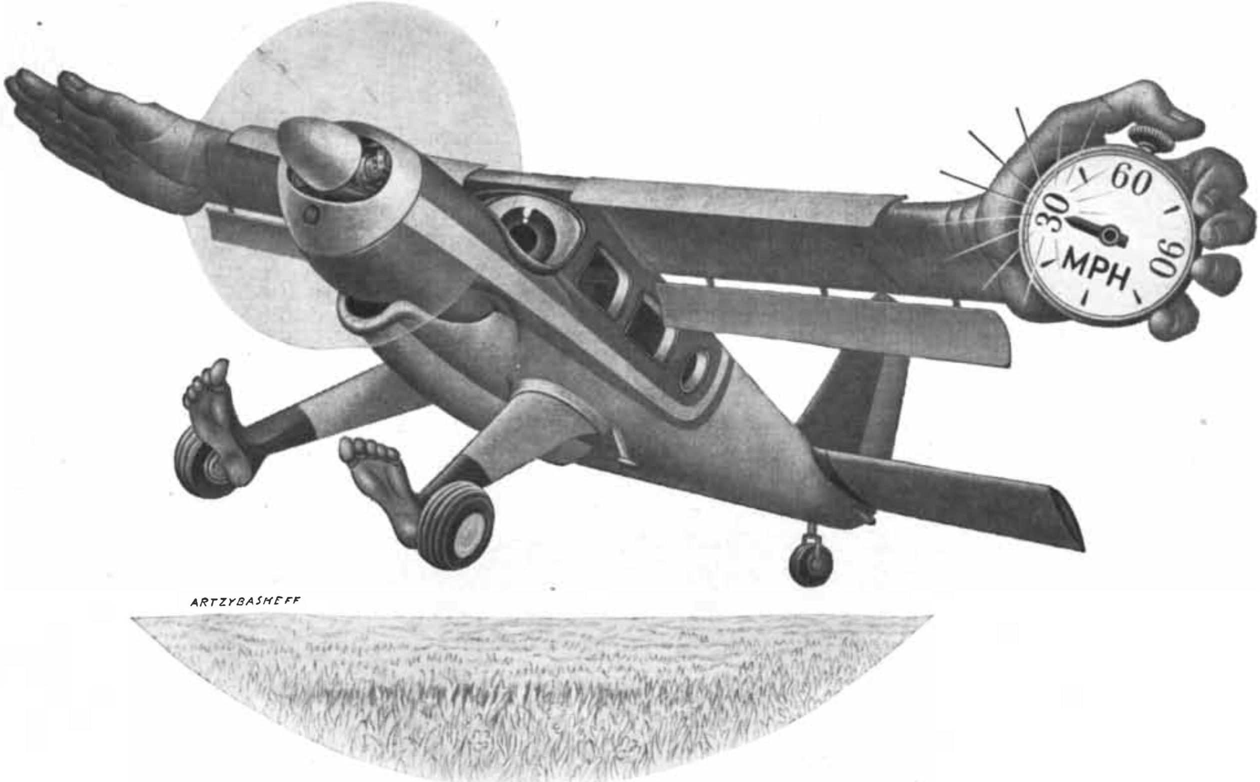
DON D. JACKSON ("Suicide") is a psychiatrist on the staff of the Palo Alto Clinic in California. After an internship in internal medicine and a residency in psychiatry at Stanford University Hospital he entered the Army, of which he notes: "It would be difficult to imagine an experience more calculated to increase one's interest in psychiatry." Following the war he worked at the Chestnut Lodge Sanitarium in Maryland with Harry Stack Sullivan and Frieda Fromm-Reichman. He has been at the Palo Alto Clinic since 1951, and also teaches at the University of California Medical School.

LIONEL CASSON ("Trade in the Ancient World") writes his article from two vantage points—as a classicist (associate professor of classics at New York University) and as a sailor. He has sailed in everything from sailing canoes to schooners, and owned his own 30-foot sloop before the war. In recent years he has visited the site of practically every ancient harbor on the north coast of the Mediterranean. His attention was originally drawn to ancient trade routes when he noted that St. Paul in A. D. 62 and Admiral Nelson in 1798 took the same seemingly roundabout course in sailing from Asia Minor to Italy. He spent the year 1952-1953 in Europe on a Guggenheim fellowship, preparing *A History of Maritime Commerce in Hellenistic and Roman Times.*

MARSTON BATES, who reviews Weston La Barre's *The Human Animal* in this issue, is himself a worker in the field he calls "social biology." After graduating from the University of Florida in 1927, he spent three years in Honduras and Guatemala with the United Fruit Company, doing research on tropical insect life. Later at Harvard he studied under William Morton Wheeler, known for his studies of social insects. From 1935 to 1952 he was with the Rockefeller Foundation as a field biologist; for eight years he headed the Foundation's laboratory for research in yellow fever in Colombia. Since 1952, as a professor of zoology at the University of Michigan, he has been "trying to bridge the gap between the biological and the social sciences." He has just finished a book called *The Prevalence of People.*



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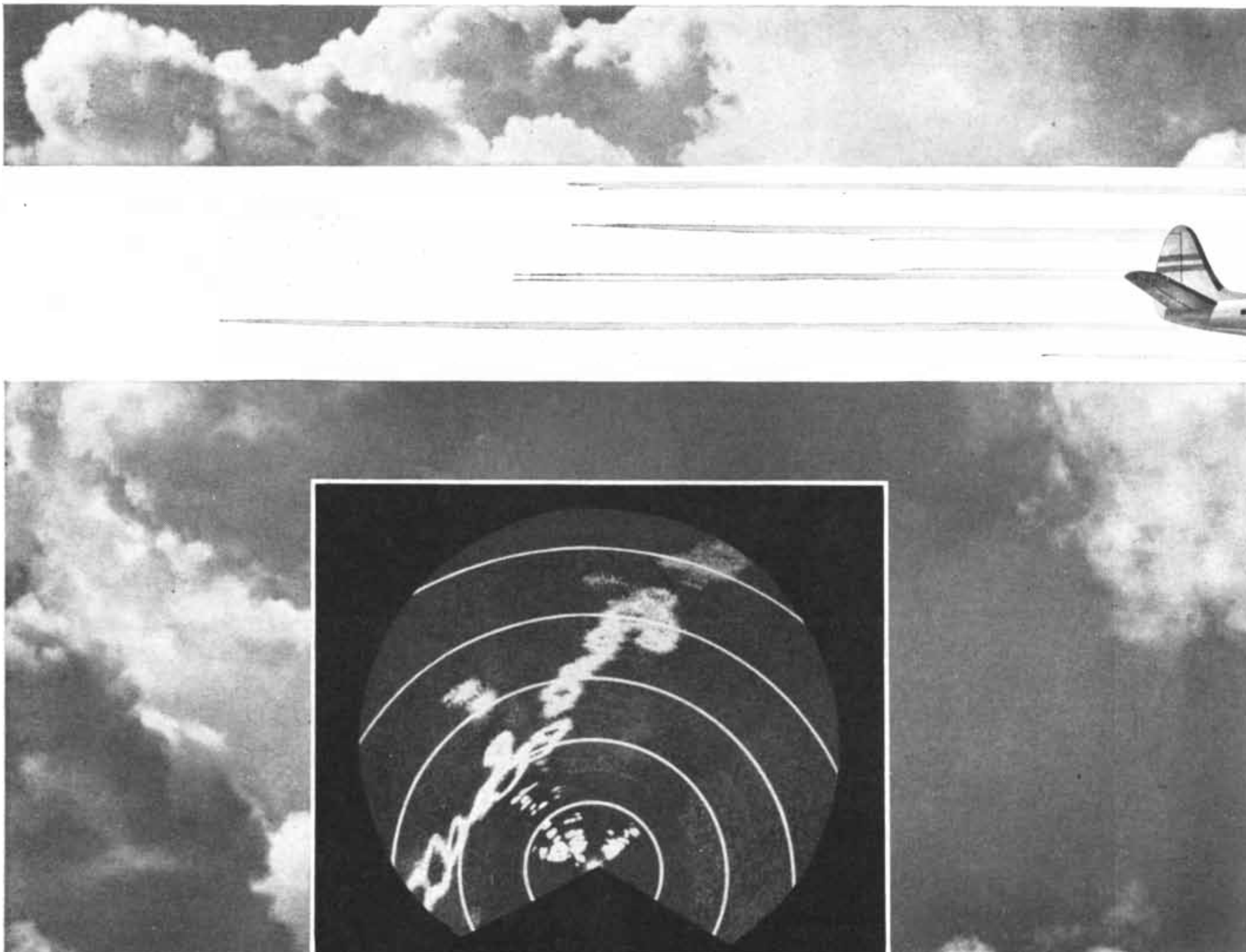

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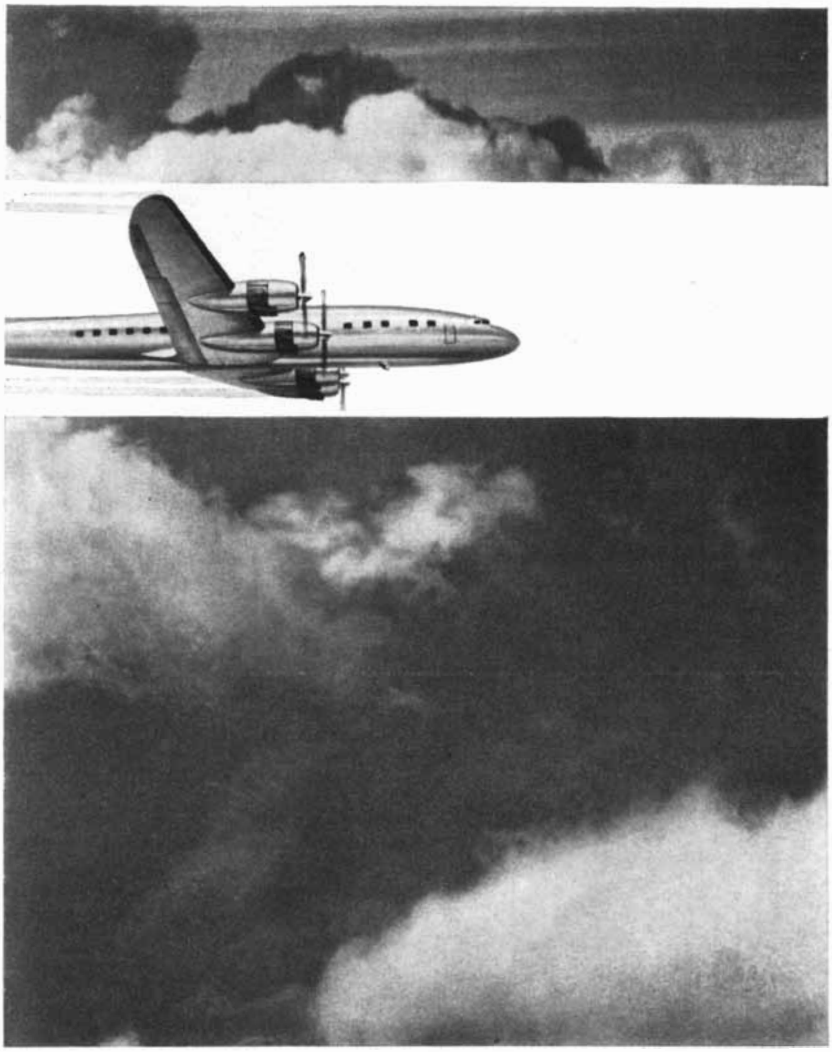

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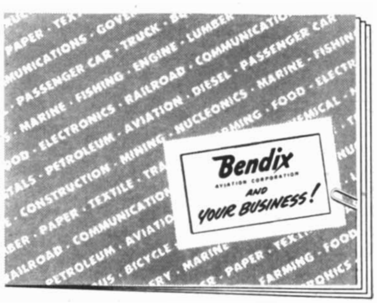

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THE COVER

On the cover is an unusual view of the George Washington Bridge (*see page 60*). The photograph was made from the East, or New York, tower, and shows the New Jersey tower. The towers are 595 feet high; the distance between them is 3,500 feet. This is the second longest suspension span; the longest is the Golden Gate Bridge. The George Washington Bridge was designed to support two decks, of which only one, carrying eight lanes of traffic, has been built. Designed by O. H. Ammann of the Port of New York Authority, the bridge was completed in 1931 at a cost of $76 million.

THE ILLUSTRATIONS

Cover photograph by Gjon Mili

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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. 8

CHOOSING A WROUGHT ALLOY

NEW RESEARCH DATA SHOWS ALUMINUM PROVIDES REDUCED HEAT AND FRICTION LOSSES

THE PROBLEM of selecting the most suitable aluminum wrought alloy and temper for a particular application can be a bewildering task for one not thoroughly familiar with all of the possibilities.

Although only about two dozen out of the list of nearly a hundred wrought alloys recognized by the Aluminum Association are in fairly regular use, each of them is available in a variety of cold worked or heat treated conditions.

Wrought alloys are available in three major classes of mill products: 1) sheet and plate; 2) rod, bar and wire; 3) extrusions. They are generally used in one of these forms or as forgings, in which case the forging blank is ordinarily produced from one of the standard mill products.

All of these alloys are not available in all four forms and it is usually possible to halve the list of alloys to be considered on the basis of the type of product involved. (Table I indicates the forms in which the various alloys may be obtained.)

Mechanical Properties Requirements

Every design places certain minimum requirements on the mechanical properties of the material from which it is fabricated. Thus, specified values of one or more of the following: yield strength, ultimate strength, per cent elongation, shearing strength, bearing strength, endurance limit and hardness, will automatically eliminate certain alloys and tempers from consideration.

Because the different methods by which wrought alloys are produced result in different amounts of plastic working of the metal, a given alloy may exhibit slightly different typical strengths in different forms.

The designer will recognize, of course, that mechanical properties differ widely among the various alloys available. Therefore, he must often find a single suitable alloy with the best combination of the various properties. To aid the designer, we have prepared typical mechanical and physical property tables on the various alloys. These tables may be obtained by writing to: Kaiser Aluminum & Chemical Sales, Inc., Industrial Service Division, 51175 Kaiser Building, Oakland 12, Calif.

If the design has not reached an advanced stage it may sometimes be altered to compensate for a deficiency in one aspect of a material having otherwise desirable characteristics. Sound engineering judgment is the only guide at this point.

Of equal importance is the ability of the material to retain its properties in the environment to which it will be exposed in service. In general, it may be said that alloys 1100 (2S) and 3003 (3S) are most corrosion resistant, followed closely (even exceeded in some environments) by the 5000 and 6000 series. Least resistant of all are the 2000 and 7000 series. (The reader is referred to No. 4 of this series "Designing with Aluminum" for a more detailed discussion of the corrosion resistance of aluminum alloys.)

TABLE I Alloy Availability

Alloy Designation				Rolled or Rolled & Drawn							Extrusions						
New	Old	Sheet	Plate	Round Drawn Wire	Rivet Wire & Rod	Screw Machine Stock	Rolled & C.F. Rod	Welding Wire	Round Forge Stock	Hex Wire & Bar	Rod	Bar	Solid Shapes	Tube & Pipe	Hollow Shapes	Drawn Tubes	Forgings
	EC			A							S	S	S	S	S		
1100	2S	A	A	A	A		S	S	A								A
2011	11S			A		A	A		S	A							A
2014	14S	A	A	A			S		A		A	A	A	A			A
2017	17S			A	A	A	A		A	A							A(6)
2018	18S								A								A(7)
2024	24S	A	A	A	A		A			A	A	A	A	A			
2025	25S								A								A
2117	A17S				A												
2218	B18S								A								A(7)
3003	3S	A	A								S(3)	S	S	S	S		
3004	4S	A	A													S	
4032	32S								A								A(7)
4043	43S							S									
5005	K155	A	A														
5050	50S	A	A													S	
5052	52S	A	A	A			S									S	
5056	56S			A	A												
L5083	LK183		A(2)								S(4)	S	S	S			
5086	K186	A	A														
5357	K157	A(1)															
6053	53S										S(5)	S	S	S	S		
6061	61S	A	A	A	S		S		A		A	A	A	A	A	A	A
6062	62S										A	A	A	A	A		
6063	63S										A	A	A	A	A		
6151	A51S								A								A
7075	75S	A	A								A	A	A	A			A

Notes: A = Available. S = Special Inquiry.
(1) Special purpose alloy. Bright finish alloy used for decorative purposes only. Strength comparable to 3003 or 5005. Higher cost justified only when appearance is of maximum importance.
(2) High strength alloy. Used for heavy weldments where strength greater than 5086 is desired.
(3) Largely replaced by 6063.
(4) Structural members to be assembled by welding. Strength greater than 6061-0 or T4. Less than 6061-T6.
(5) Obsolescent alloy, generally replaced by 6061, 6062 or 6063.
(6) Largely replaced by 2014.
(7) High temperature service. Internal combustion engine pistons, etc.

Appearance, Ease of Operation, Cost

Having narrowed the choice of alloy and temper to those which will provide adequate strength and corrosion resistance, the final selection must be made on the basis of three other factors which are somewhat inter-related. They involve the appearance, suitability for intended method of manufacture and the cost.

Obviously, appearance of the finished product will not be a factor in all cases, but in some it may be paramount. If appearance is important, the ability of the material to respond to chemical or mechanical polishing must be considered. The color after anodiz-

PLEASE TURN TO NEXT PAGE ➡

ing depends on the nature and the quantity of alloying elements present.

The brightest and clearest surface available is that of 5357 (K157) which is used for light reflectors and for decorative trim in much the same manner as stainless steel and chrome plating. Only slightly less clear are alloys 5005 (K155), 5050 (50S) and 6063 (63S). Alloys containing manganese (3000 series) tend to show a yellowish color in the anodized coating while those containing sizeable amounts of magnesium exhibit a brownish-grey color. The 2000 series of alloys (containing copper) also yield dark anodized coatings unless used in clad form.

Matching Colors

One very important aspect of this problem which is too often overlooked is that of matching colors in different types of products.

As an example, it is usual practice to make the structural frame of a storm door from 6063 (63S) extrusions. The panels and/or kick plates do not require a strong alloy and it would be most uneconomical to use 6061 (61S) sheet for this purpose, and even if used it would be very slightly darker in color. While 3003 (3S) has adequate strength its color would be noticeably darker than that of the 6063 frame. The logical choice would be 5005 (K155) which matches the 6063 very nicely in color and the 3003 in strength and cost.

If cast alloys are involved in the finished product the problem of color matching becomes even more critical, since many of the casting alloys contain a high percentage of silicon which anodizes to a dark grey color. And, if parts are to be assembled by welding, care also must be shown in the choice of welding wire. Even when the welding wire is of the same alloy as the metal being welded, the bead is apt to be noticeable after polishing and anodizing.

Suitability for Production

In checking the suitability of the metal for the intended method of manufacture the engineer must answer questions of the following nature. 1) Can the alloy be formed easily? 2) Will it machine freely? 3) Is it weldable by shielded metal arc? Or shielded tungsten arc, gas welding, resistance welding? 4) Can it be brazed, soldered?

TABLE III Relative Fabrication Rating

Alloy and Temper	Cold Work	Suitability for		Welding		
		Machining	Brazing	Arc	Gas	Resistance
1100-0	E+	G	E	E	E	E
1100-H18	G−	G	E	E	E	E
3003-0	E+	G	E	E	E	E
3003-H18	F+	G	E	E	E	E
3004-0	E+	G	—	E	G	E
3004-H38	F+	G	—	E	G	E
2011-T3	F−	E	NS	P	P	G
2011-T8	P	E	NS	P	P	G
2014-T4	F	E	NS	F	P	P
2014-T6	F−	E	NS	F	P	P
Clad 2014-T4	F	E	NS	F	P	P
Clad 2014-T6	F−	E	NS	F	P	P
2017-0	E	G	NS	P	P	F
2017-T4	F	E	NS	P	P	F
2117-T4	G−	E	NS	P	P	F
2018-T61	—	E	NS	P	P	P
2024-0	E	G	NS	P	P	F
2024-T3	F−	E	NS	P	P	G
2024-T36	P+	E	NS	P	P	G
Clad 2024-T3	F	E	NS	P	P	E
Clad 2024-T36	F−	E	NS	P	P	E
2025-T6	—	G	NS	P	P	P
4032-T6	—	F	NS	P	P	P
5050-0	E+	G	G	E	E	E
5050-H38	F+	G	G	E	E	E
6151-T6	—	G	E	E	E	E
5052-0	E+	G	F	E	G	E
5052-H38	F+	G	F	E	G	E
5086-0	E	G	NS	G	—	—
5086-H36	F	G	NS	G	—	—
6053-T4	G−	G	E	E	E	E
6053-T6	F+	G	E	E	E	E
5056-0	E	G	—	—	—	—
5056-H38	G−	G	—	—	—	—
6061-0	E	G	E	E	E	E
6061-T4	G	G	E	E	E	E
6061-T6	G−	G	E	E	E	E
6063-T5	G−	G	E	E	E	E
6063-T6	F+	G	E	E	E	E
7075-0	E	G	NS	F	P	F
7075-T6	P	E	NS	F	P	G

These ratings are relative for aluminum alloys and should not be used for comparing aluminum with other metals. E = Excellent, G = Good, F = Fair, P = Poor, N.S. = Not Suitable.

For example consider a deep drawn part requiring good corrosion resistance with a yield strength in excess of 35,000 psi. Here are four possibilities:

5052 - H36 . . . YP=35,000
3004 - H38 . . . YP=36,000
5052 - H38 . . . YP=37,000
Clad 6061 - T6 . . . YP=37,000

The 3004 alloy will probably not qualify because its corrosion resistance is less than the others. Table III shows that 5052 is not very suitable for cold working in the harder tempers. On the other hand, clad 6061 is excellent for forming in the O temper. The part might also be deep drawn after solution heat treating (W condition) and precipitation-hardened to the T6 condition after forming. If the required draw were not too deep it might be possible in 5052-H36 and the resulting savings in heat treating costs would make it worth investigating.

Material Costs

Most designers find it necessary to keep the cost of their finished products to the lowest possible figure. In order to accomplish this it is necessary to consider the choice of an alloy early in the design, because the cost per pound of metal does not tell the entire story. In the case of a welded pressure vessel, alloy 5086 (K186) costs approximately 1.3 times as much per pound as alloy 3003 (3S) yet its allowable strength is 2.6 times as great. The result is that much less material is needed and the final material cost of the more expensive (per pound) alloy is only one-half as great.

Cost in Production

Similarly, cost must be considered in relation to method of manufacture. Suppose that a requirement exists for a screw machine part to be made from 1.5 in. round rod, and that the mechanical properties of 1100-F (2S-F) are adequate. The 1100 alloy would cost less per pound, yet 2011-T3 (11S-T3) would probably be a much more economical choice because of the greater ease with which it could be machined.

It is difficult to give cost data upon which to base comparisons of the sort shown above since the price per pound of a given alloy is a function of many things: 1) the amount of work done in reducing it to the desired gauge, 2) the quantity ordered at one time, 3) the need for special tolerances, among others. Comparisons of the kind made here require an exact knowledge of the sizes and quantities of material involved and the availability of a complete price book.

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.

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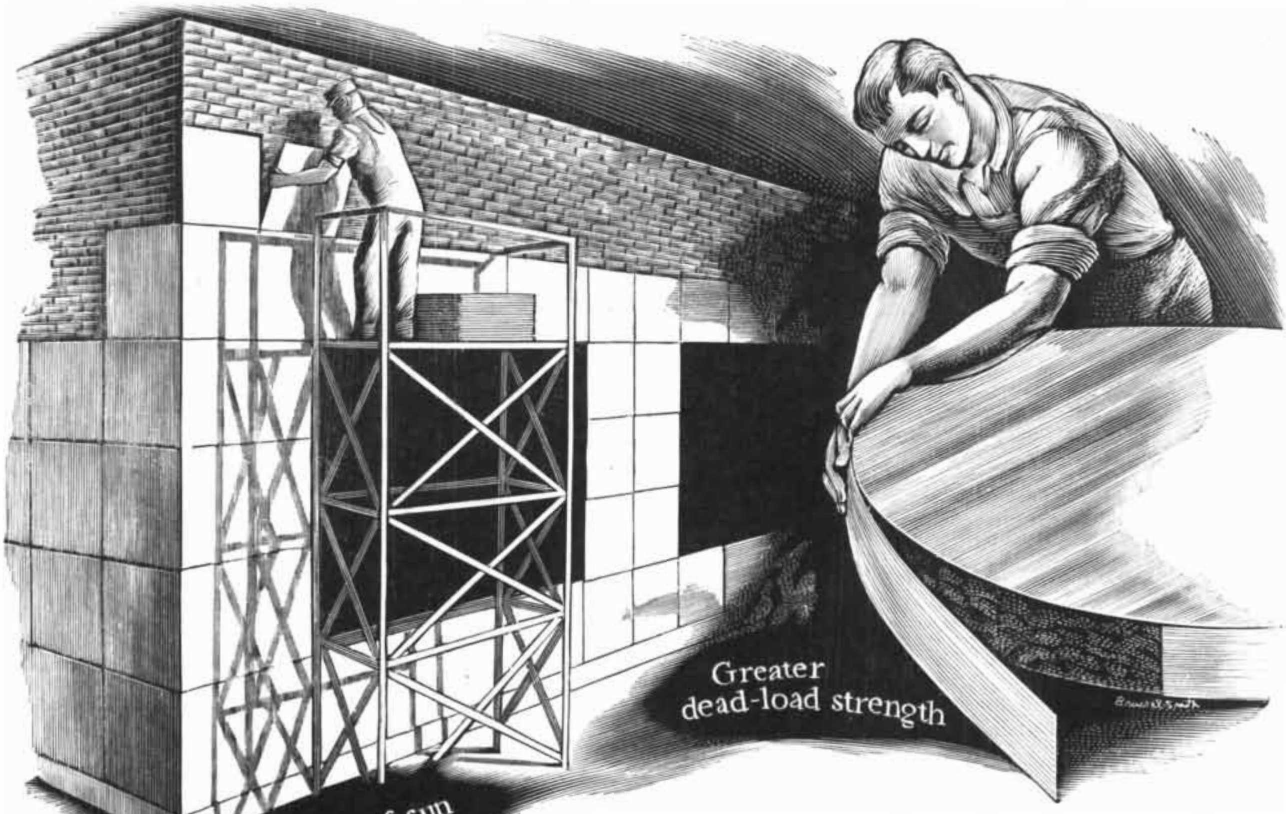
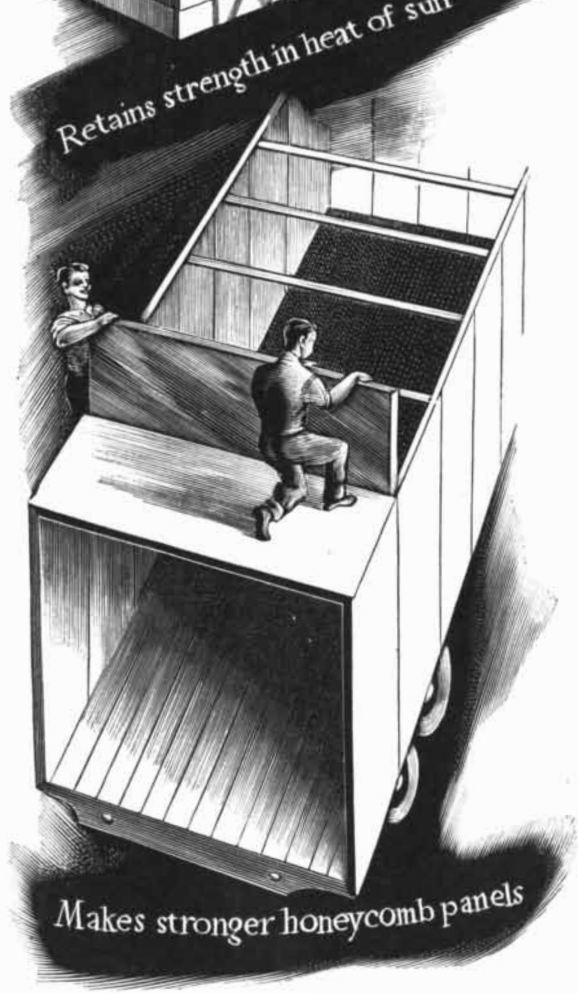
ARTICLES

DEPARTMENTS


Greater
dead-load strength


Retains strength in heat of sun
Makes stronger honeycomb panels

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The Atomic Energy Act of 1954

A legal scholar and long-time student of atomic energy matters examines the new legislation, discussing its major provisions and attempting to forecast how they will work out in practice

by David F. Cavers

Eight years ago a great debate came to a close with the adoption of the Atomic Energy Act of 1946. The Act created what James R. Newman, one of its draftsmen, later termed "an island of socialism in a sea of private enterprise." It turned over to the civilian Atomic Energy Commission a monopoly of the production and ownership of fissionable materials. Only research and development in nuclear energy escaped its complete control, and even this opening for private exploitation of the atom was limited by a ban on patents except for nonmilitary uses of fissionables—and then subject to compulsory licensing.

In the long and stormy recent Senate debate over revision of the 1946 Act and adoption of the Atomic Energy Act of 1954, this "island of socialism" was the center of the controversy. Rising against a revision which they called a $12-billion atomic giveaway, a little band of Senators talked on through the summer days and nights, wresting concessions now and then from the exasperated majority. But neither the public nor even the scientists who had fought for the original Act came to their aid. The efforts of Representative Chet Holifield, of the Joint Congressional Committee, to sharpen the issues and arouse public opinion had evoked little response. Civilian control of atomic energy was no longer at issue. Scientists had become discouraged about the possibilities of regaining freedom of information—domestic and international—during the 12 years of tight governmental monopoly. There was an inviting chance that a wider scope for private enterprise would bring with it greater freedom for science.

Be that as it may, pressures had long been building up for a change in the basic policies of the 1946 Act. How the Congress responded in the 1954 Act this article will seek to examine, in the light of the issues raised.

Perhaps the initial impetus to the drive for revision came from the "industrial participation program" begun in 1951 by the AEC in cooperation with four industrial groups who wished to look into the economic feasibility of atomic power. These groups, originally comprising eight electric utility and chemical companies, grew steadily in membership and later in number. Meanwhile forecasts of reactors competitive with conventional power plants were cropping up in the press, and atomic power began to capture the public imagination.

The final official stimulus to revision came when, last February, President Eisenhower recommended to the Congress the Act's amendment for three purposes: "widened cooperation with our allies," "improved procedures" for the handling of information and "broadened participation in the development of peacetime uses of atomic energy." After hearings before the Joint Congressional Committee on Atomic Energy, a comprehensive measure rewriting the law was reported out to both houses on July 12.

The bill might have been passed with less debate than actually developed had there not arisen an issue which focused attention on the Administration's general power policy. This issue was posed by the so-called Dixon-Yates contract. Because its injection into the debate gave a special cast to the consideration of the entire bill, the background of this contract must be examined.

The TVA had joined with a corporation, Electric Energy, Inc., created by five utility companies, to furnish power to the AEC's great Paducah development. Power shortages in the Memphis area had led the TVA to propose to build a steam plant at nearby Fulton, Tenn. However, the Administration is opposed to building up publicly-owned power, especially steam power. An alternative proposal suddenly appeared, sponsored by two Southern utilities in the Paducah group which became known as the Dixon-Yates combination. Their plan was to create a subsidiary with $5-million capital to build a $107-million power plant at West Memphis, Ark. This would sell its power on a contract of 25 to 35 years to the AEC, which in turn would resell to TVA, the latter lacking legal power to commit itself for a 25-year period.

Democrats, led by Senator Albert Gore of Tennessee, attacked the Dixon-Yates contract as going beyond AEC's contractual powers and as putting the AEC in the power business in "an awkward and unbusinesslike way," to quote Henry D. Smyth, one of the three AEC

CHIEF CHANGES IN THE LAW

Licensing

The Atomic Energy Commission is empowered to license private and public applicants to own and operate facilities for producing and using nuclear materials for purposes of "practical value."

Before issuance of commercial licenses the Attorney General must be consulted as to antitrust questions.

All individual operators of atomic facilities must be licensed.

The AEC may supply large quantities of nuclear materials to licensees at a "reasonable charge" for their use. But the Commission continues to own these materials.

The AEC automatically gets title to all nuclear material produced by its licensees, paying them a "fair price" for it.

Patents

Patents may be issued for all inventions in the atomic field except for weapon uses.

Those seeking patents within the next five years may be compelled to license the AEC and others to use inventions of "primary importance."

To obtain a patent an inventor must show that he conceived his invention independently of any relationship with the AEC.

Power

The AEC may sell by-product power from its fissionables-producing reactors, and it may build and operate "demonstration" power reactors. In selling power and issuing licenses the AEC must give preference to public agencies, cooperatives and areas of high power costs.

Other authorized Government agencies may be licensed to produce and market atomic power.

Research

All research and development activities using special nuclear materials, and all medical uses, must be licensed.

The AEC may conduct research and development studies for private individuals or companies.

Security

The AEC may adjust the requirements for security investigations of employees—its own or those of contractors or licensees—to the type of work done and the importance of the restricted data involved.

Any atomic employee (past or present) or member of the Armed Forces who communicates data, having reason to believe that the data are restricted and the recipient is unauthorized, is liable to a fine of $2,500. No proof of intent to injure the U. S. or to aid a foreign power is required.

International Cooperation

The President, with 30 days' notice to Congress, is authorized to make agreements with other single nations or regional defense organizations for cooperation in development and use of atomic energy.

The cooperation may include providing information, materials and facilities. Cooperators may receive facts about external features of atomic weapons but not about design or manufacture.

Cooperation with a group of nations in an atomic pool requires a treaty or approval by both Houses of Congress.

Commissioners who acquiesced in the plan only after a Presidential directive. The objectors declared that the contract would cost the Government $3,685,000 more per year than the proposed TVA plant, and they offered it as evidence of the lengths to which the Administration would go to cripple TVA and subvert public power.

Although the question about the AEC's authority to enter into such a contract was disposed of by adoption of a Republican-sponsored amendment giving it that authority, the opponents did not relax their attack. They argued that the Administration was departing in the bill from the Federal power policies of the past half-century. The Senators were much more at home on this subject than on the atom itself, and they were able to bring to their aid political forces—such as REA cooperatives and the public power bodies of the West—far stronger than any lobby of scientists.

This impact forced a number of amendments and compromises in the final form of the bill. It also must inevitably guide any attempt to define the principal questions resolved by the new Atomic Energy Act.

First let us see how the Congress, in revising the law, carried out its purpose of providing for the development of an atomic power industry. The Act leaves in the hands of the AEC the exclusive ownership of all atomic fuel, renamed "special nuclear materials" to encompass fusibles as well as fissionables. However, Section 103 empowers it to issue nonexclusive licenses authorizing applicants to have "any type of utilization or production facility" that the AEC has found "sufficiently developed to be of practical value for industrial or commercial purposes." Such licensees can then apply for a license to obtain source materials or special nuclear materials upon the payment of a "reasonable charge." (Of course, all licensees must observe conditions specified for public health and safety and the common defense and security.) The AEC retains title to the special nuclear materials it has distributed, even though these may in time be transmuted beyond recall. Further, the AEC automatically acquires title to any special materials, such as plutonium, produced in private reactors. In sum, the Commission becomes by law the producer's sole customer. The producer must receive a "fair price" for the plutonium or other nuclear material manufactured. As for the electricity he may produce in his power reactor, the Act leaves to existing public authorities regulation of the prices at which he may sell it to consumers.

For the immediate future, until the AEC finds that atomic power plants have attained commercial value, it may issue licenses for private research looking toward power development.

Such is the legal position of the private atomic power industry. The first major question is: Does the Act safeguard the national interest in public power? This was the focal point of the fiercest battles and the hardest-won compromises. As the Act now stands, the AEC itself is specifically forbidden to produce commercial power. But it is authorized to sell "by-product energy" (from its military production or experimental facilities) to public and private purchasers at "reasonable and nondiscriminatory prices." It is granted the right to build a large-scale "demonstration" power plant (provided Congress specifically authorizes the construction) and to sell the plant's output commercially. And it may license an authorized Government agency to produce and sell power under Section 103.

In sum, the Act leaves the door open for public power, though only in principle and without specific authorizations or grants of funds. The public-power proponents also succeeded in inserting into the Act the traditional "preference clauses" that give public agencies and cooperatives preference in the purchase of government-generated power. In this case the same preference is also given to regions where electricity is costly. The preference clauses relate to by-product power and the issuance of licenses under Section 103 when there are more bidders than available licenses. How significant these clauses will be is hard to tell. The AEC is not required to locate its plants in areas where public power-using agencies or cooperatives flourish or where power costs are high. It may instead be enticed by attractive terms to build a plant in a location where it may serve a large utility.

A second major question is: Will private atomic power be fairly and effectively regulated?

Under the Federal Power Act private hydroelectric projects are licensed for a 50-year period, at the end of which the Government may retake them upon reimbursing the remaining net investment. No such recapture is provided for private atomic power installations. Congress can justly argue that the water-power and atomic-power situations are different. A dam site represents a unique location; its possession by one private interest precludes its development by others. Atomic power plants, in contrast, can multiply in response to need. Recapture of these plants seems a needless precaution, especially since the Government is authorized to retake them in case of national emergency upon payment of just compensation.

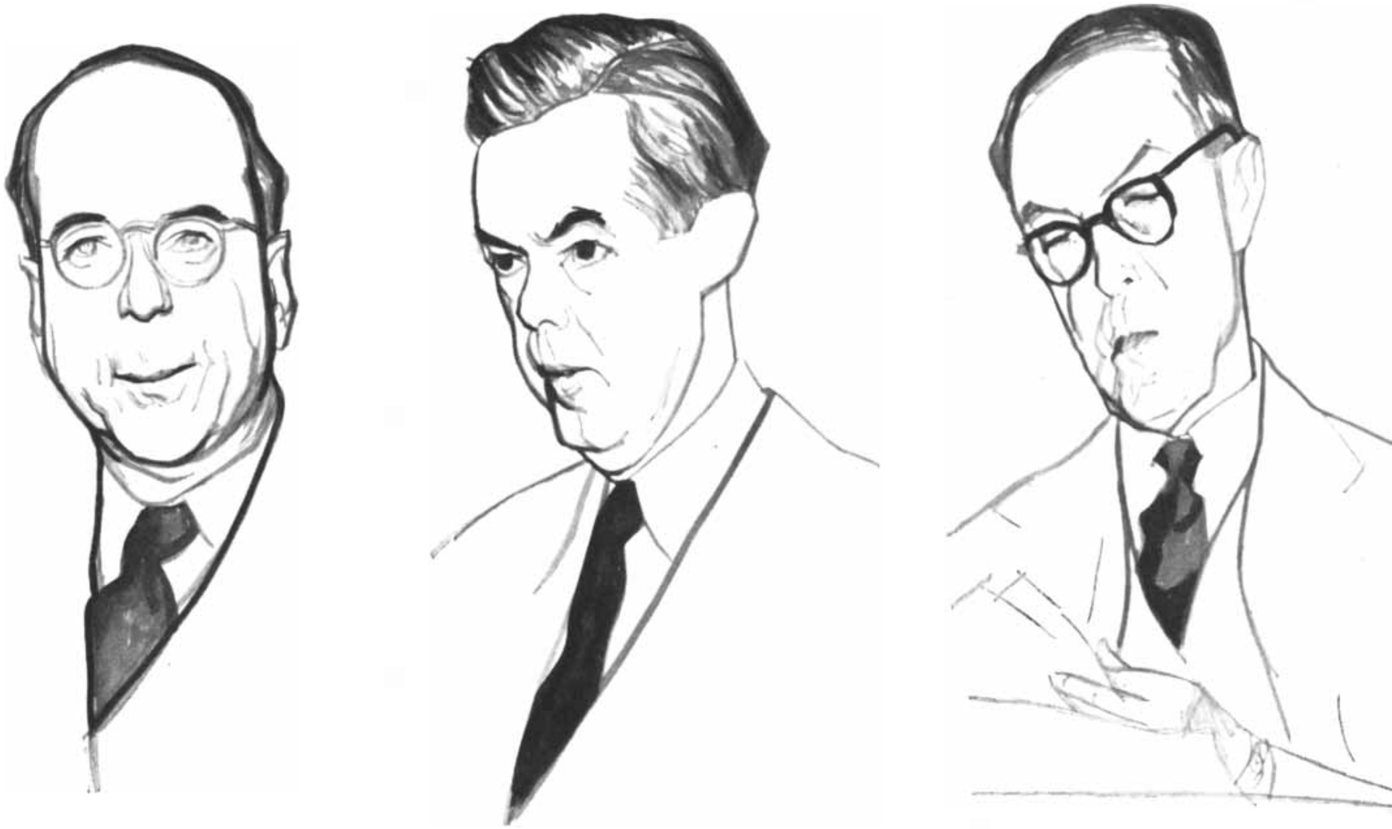
Of greater concern is the question as to how the AEC is to decide what is a "reasonable charge" for the atomic fuel it sells to licensees, and what is a "fair price" for the fissionable products it buys from them. The Act gives relatively little guidance on these points. In setting its "reasonable charge" for fuel the AEC is directed to take its production costs into account, but if the average "fair price" paid to private producers for the same material is lower than its own production costs, it must sell at the lower figure. The standard for "fair price" is even more nebulous. The AEC is directed to consider production costs and the value of the purchased material for the use to be made of it. Certainly the value of, say, plutonium for bomb purposes is hard to gauge. If the plutonium is acquired with a view to resale, the "fair price" would seem to depend on the "reasonable charge," but this may depend on "fair price." Furthermore, the "fair price" must be uniform to all producers; will the higher-cost producers consider a price "fair" if it fails to cover their production costs? Covering them may push the "fair price" paid by the AEC to a level well above its own production cost. In that case the AEC may have to sell fissionables at a low price and buy them at a higher one, thus subsidizing the industry, especially the lower-cost producers who would need it least. To cap the matter, the AEC is authorized to commit itself to paying a fixed, guaranteed price for a period up to seven years ahead.

In the Congressional debate no one objected to the major source of this difficulty: the fact that the Government must hold title to all special nuclear materials and thus take all the material produced by private operators. This Government monopoly is not dictated by any Constitutional or international control consideration. Yet it will prevent the U. S. economy from benefiting fully from the creation of a private atomic industry. The impact of the efficient producers will be blunted by the Act's price-setting standards. Moreover, producers will lack incentive to open new markets for fissionables by cutting prices. If a subsidy is necessary, surely a better one could be devised.

Government ownership of fissionables gives rise to another concern. Suppose the AEC licenses a number of dual-purpose reactors providing both plutonium and electric power. What will it do if and when the U. S. decides that it has enough atomic weapons? The private reactors will still go on producing plutonium, and title to every gram they produce will promptly pop into the Government, carrying with it the duty to pay a "fair price." No doubt if the market for plutonium were glutted the AEC would stop issuing new licenses, and it might stop the output of surplus plutonium by an existing licensee by denying it new fissionables. But this would be a death sentence for the licensee. Can industry take this risk?

A third major question about the new Act is: Do the patent provisions provide adequate incentives and safeguards? The Act allows an inventor to patent his invention or discovery (save for military uses), but it requires him to license the invention to the AEC and others if it is of "primary importance" in the "production or utilization of special nuclear material for atomic energy," if the patent is of "primary importance" to the activities of the applicant and if his activities are of "primary importance" to the effectuation of the Act. The AEC may order a reluctant patentee to license an applicant at a reasonable royalty, provided the applicant can prove his case fulfills the three requirements. Obviously the hurdles the applicant must clear will deter recourse to such appeals for compulsory licensing. Probably it will remain a tool to aid in bargaining save in exceptional cases where the interests at stake are great. It may also induce many inventors to seek "awards" from the AEC instead of patents.

Yet even this well-hedged clause alarmed the Joint Committee's chairman, Representative W. Sterling Cole, Republican of New York. He declared that the compulsory licensing provision was unconstitutional, arguing that, since the Constitution gives to the Congress the power to grant an "exclusive right" to inventors, Congress cannot make any lesser grant (a contention of dubious legal validity). Cole did not succeed in eliminating compulsory licensing from the final Act, but he did manage to include a provision of his own giving the Government the patent on any invention made under any contract or other relationship with the AEC, unless the



ATOMIC ENERGY COMMISSIONERS are depicted in these drawings by William Auerbach-Levy. At the left is Lewis L. Strauss, chairman of the Commission. Second from the left is Commissioner Thomas E. Murray. Third is Commissioner Joseph

inventor could prove that he had conceived the invention independently. One trouble with this is the difficulty of proving a negative, as the applicant must often do to rebut the presumption that the invention was conceived because of connection with the AEC. The big companies wishing to take advantage of their new freedom under the new Act are also companies which have been active as AEC contractors and presumably will continue to be so for many years. It is hard to see how their employees will be able to prove that they have not at some time come into contact with AEC work which may have inspired their inventions. Indeed, Cole's provision may prove much more depressing to private invention than the compulsory licensing provisions.

The Act, as the President recommended, limits the period during which new patents are subject to compulsory licensing to the next five years. It should be noted that compulsory licensing will apply to patents issued during that period throughout their 17-year lifetime and not merely for the five years. Whether the next five years will be the period of most important invention is, of course, unknown; the five years following may be still more active, especially if many companies stop doing contract work for the AEC.

In gauging the significance of the patent problem, one must give due weight to the fact that the discoveries will fall principally in the domain of the equipment manufacturers, not of the power companies. Probably the pressure to reduce the cost of atomic power to a level competitive with conventional fuels will deter excessive charges for equipment. There may even be a pooling of patents of the sort that was so helpful in launching the automobile industry.

The atomic-patents situation is likely to remain clouded for the next five years.

A fourth major question about the Act is: Does it adequately fulfill its purpose of promoting international cooperation in the development and use of atomic energy?

The 1946 Act blocked the disclosure of restricted atomic information to other nations, however friendly. The atomic bomb was our "secret," and we were taking no chances with it—except the chances involved in failing to give to an ally military information essential to effective cooperation. In time the self-defeating character of rigid restraints became clear. In 1951 the Congress edged closer to cooperation in military matters by a tightly drafted amendment authorizing some disclosure of restricted data to friendly nations.

The new Act goes further. It authorizes the President to make agreements for cooperation with other nations or regional defense organizations. The agreements do not require Congressional approval, though they must be submitted to the Joint Committee for its information 30 days in advance. The Government may export source and by-product materials, fissionables and production and utilization facilities. However, there are precautions and restrictions aplenty. Besides the President, the AEC and (on military matters) the Defense Department must give assurances that the cooperation is in the interests of the U. S.; the cooperating nations must guarantee not to divert materials granted for peaceful uses to military purposes, and they must contract to observe strict security safeguards.

The authority to transmit nonmilitary information is wide, but disclosures of military data are limited to those which will not "reveal important information concerning the design or fabrication of the nuclear components of an atomic

Campbell. Fourth is Commissioner Willard F. Libby, recently appointed. Fifth is Henry D. Smyth, who recently resigned. One of the five commissionerships is presently vacant.

weapon." Our allies may be told only the weapons' external characteristics, energy yields, effects and methods of delivery.

There was no debate on these provisions. But the President's atomic pool plan seemed to present a greater hazard; the pool might have United Nations sponsorship and the Soviet Union might join as a cooperator. Facing this contingency, the Congress required that any plan for pooling material and work in the nonmilitary applications of atomic energy among a group of nations must be authorized by "an international arrangement"—defined as a treaty or an agreement approved by both Houses.

Senator John O. Pastore of the Joint Committee sought to limit the safeguards in the case of a pool to the same ones provided for binational cooperation, but his amendment was tabled by a 46 to 41 vote, leaving for future discussion whether the Congress may constitutionally condition in this manner the President's freedom to enter into executive agreements with other nations.

The chairmanship of the AEC was another issue in the debate. The Joint Committee hearings on the bill had brought into the open suspicions that, under the chairmanship of Admiral Lewis L. Strauss, the AEC was not a happy family. After hearing testimony from three of the Commissioners concerning the tendency for authority to centralize in the Chairman, the Committee discarded a proposal to designate the chairman as "principal officer" of the Commission and designated him instead as "official spokesman," charged with seeing to the execution of the Commission's decisions and reporting to the Joint Committee from time to time. Representative Holifield, in dissenting from the Committee report, characterized this provision as "either redundant or a roundabout way of granting him [the chairman] the additional authority he seeks."

Perhaps this is a problem that legislation cannot solve. The Chairman's temperament may be more consequential than the statutory description of the hat he wears. A chairman may be a good executive and yet lack the nice ability to draw effectively on the collective wisdom of his peers.

Behind all the argument over the Act lurked a big undebated issue: secrecy. Many have complained that the secrecy of atomic operations has impeded both the advancement of scientific knowledge and the creation of an informed public opinion. These critics had no aggressive spokesman in the Congress. Indeed, in the new Act the Congress imposed a sweeping new criminal sanction: a fine of $2,500 on any past or present employee of the AEC, other government agency, contractor or licensee, or any member of the Armed Forces, who communicates restricted data to unauthorized persons. It must be shown that the defendant knew, or had reason to believe, that the data were restricted and the recipient unauthorized, but even so the provision is scarcely a stimulus to free discussion, blanketing as it does virtually everyone who has ever known a classified fact.

The Act calls for a "continuous review" by the AEC of material that may be declassified "without undue risk" and encourages such action. Happily it also allows the AEC to prescribe clearance investigations of personnel according to the work to be done and the significance of the restricted data involved. Sensible use of this measure will reduce needless barriers of delay and inconvenience to scientific work. Moreover, the new Act's general thrust toward wider participation by industry and other countries may embolden the AEC to move more rapidly toward restoring nuclear knowledge to the public domain. Much depends on whether the law is administered reasonably or overcautiously.

As the 1954 Act emerges from the clouds of debate, one can still see part of the atomic "island of socialism" in the Federal archipelago—along with the Army, Navy, Air Force and Post Office. And the part of the island that has subsided does not leave clear sailing for private enterprise. An industry to which entry is by government permit, which requires government authority to construct its plants and acquire its raw material and fuel, which can sell its nuclear products only to the government and its radioactive by-products only to government licensees, which is subject to regulation of the price it may charge for its power output, which must license its main inventions and employ only licensed operators, is a far cry from the world of Adam Smith. It presents a mixed economy, perhaps a mixed-up one. What we have in the 1954 Act is an experiment which was rather hastily designed but which, fortunately, can be tested and restudied without putting major values in jeopardy. I look forward to the Atomic Energy Act Amendments of 1959.

THE ORIGIN OF METEORITES

Before they crash to earth these stony or metallic objects are exposed to cosmic rays. Helium produced by this bombardment provides a new clue to the planetary catastrophes of the past

by S. Fred Singer

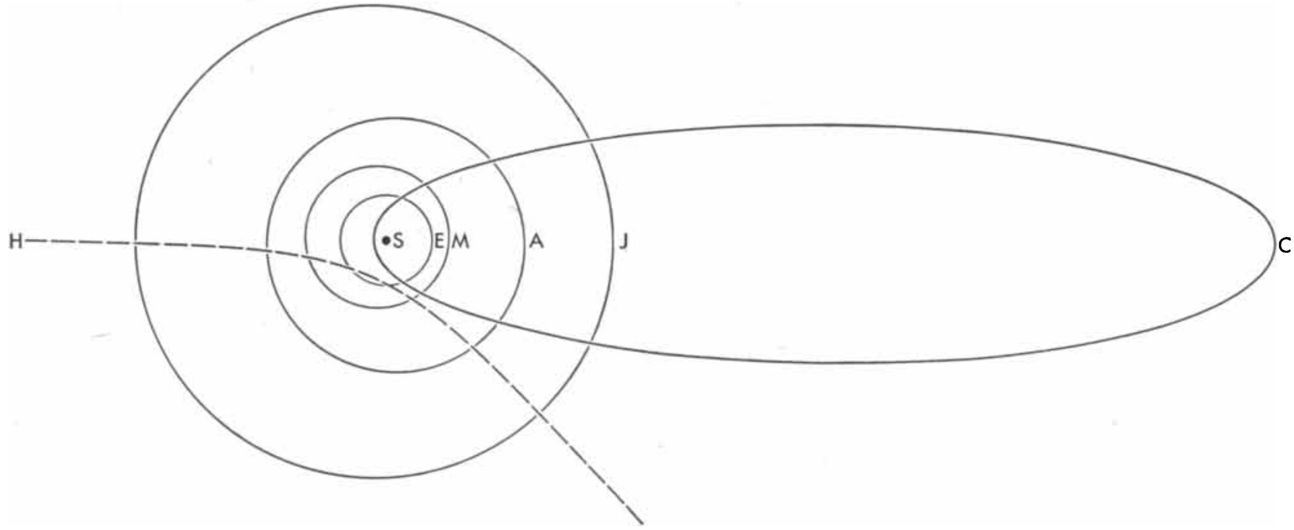
Of all the astronomical objects that we study, meteorites have a very special fascination. They are the only objects coming to us from outer space—the one sample of stuff from the great universe outside the earth that we can handle and analyze in the laboratory. As tangible clues to what has happened and is happening out there, they have been the subject of a great deal of absorbing detective work. We can now piece together much of their life history, and from this some of the story of the solar system.

Primitive peoples made objects of worship of the stones falling from heaven; later in more sophisticated times the notion that these lumps of matter fell upon the earth from space was dismissed as an old wives' tale. In 1803 Jean Biot produced evidence which satisfied the French Academy that the stones did indeed come from outside our planet. Today they are being investigated with the manifold tools of modern science—astronomy, geology, metallurgy, chemistry, nuclear physics and the helpful testimony of cosmic rays. The chief questions on which these studies have focused are: Where do the meteorites come from? What produced them? How old are they?

Let us clearly distinguish the meteorites from the other strange small objects that wander about in our solar system. Meteorites seem to have nothing in common with meteors—those tiny particles, believed to come from comets, that plunge into our atmosphere from space but burn up before they can fall to earth. The meteorites apparently have a very definite kinship with the asteroids, fragments of a former planet or planets. However, the meteorites are differentiated from the roving asteroids by definition: meteorites are bodies (probably small asteroids) that have fallen—and been found—on the earth.

The largest known meteorite is a 60-ton fall in South Africa called Hoba West. The largest "in captivity" is one of 33 tons at the Hayden Planetarium in New York City. Found by Eskimos in Greenland and named *Ahnigito*, it was brought to the U. S. by the explorer Robert E. Peary in 1897. Meteorites range in size from these giants down to very small pebbles. It is estimated that about four or five fall on the earth each day, but comparatively few are found. The total number so far discovered on the earth is about 1,400.

There seems to be little doubt that meteorites come from within the solar system, and that they are in fact small asteroids, which is to say, remnants of one or more solar-system planets that disintegrated and scattered their



TYPICAL ORBITS of an asteroid (A) and a comet (C) around the sun (S) are compared with the orbits of Earth (E), Mars (M) and Jupiter (J). A body which did not belong to the solar system and was not captured by it would have a hyperbolic orbit (H).

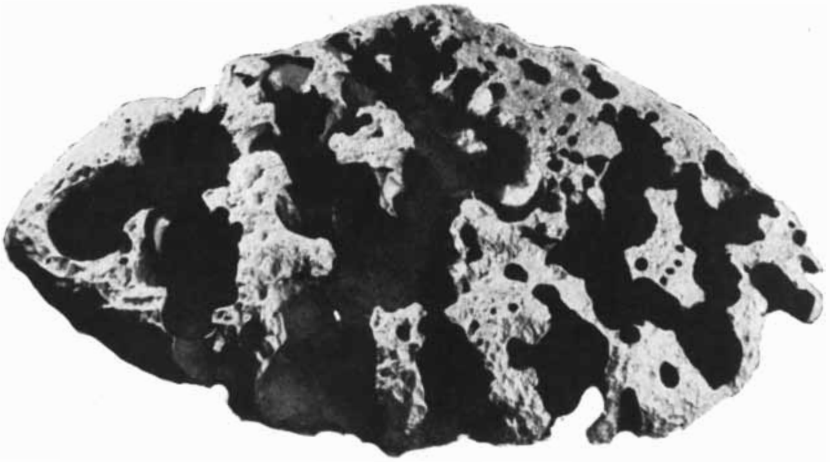
fragments in our system. Fred L. Whipple of the Harvard College Observatory has concluded that meteorites have orbits like those of asteroids. Studies of the effects of their flight on the meteorites themselves confirm the idea that they originate in the solar system. An analysis of the residues of cosmic-ray hits on their surface shows that little of the meteorites' "skin" has burned away; their flight velocity must therefore be comparatively low—well below the "escape" velocity that would be required if they entered the solar system from interstellar space.

The probability that the meteorites are fragments of planets has opened up the exciting possibility of analyzing in detail the stuff of which planets are made (even on our own planet we can examine only the crust and know little about the interior) and of discovering how, when and why the missing planets disappeared.

The meteorites are of two types: stony and metallic. The latter consist mainly of iron, plus substantial amounts of nickel. The iron meteorites survive the trip through the atmosphere better than the stony ones; they are also more easily distinguished from terrestrial rocks—hence more of them are found. The analyses to be described in this article will concern mainly the iron meteorites, because they have yielded the most interesting information.

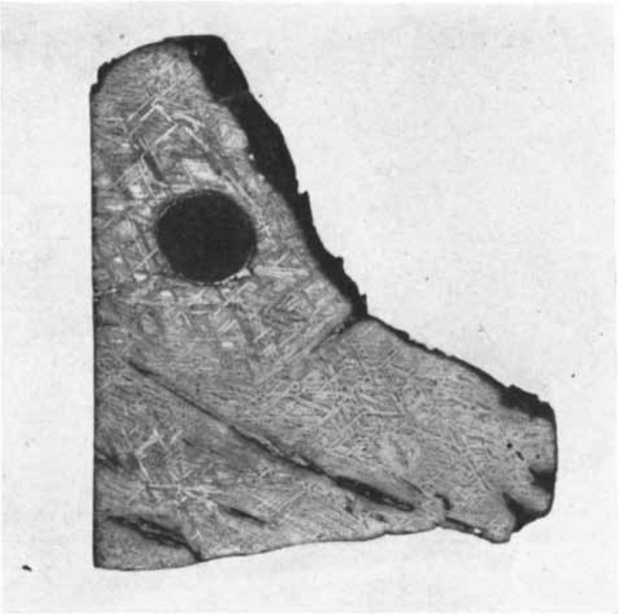
Chemical and metallographic studies of the meteorites give us a general outline of the history of the planets of which they were presumably a part. We may imagine that a planet was once in a molten state. The heavier metallic components gravitated toward the center, while a nonmetallic slag, floating, so to speak, on top, began to form the crust of the planet. H. H. Uhlig of the Massachusetts Institute of Technology has investigated certain crystalline patterns in the iron meteorites which shed light on the planet's subsequent history. These formations, called the Widmanstätten pattern, are made up of separated bands of iron, some with a low nickel content (about 6 per cent) and some with a high nickel content (about 40 per cent). Now it turns out that the Widmanstätten pattern can be reproduced on a smaller scale in the laboratory by very slow cooling of a hot synthetic iron-nickel mixture. Hence we may conclude that the crystal structures were formed in the meteorites by extremely slow cooling from high temperatures; the sizes of the crystals indicate that the cooling period

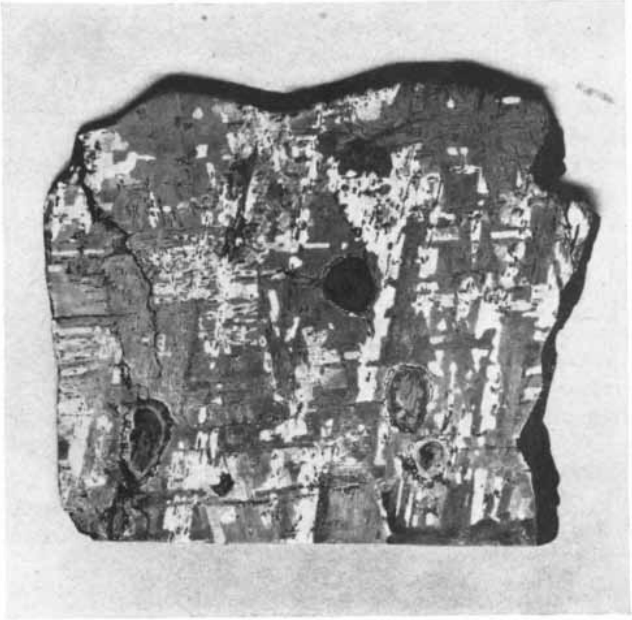
AHNIGITO METEORITE is the largest "in captivity." It weighs 33 tons. Found in Greenland, it was brought to the U. S. in 1897. It is in the Hayden Planetarium in New York City.

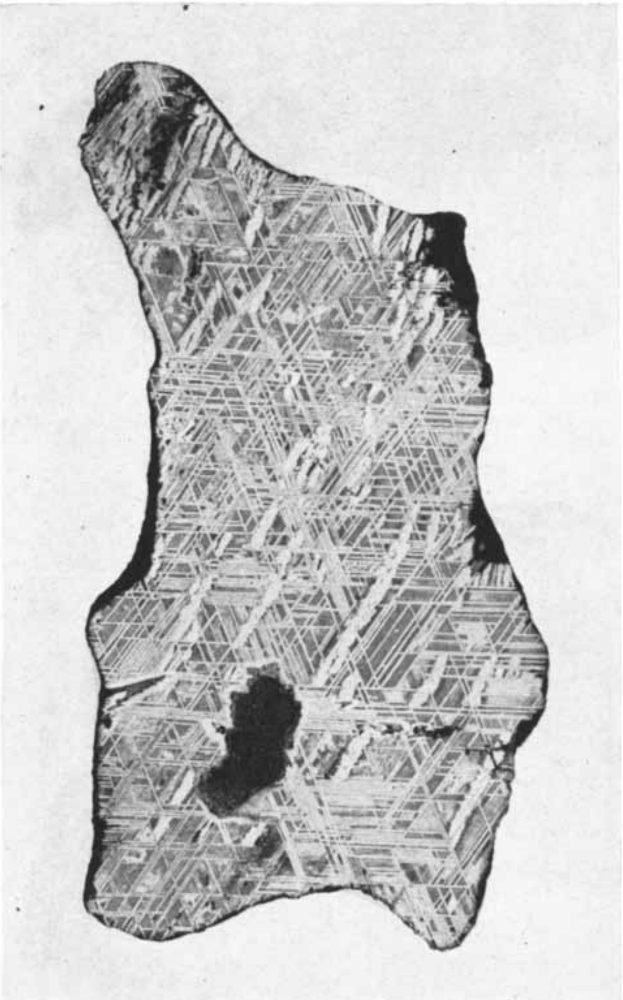


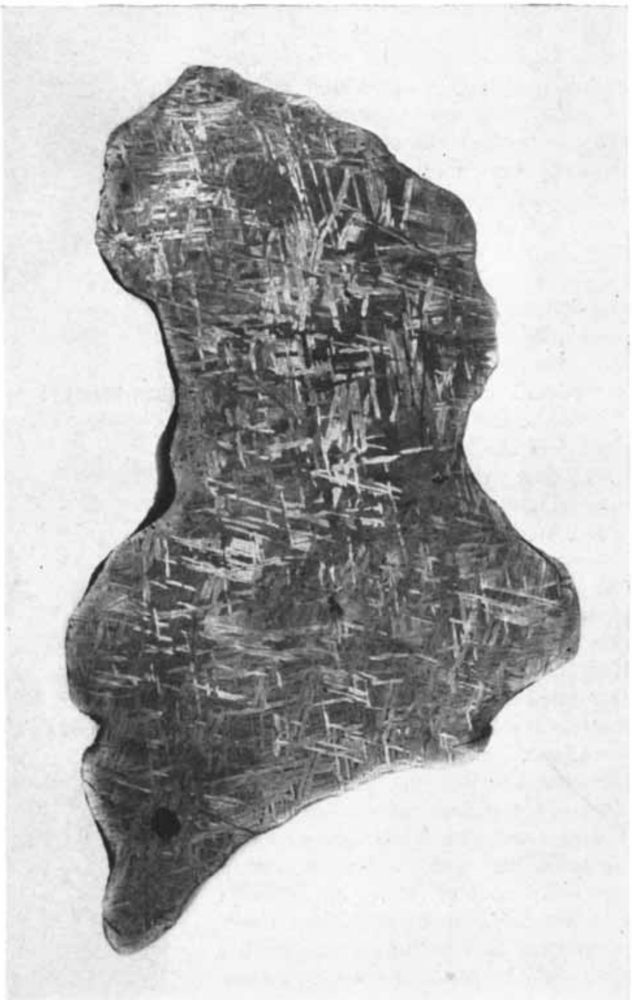
WILLAMETTE METEORITE is also in the Hayden Planetarium. It was found in the Willamette Valley of Oregon. The deep pits in its surface appear due to terrestrial corrosion.

GOOSE LAKE METEORITE is in the Smithsonian Institution in Washington, D. C. It was found in northern California. These pits appear due to collisions with other meteorites.









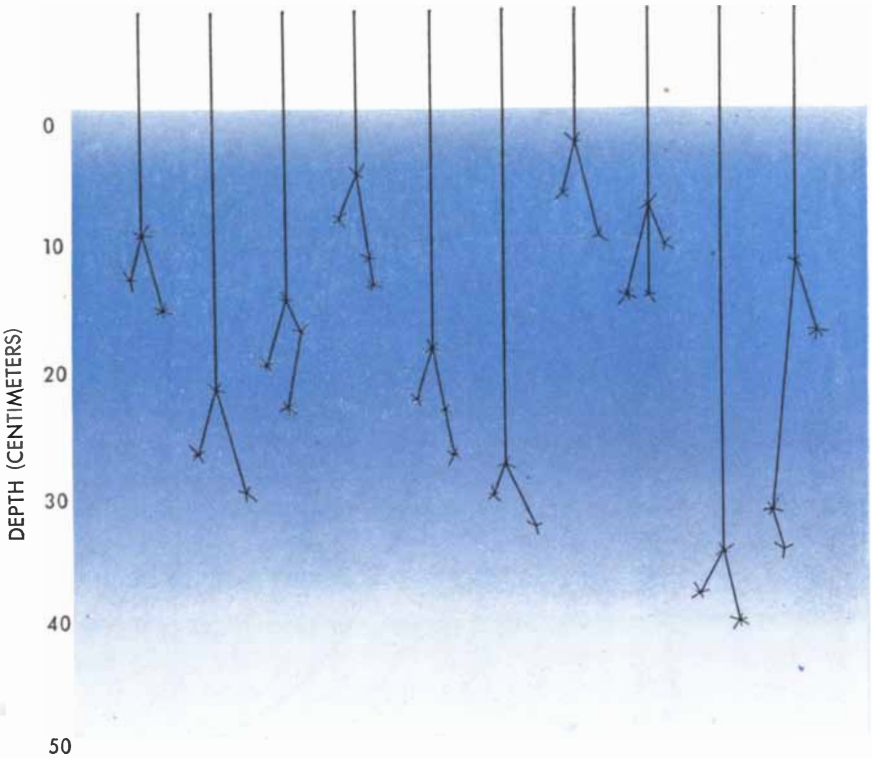
WIDMANSTÄTTEN FIGURES are made by cutting a meteorite, polishing the cut surface and etching it. The pattern preserves the orientation of the large crystals that formed in the metal when it slowly cooled from 1,500 degrees centigrade. When the metal had cooled to 1,000 degrees, it separated into two phases: a nickel-poor phase (kamacite) which formed wide bands, and a nickel-rich phase (taenite) which formed narrow bands. At upper left is the Apoala meteorite from Mexico; at upper right, the Wichita County meteorite from Texas; at lower left, the Drum Mountains meteorite from Utah; at lower right, the Edmonton meteorite from Kentucky.

was of the order of millions of years. A second conclusion reached from the laboratory studies is that the Widmanstätten figures were formed under pressures of many thousands of atmospheres. Both of these observations strongly suggest that the solidification of the liquid iron mass took place in the interior of a fair-sized planet.

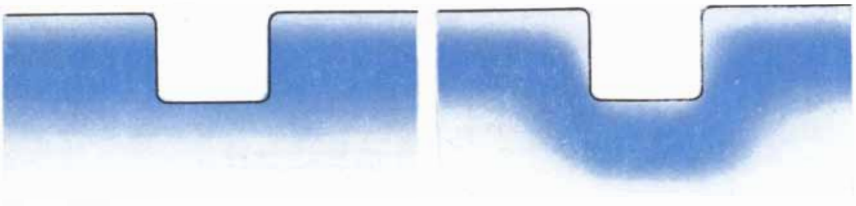
On detailed microscopic examination metallurgists can even see in the meteorites evidences of the sudden release of pressure, presumably due to an explosive collision, which disintegrated the planet. The signs are certain distortions in the crystal structure and sudden transformations of phase in the content of the iron-nickel alloy.

Perhaps the most fascinating part of the detective story is the search for clues to the age of the meteorites, or, in other words, the date of the catastrophic explosion of the planet. This is where nuclear physicists entered the case, and their tool was the clock of radioactivity, which spans centuries, millennia and even billions of years ["Radioactivity and Time," by P. M. Hurley; SCIENTIFIC AMERICAN, August, 1949]. In 1928 F. A. Paneth of the University of Durham set out to apply this technique to determine the geological age of meteorites. His clock was uranium, and the measure of time was the yield of helium from the uranium's radioactive breakdown in the course of geological eons.

To appreciate the difficulties of making such measurements, we must realize that iron meteorites contain extremely small amounts of uranium—of the order of one 100-millionth of a gram per gram of iron—and the helium content is correspondingly small—something like one millionth of a cubic centimeter per gram of meteorite material. Over the years Paneth and his colleagues developed methods of measuring such minute quantities of helium, and in 1945 they were able to give what were thought to be fairly reliable geological ages for a number of meteorites. These "ages" turned out to be very strange indeed. They ranged from less than a million years (for the Greenland meteorite *Savik*) all the way up to about 7.6 billion years for the Mount Ayliff meteorite. This astounding figure, as Paneth himself pointed out, was roughly twice the estimated age of the solar system.



PRODUCTION OF HELIUM in an iron meteorite by cosmic rays is due to the disruption of nuclei by primary and secondary particles. The distribution of helium is in blue.

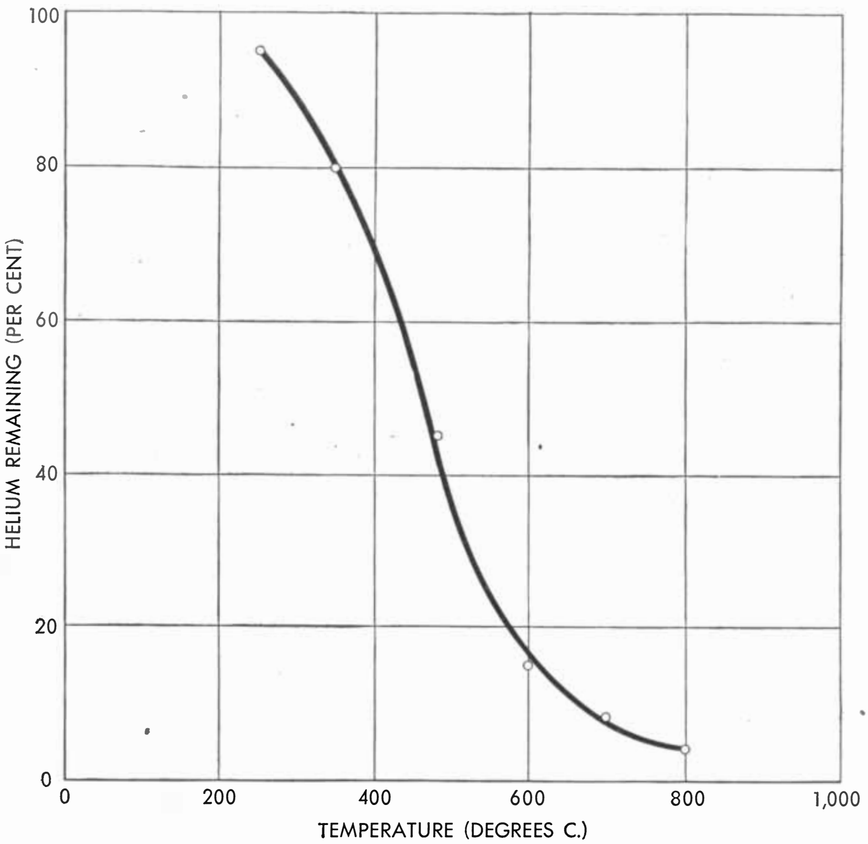


DISTRIBUTION OF HELIUM around pits on the surface of an iron meteorite would depend upon whether the pits had been formed before the meteorite fell (*left*) or after (*right*).

How to explain these remarkable results became a burning problem. In 1947 Whipple and C. A. Bauer at Harvard, and independently H. E. Huntley in South Africa, suggested that perhaps energetic cosmic rays had contributed some helium to the meteorites by breaking down atoms into alpha particles (helium nuclei). Bauer developed these ideas in some detail, but his suggestions did not gain wide acceptance.

In 1950, after a visit to Paneth's laboratory during which he told me of the problem, I decided to re-examine the influence of cosmic rays in greater detail. Calculating precisely what effects the bombardment of cosmic rays would have on a small iron body, such as a meteorite, in space, I got some interesting results. It appeared that not only would energetic cosmic rays break up iron nuclei and thus produce helium, but some of the less energetic secondary particles generated in these nuclear breakups, including pi mesons, would produce further disintegrations. As a result, cosmic rays (primary and secondary) should produce much more helium, and to a much greater depth in the meteorite, than Bauer had estimated.

Even more important, this detailed study led to the finding that cosmic rays, by disintegrating iron nuclei, would create not only the ordinary isotope helium 4, which corresponds to the alpha particles produced in radioactive decay, but also appreciable quantities of helium 3, which cannot be produced by radioactive decay. In fact, there should be about one helium-3 atom for every two helium-4 atoms. Here, then, was a powerful method of deciding the origin of the helium in meteorites: any helium 3 found must be due to cosmic rays. These predictions were strikingly confirmed



HELIUM LOSS in meteorites was demonstrated to be a function of temperature by F. A. Paneth of the University of Durham. The samples were heated for three hours at each stage.

	He CONTENT (10^{-6} c.c./gm.)	OBSERVED He^3:He^4 RATIO	He^3 CONTENT (10^{-6} c.c./gm.)	DIAMETER (cm.)
MOUNT AYLIFF	36.8	0.315	8.8	14.6
TAMARUGAL	23.6	0.309	5.57	42
CARBO	22.0	0.286	4.5	48
TOLUCA (DURHAM)	18.9	0.297	4.33	VERY LARGE
SAN MARTIN	1.76	0.168	0.255	
BETHANY (HARVARD)	0.36	0.178	0.055	150
TOLUCA (HAMBURG)	0.16	0.196	0.0267	VERY LARGE
SAVIK	<0.0002			220

HELIUM CONTENT of some iron meteorites is listed in this table. The diameters refer to the presumed size, as calculated by Paneth, of the meteorites before they fell to earth.

recently by K. I. Mayne at Oxford University. He found that the proportion of the helium 3 isotope ranged from 11 to 31 per cent. In helium on the earth, the percentage of helium 3 is never more than about one 10,000th of 1 per cent. Significantly the highest helium 3 percentage measured, 31 per cent, was found in Mount Ayliff, the meteorite that had been thought to be the oldest. The Oxford and Durham workers have also confirmed our predictions as to how the helium 3 content would vary with depth in a meteorite; they measured it in samples from various depths of the Carbo meteorite at Harvard.

It is of some interest to inquire into just how cosmic rays produce helium 3 and helium 4 from iron nuclei. The process can be pictured as follows: When a high-energy particle of the cosmic radiation hits a nucleus, it may knock out some protons and neutrons, which go on as cosmic-ray secondaries. The nucleus itself is left with some energy, perhaps several hundred million electron volts, which is very rapidly distributed among its remaining protons and neutrons. Speaking in classical terms, the nucleus "heats up" and "evaporates," somewhat like a drop of liquid evaporating molecules. Among the particles that come off in this nuclear evaporation are helium 3, helium 4 and hydrogen 3. Hydrogen 3 (tritium) is radioactive (half-life: 12½ years) and decays into helium 3; in fact, it is the major source of the helium 3 found in meteorites.

I have calculated that a meteorite as it hits the earth should contain a measurable quantity of tritium; from a freshly fallen meteorite we may obtain valuable information about the intensity of cosmic rays in the region of outer space from which it came. A question often asked is whether cosmic-ray bombardment makes the surface of the atmosphereless moon so radioactive that human explorers would need shielding. My calculations indicate that the moon's radioactivity is much too small to have any biological effects.

Now it seems a simple matter to correct the estimated ages of the meteorites with our new information: just subtract the cosmic-ray helium (all the helium 3 and twice that amount of helium 4), then calculate the age from the remaining helium, which must have come from the radioactive decay of uranium. When Paneth and his collaborators applied this correction recently, however, they came out with ages that were astonishingly young: it appeared that the material in nearly all the meteorites they examined had taken solid form only about 100 million years ago. This implied that the parent body from which the meteorites came had broken up even more recently.

It seemed to me that a better indication might be obtained by a different attack: namely, calculation of the length of time the meteorites had been wandering in space from the amount of cosmic-ray helium produced in them. This would give the date of breakup of the parent body. I concentrated on the helium 3 in the samples, and computed their lifetime as meteorites by dividing the amount of this cosmic-ray helium by the calculated rate of production. For Mount Ayliff, for Carbo and for two other meteorites, this time turned out to be at least 300 million years.

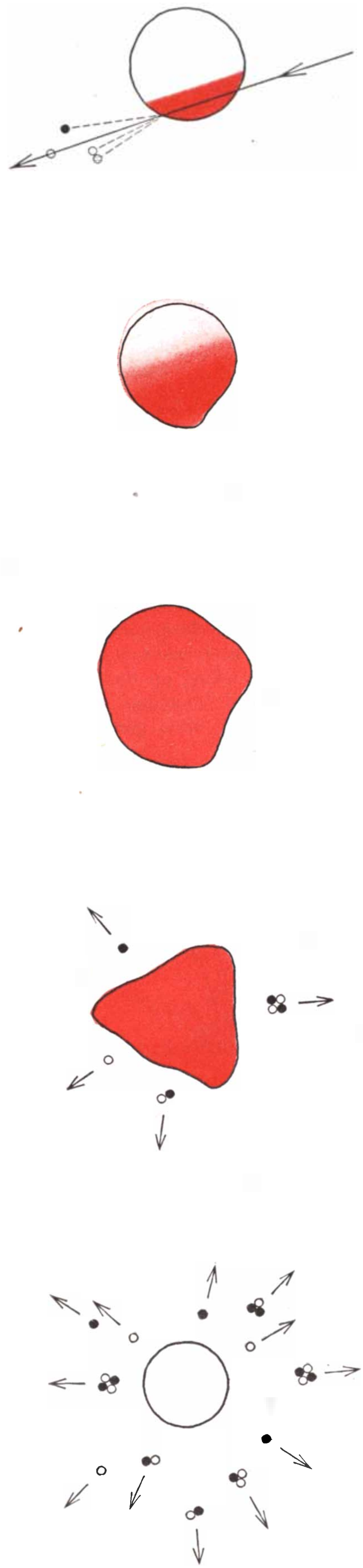
Paneth's group argues that this figure may be incorrect because it is based on the assumption that the intensity of cosmic radiation has been constant through all this time; they suggest that the cosmic-ray intensity may have been much greater in the past than it is now. I prefer another possible explanation of the discrepancy between the 300-million and 100-million figures. Their uranium-helium method made no allowance for helium leaking out of the meteorites. In terrestrial rocks helium produced by uranium's decay does leak out slowly, and it may be assumed that it also diffuses out of meteorites. On the other hand, there are reasons to believe that cosmic-ray helium does not leak out.

Why this fundamental difference between the two types of helium? One can hypothesize that cosmic-ray helium is created inside the iron crystals and is bound tightly, whereas uranium helium may escape easily because the uranium atoms are somehow separated from the iron atoms as the mass solidifies, so that they lodge in the spaces between the crystals. This point of view can be backed up by several pieces of evidence. It has been shown (1) that in iron meteorites the average content of uranium is much lower than in stony meteorites, (2) that the uranium is concentrated mainly in impurities (*e.g.*, iron sulfide) which separate out when iron-nickel crystals form, and (3) that uranium is relatively insoluble in iron, as Harold C. Urey has recently reported.

Now it is true that Paneth performed certain experiments which showed that very little helium leaked out of meteorite material even when filings from it were heated to a temperature of 1,000 degrees centigrade. However, the meteorite on which he carried out the experiment was Mount Ayliff, most of whose helium, as we know now, was produced by cosmic rays. Thus the experiment does not necessarily refute the hypothesis that radiogenic helium may escape easily. It should be possible to settle the issue by repeating Paneth's heating experiment on a meteorite that contains a large fraction of radiogenic helium, *e.g.*, the Bethany meteorite at Harvard. Our theory suggests that some helium 4 will disappear on heating.

To round out the picture, a group including Harrison Brown, the noted investigator of meteorites, has just reported after a study of radiogenic lead 206 (a uranium breakdown product) that the uranium in the meteorite must have been decaying for about 4.5 billion years. This "uranium-lead age" probably represents the time of solidification of the meteorite within the parent planet.

The present picture of the origin and history of meteorites, on the basis of the various lines of evidence described here and of a general account of the solar system proposed recently by G. P. Kuiper of Yerkes Observatory, is as follows. Some four to five billion years ago a group of small protoplanets about 30 to more than 500 miles in diameter formed from collections of dust between Mars and Jupiter. After they condensed, their internal radioactivity heated them very rapidly. They melted, but soon thereafter began to solidify. During this slow solidification the planets' matter separated into the metallic and stony phases. Widmanstätten figures formed in the iron-nickel phase as it cooled under high pressure in the planet core. Eventually the protoplanets collided with one another and broke up into asteroids and meteorites. The new cosmic-ray studies allow us to date these catastrophes—some seem to have taken place around 300 million years ago. It is hoped that detailed laboratory study of other meteorites will eventually enable us to identify meteorites belonging to the same protoplanet and to date the breakup of individual planets.



NUCLEAR EVAPORATION is depicted in these drawings. At the top a proton passes through an iron nucleus, knocking out another proton, a neutron and a pi meson. In the second and third drawings the entire nucleus is excited. In the fourth and fifth various simple and compound particles evaporate from the nucleus, leaving a smaller one.

The Courtship of Animals

The elaborate patterns of behavior that precede mating in some species present a puzzling biological problem. Their function is sought through the classic interplay of theory and experiment

by N. Tinbergen

When a golden pheasant cock displays his brilliant plumage before a hen, we are accustomed to say he is courting her. Just what this expression means when applied to a nonhuman animal is far from clear; the idea is so obviously anthropomorphic that zoologists have been reluctant to pursue it seriously by taking up the study of animals' so-called "courtship" activities. Yet these strange, often grotesque activities are there, like Mount Everest, and they have challenged some of us to explore them.

In contrast to such clearly motivated behavior as feeding or flight from predators, the courtship postures of animals are altogether puzzling, because it is difficult to see at first glance not only what circumstances cause them to occur but even what functions they serve. We may suppose that the male's display and activities stimulate the female to sexual cooperation, but even this elementary assumption has to be proved. And then we have to ask: Why does the female have to be stimulated in so elaborate a fashion, and what factors enter into the male's performance?

HERRING GULL CHICK "begs" for food by pecking at a red spot on the lower mandible of an adult. This behavior was studied by Tinbergen in order to check the "releaser" theory.

Among the famous students of animal courtship have been T. H. Huxley and F. C. Selous of England, J. Verwey of the Netherlands and, more recently, Konrad Lorenz of Austria. Encouraged by their work, I have, together with my associates J. van Iersel, M. Moynihan and D. Morris, studied the courtship of various animals for several years, and we believe we have discovered some highly interesting facts which may apply to many other animals besides the specific ones we have observed.

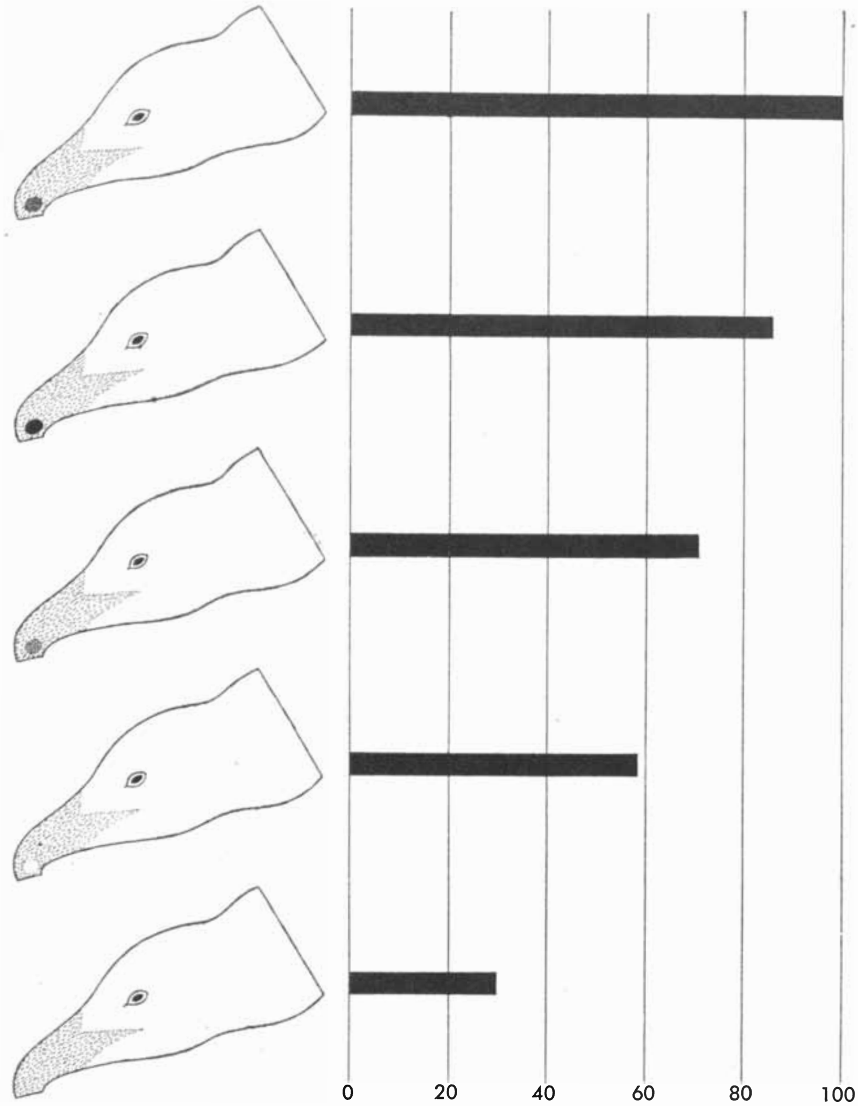
We started by experimentally checking the well-known "releaser" theory of Lorenz. This theory holds that many animals have evolved special organs whose only function is the presentation of specific stimuli to fellow members of the same species. Thus birds' songs often have the specific functions of attracting females and repelling males. The gaping mouths of songbird babies in the nest, according to this theory, prompt the parents to feed them. Lorenz suggested that the releasers included movements, calls, brightly colored structures and so on. The releaser theory goes back to Darwin's writings on sexual selection, but Lorenz described the functions of the releasers more exactly than Darwin could, and he united under one heading a wide variety of phenomena. His theory is the only attempt so far to define the survival value of structures such as the vocal organs of songbirds, and thus to indicate how selection can account for the evolution of such complicated organs. It is also an attempt to explain communication among socially cooperating animals. We have shown the application of the releaser theory to many kinds of communication among animals, and present here some examples.

That sounds commonly act as releasers is abundantly clear: one proof is the fact that animals respond to auditory signals, including imitations or recordings, with all other stimuli excluded. The strident screeching of locusts has been shown to act on the tympanic organs, and, through them, on the behavior of the recipients. So-called alarm signals of birds are another example: it is often possible to make a bird crouch or exhibit some other anti-predator response by imitating the alarm call of its species.

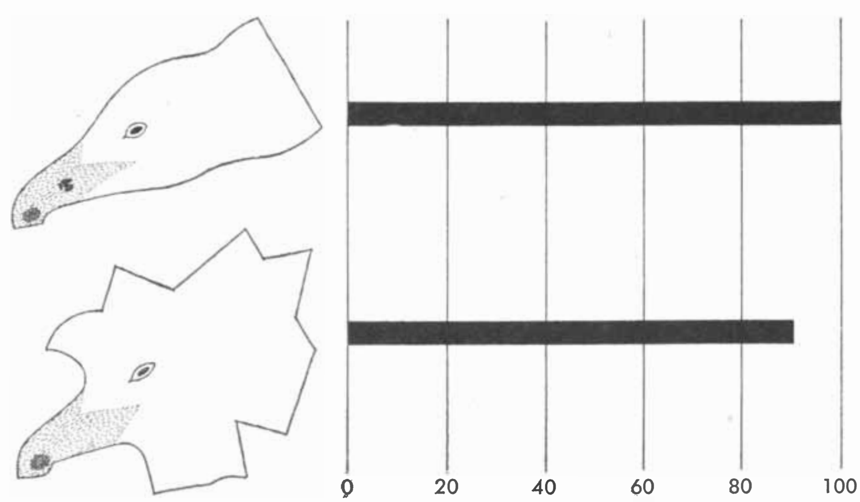
There is some evidence that odors act as releasers. The virgin females of many moths are known to attract males by specific scents. It has been shown that the female of the grayling butterfly does not cooperate in copulation if the male's scent organs on the forewings have been covered up.

As for visual releasers, an example is the typical mating posture of a willing female bird; among many birds, for instance, a male in sexual condition will mate not only with a female but also with another male or even with a stuffed or dead male, provided the latter is presented in the typical female posture. As another instance, the male grayling butterfly can be induced to pursue a dummy of almost any color, size or shape if the dummy is moved in a certain sexually inviting way. Again, the red patch on the lower mandible of the adult herring gull has been shown to release and direct food-begging behavior in the young. To take still another example, when the underside of a male three-spined stickleback fish turns red, it releases sexual behavior in the female.

We can conclude, then, that the releaser theory illuminates at least one aspect of courtship: the stimulation to sexual cooperation. Still, there is another side to the story. Every naturalist knows that these conspicuous displays must make their performers vulnerable to attack by predators. For this reason one might expect the releasers to be restricted to the bare minimum—just an occasional flash of bright color or a short outburst of calling, followed by an immediate reaction of the female. But that is not what happens. Courtship is usual-



INFLUENCE OF SPOT COLOR was tested by showing chicks models with red (*top*), black, blue, white and no spots. The number of pecks on model with red spot was given value 100.



INFLUENCE OF HEAD SHAPE was also tested with models. Both of these models had a red spot. The shape of the head had less influence on the chicks than the color of the spot.

ly a prolonged affair; the female's co-operation comes only hesitantly and after a period of hours, days or sometimes even weeks.

The English biologist Fraser Darling suggested as a possible explanation that the prolonged courtship might be necessary to stimulate the growth of internal organs indispensable for mating, such as the gonads and other endocrine glands. This may be true; the evidence is still meager. Our work suggests another reason, namely, that courtship serves not only to release sexual behavior in the partner but also to suppress contrary tendencies, that is, the tendencies to aggression or escape.

In many animals aggression and flight are just as important elements in reproductive behavior as the physical union itself. They serve the function of segregating the pairs, and thereby preventing overcrowding. The best-known examples is the system of staking out a territory. The males of many species of birds and of other animals select a territory in the spring and drive other males of their species away from it. Conversely, and this is just as important, males still searching for a suitable place do not waste their time and energy in hopeless battles to take one already occupied. All animals have developed a delicate balance between the tendency to attack and the tendency to flee. The relative strength of these two tendencies, the size of the distance kept between males, the stimuli by which each animal recognizes its own species—all these differ from one species to another. The function of the segregation system also varies widely: it may be to reserve a special nesting site or to guarantee sufficient food for the brood. In general it seems that the system serves to ensure to each breeding pair something that is essential for success in breeding.

When one studies hostile behavior between animals of the same species in detail, it becomes clear that much of it consists of "threat displays" rather than actual fighting. The object is to scare intruders away. Often the overt threat movements or postures combine elements of both attack and escape tendencies. For instance, the stickleback fish and some birds alternate short dashes toward the opponent with quick retreats; the herring gull and related species alternately bristle in a posture of attack and cringe as if to escape. Often the antagonists busy themselves with irrelevant "displacement activities"; thus an excited male stickleback may suddenly start digging purposelessly in the sand ["The Curious Behavior of the Stickleback" by N. Tinbergen; SCIENTIFIC AMERICAN, December, 1952]. Herring gulls show displacement collecting of nest material in the same situation. These activities have an intimidating effect on the opponent.

Now when, armed with this knowledge, one returns to mating behavior, one suddenly sees that much of the courtship of animals is very similar to their threat displays. In other words, if we are to judge by overt behavior (and on what else could we base our work?) we must assume that when male and

THREAT BEHAVIOR of the black-headed gull is shown in these three photographs. This behavior occurs when an unmated male lands in mating territory. In the photograph at the left the gull emits a "long call" and adopts an oblique posture. In the photo-

female come together they are motivated not only by sexual attraction but also by attack and escape tendencies.

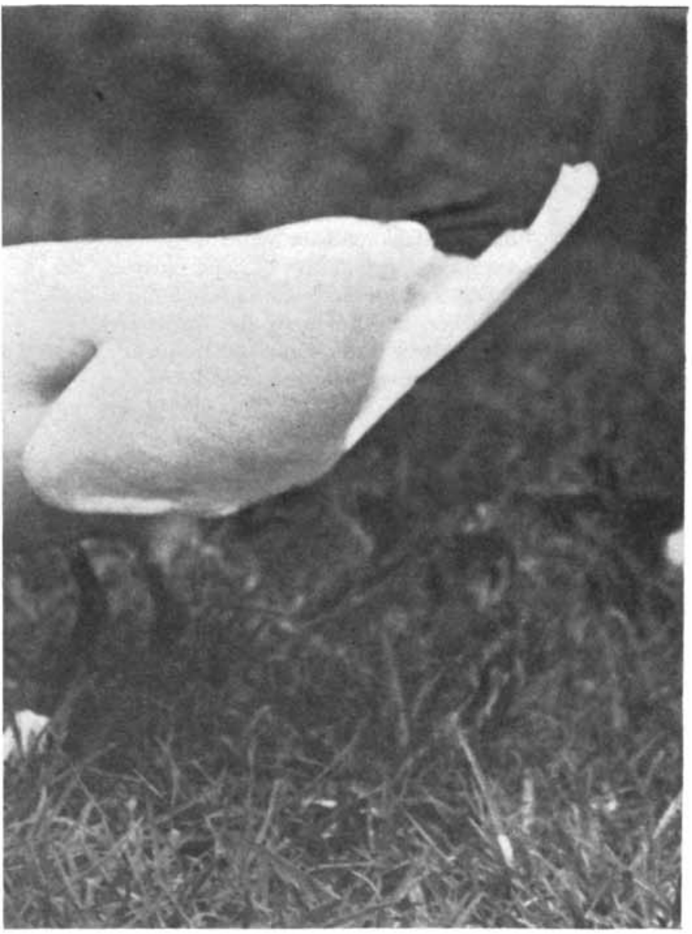
As an example let me give a brief sketch of what happens when gulls of the black-headed species form pairs at the beginning of the breeding season. The two sexes are very alike in color and in display, and aggressiveness is not an exclusively male attribute. An unmated male settles on a mating territory. He reacts to any other gull that happens to come near by uttering a "long call" and adopting an oblique posture [*see first photograph on next page*]. This will scare away a male, but it attracts females, and sooner or later one alights near him. Once she has alighted, both he and she suddenly adopt the "forward posture" [*second photograph*]. Sometimes they may perform a movement known as "choking." Finally, after one or a few seconds, the birds almost simultaneously adopt the "upright posture" and jerk their heads away from each other [*third photograph*].

Now most of these movements also take place in purely hostile clashes between neighboring males. They may utter the long call, adopt the forward posture and go through the choking and the upright posture [*see photographs below*]. All these movements may alternate with actual flights; the motivation underlying them has been shown to be a mixture of the tendencies to attack and to escape. Their function is intimidation; in other words, they are true threat postures.

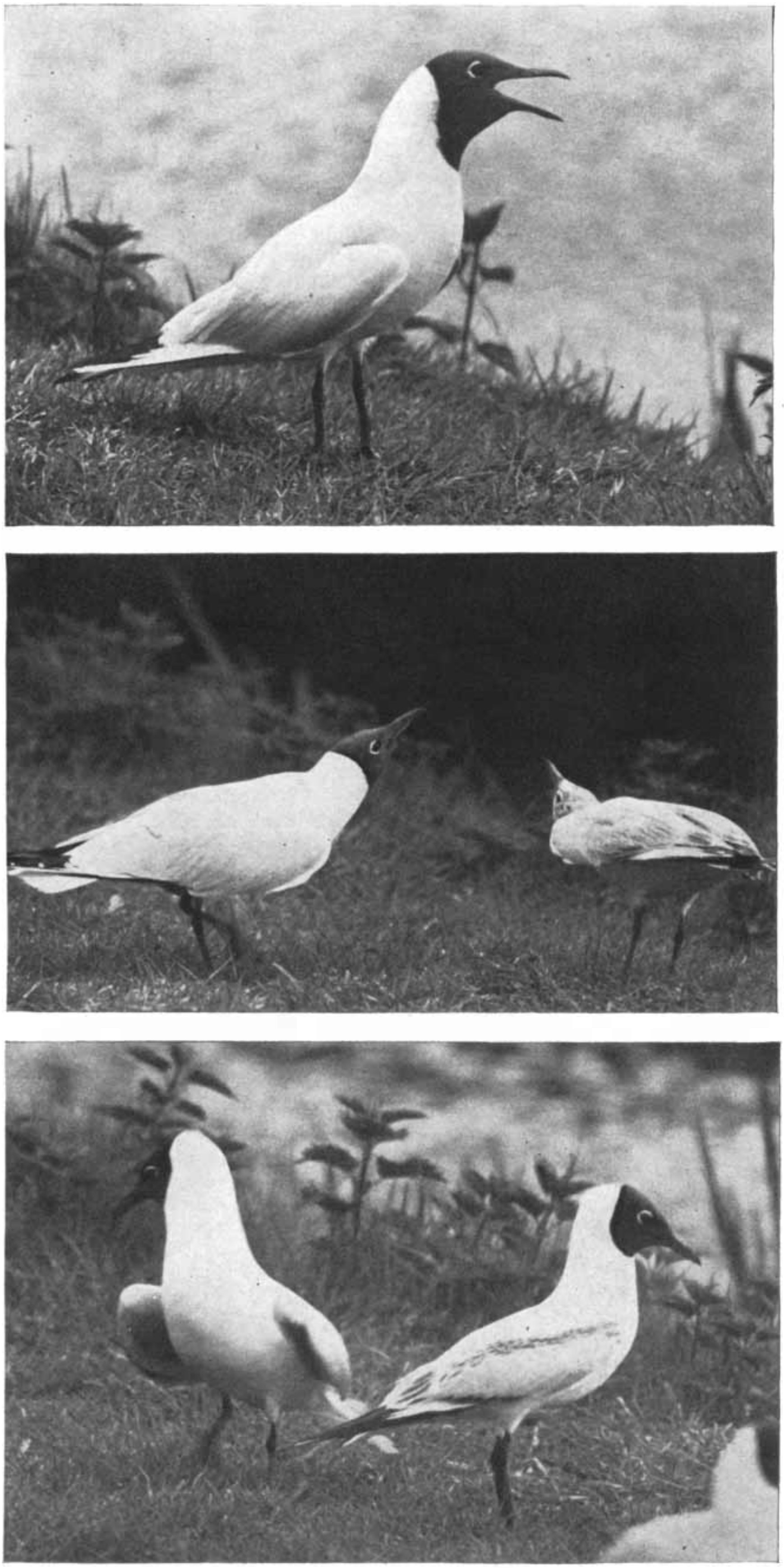
To those who have studied the reproductive behavior of various animals in natural surroundings it is not at all surprising that the male and female show signs of hostility. Despite the attraction between sexes, their close proximity to each other also evokes fear and aggressiveness. The spacing-out mechanism conflicts with the mating mechanism.

The final gesture in the courtship sequence—the partners' turning of their heads away from each other, or "head-flagging"—is different from the others: it is not a threat posture. Sometimes during a fight between two birds we see the same head-flagging by a bird which is obviously losing the battle but for some reason cannot get away, either because it is cornered, or because some other tendency makes it want to stay. This head-flagging has a peculiar effect on the attacker: as soon as the attacked bird turns its head away the attacker stops its assault, or at least tones it down considerably. However, he does not do so because he is intimidated; there is no sign of fear in his behavior. Head-flagging stops the attack because it is an "appeasement movement"—as if the victim were "turning the other cheek." The appeasement posture soothes the aggressor by removing the provocation, the attack-releasing stimulus. An appeasement posture is motivated by a mixture of the tendency to stay and the tendency to escape.

We are therefore led to conclude that in their courtship these gulls begin by threatening each other and end by appeasing each other with a soothing gesture. Their courtship sequence is ob-



graph in the center it adopts a forward posture, often accompanied by a movement called choking. In the photograph at the right it adopts an upright posture. The threat behavior of the gull is remarkably like its mating behavior (*photographs on next page*).



MATING BEHAVIOR of the black-headed gull includes elements of its threat behavior. In the photograph at the top the male adopts the oblique posture. In the middle both male and female adopt the forward posture. At the bottom they adopt the upright posture.

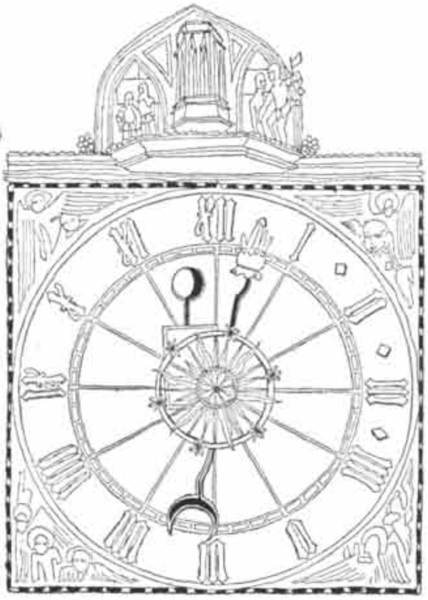
viously made up of three elements: sexual attraction draws the partners together, attack and escape tendencies make them adopt threat postures, and at the end increasing escape tendencies cause them to turn their heads away. After the head-flagging, one or both birds frequently fly off, only to return.

The black-headed gull is not an isolated case. We have learned that our courtship theory applies to many other birds (including various finches, tits, cormorants, gannets, ducks) and to animals of quite different groups, such as fish. The expression of the triple motivation is different in each case. For instance, the relative strengths of the attack and escape tendencies may be very different from those in the black-headed gull. Often the male is aggressive, the female timid. Also, the males of some species are much more aggressive than those of others. The male river bullhead, for instance, attacks the female, grabs her with his huge mouth and throws her into his burrow. The males of some finches, on the other hand, show very little aggressiveness; they are torn mainly between sexual attraction and fear.

Let us return to our starting question: Why is courtship so prolonged? A pair of black-headed gulls may repeat again and again the courtship sequence of approach, threat and appeasement. Often the female flees or the male flies off to attack another male before the sexual union is achieved. The partners repeatedly are reattracted to each other, however, and gradually the threat elements decrease in vigor and frequency, aggressiveness and fear die down and the purely sexual movements get the upper hand. How this comes about is not known in detail; the process is certainly different from one species to another. In the gulls it appears that hostility declines because the partners get used to each other as individuals. The sticklebacks do not learn to recognize individuals; it looks as if in their case the mere repetition and summation of sexual stimulation ultimately overrides fear and aggression.

It is still an open question whether this gradual change in the motivational situation is mediated by endocrine changes, such as growth of the gonads. Future research will have to settle this. Our theory, as very briefly outlined here, is but a first step in the unraveling of the complicated causal relationships underlying the puzzling but fascinating phenomena of courtship.

SCIENCE AND



Changes in the AEC

Henry D. Smyth resigned as a member of the Atomic Energy Commission last month to return to an academic post at Princeton University. As his successor President Eisenhower appointed Willard F. Libby, professor of chemistry at the Institute for Nuclear Studies in the University of Chicago. Another place on the Commission, left vacant by the expiration of Eugene M. Zuckert's term last June, has not yet been filled.

Pandora's Box

Aikichi Kuboyama, one of the 23 Japanese fishermen exposed to radioactive fall-out from the hydrogen bomb exploded at Bikini on March 1, died in a Tokyo hospital last month.

His death gave evidence that the thermonuclear weapon's lethal effects are not limited to the vicinity of the explosion. According to the newspaper columnists Joseph and Stewart Alsop, physicists have been increasingly disquieted by their calculations of the potential coverage of a hydrogen bomb's fall-out. A superbomb of five megatons (equivalent to five million tons of TNT) would, they estimate, shower lethal radioactivity over 6,000 square miles. Thus a hydrogen bomb dropped on the city of Hartford, say, would not only pulverize that city but would make the atmosphere deadly for two days afterward in the entire state of Connecticut.

A distinguished British scientist has suggested that if enough bombs are dropped it will make no difference what country they are aimed at or whether they hit the target. In his presidential address to the British Association for the Advancement of Science, the physiologist E. D. Adrian said: "The human race cannot stand more than a few thousand large atomic explosions. . . . Repeated explosions will lead to a degree of general radioactivity which no one can tolerate or escape."

In the opinion of A. H. Sturtevant, a California Institute of Technology geneticist, the contamination of the atmosphere is already sufficient to cause concern. He told a sectional meeting of the American Association for the Advancement of Science that every test explosion of a fission or a fusion bomb will increase the "ultimate harvest of defective individuals" in future generations. Genetically, Sturtevant declared, there is no "safe" level of radioactivity, "no threshold value below which radiation is ineffective." He deplored a recent statement by Lewis Strauss, chairman of the Atomic Energy Commission, that the increase in background radioactivity due to the bomb tests was far too small to be harmful. Said Sturtevant: "Every geneticist familiar with the facts knows that any level whatsoever is certain to be at least genetically harmful to human beings when it is applied to most or all the inhabitants of the earth. . . . I regret that an official in a position of such responsibility should have stated that there is no biological hazard from low doses of high-energy radiation."

Chemical Society Meeting

More than 13,500 chemists, a record number, attended the 126th national meeting of the American Chemical Society in New York City last month. A total of 1,416 technical papers were read before the meeting's 21 sections.

Announcement of a new process which may recover large quantities of uranium from an industrial waste product attracted much attention. Victor K. La Mer of Columbia University reported that he and two colleagues have developed a method of precipitating colloidal material out of the slime left from phosphate manufacture, which contains considerable uranium. La Mer's is the first practical process for removing solids from the muddy waste, now accumulating in huge artificial lakes at the rate of millions of tons a month. The process uses polyelectrolytes to make the ultrafine colloidal particles clump together.

High-temperature chemistry was the subject of a symposium. Most of the discussion revolved around unusual molecules, such as Na_2Cl_2 and multiple-atom carbon molecules, that are found in very hot vapors. W. A. Chupka and M. G. Inghram of the Argonne National Laboratory reported a new technique for measuring the heat of sublimation (heat required for vaporizing) of carbon. The figures for C, C_2 and C_3 are 170.4, 183 and 200 kilocalories per mole.

There were many reports on cancer research. Joseph W. Beard of the Duke University School of Medicine has isolated a virus which causes a disease in chickens resembling human leukemia. Unlike most viruses, this agent acts as an enzyme; it can break down adenosine triphosphate (ATP). Beard suggested that the enzyme property may explain the ability of certain viruses to disrupt normal cell activity and produce human cancers. N. P. Buu-Hoi of the Radium Institute in Paris put forward a new explanation for the cancer-inducing action of certain chemicals. Buu-Hoi believes that the molecules of carcinogens fit like keys into "holes" in cell proteins. Normally these holes contain growth-regulating substances. The substitution results in a derangement of growth and the production of altered cell protein which no longer has holes of the same shape and can accept neither growth-regulators nor carcinogens. Evidence of the theory is the fact that liver cells made tumorous by an agent called "butter yellow" are unable to bind this carcinogen to themselves, although normal liver cells take it up strongly.

Among other reports:

Fluorocarbon "elastomers" (rubber-like materials) will soon be commercially available. These substances will be useful in rubber applications where chemical inertness and resistance to heat and solvents are important.

The substances responsible for the lethal effect of certain smogs may finally have been identified. W. C. L. Hemeon of the Mellon Institute believes that they are tiny particles of so-called acidic salts—sulfates and chlorides of ammonia combined with zinc or other metals—which dissolve in the fluids of the respiratory tract and irritate the surrounding tissue.

Arthur I. Mirsky of the University of

Pittsburgh School of Medicine reported a new clue to the cause of diabetes. He has located a liver enzyme which destroys insulin. Diabetics may produce too much of the enzyme and thus deplete their own insulin supply.

A process for converting a liquid called acrylomide into a solid plastic by simple exposure to light has been developed by Gerald Oster of the Polytechnic Institute of Brooklyn. The solidification takes place without the high temperatures and pressures needed by the usual processes and is thousands of times faster.

Evidence that bacteriophage changes its shape under varying conditions of acidity and alkalinity was presented by Max A. Lauffer of the University of Pittsburgh. Changes in shape may figure in the mysterious methods by which the virus attaches itself to host bacteria, Lauffer believes.

Atomic Meat Packing

One of the most likely uses for the radioactive fission products from nuclear reactors is in sterilizing food. Irradiating pork with gamma rays, for example, eliminates any danger of its transmitting trichinosis. A group of researchers at the University of Michigan has now calculated that this treatment should add only about two tenths of a cent per pound to the meat.

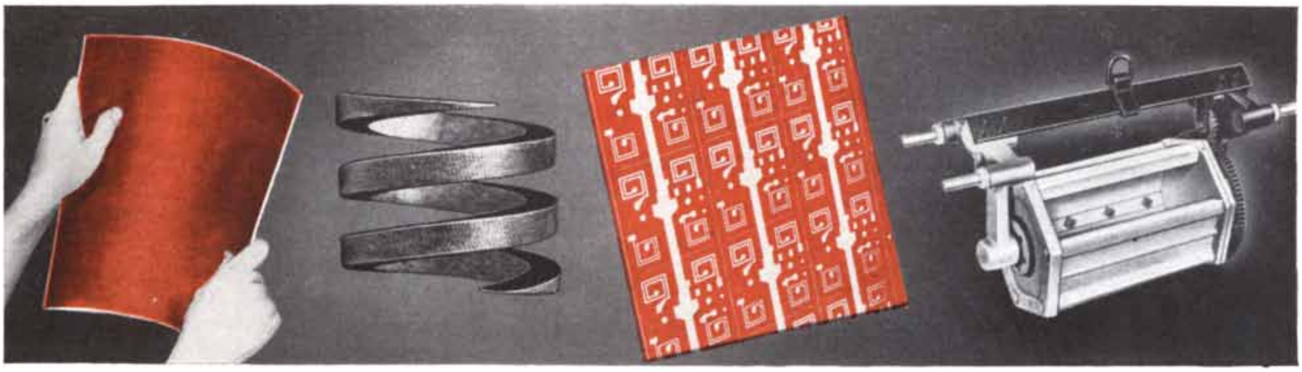
The estimate is based on a hypothetical irradiating plant which could process 2,000 hogs per day. The radiation source would be a six-by-five-foot wafer of cesium 137 with a radioactive strength of 1.5 million curies. Hog carcasses would be conveyed past this plaque at about six feet per minute. This exposure would be more than enough to sterilize all trichina throughout the carcass.

The initial investment in the irradiating plant is put at $566,000, of which $483,000 would be the cost of the cesium source. It would cost about $125,000 every five years to restore the full activity of the cesium.

The estimate was prepared by H. J. Gomberg, S. E. Gould, J. V. Nehemias and L. E. Brownell, who reported the figures in *Nucleonics*.

Viruses, New and Old

Improved tissue culture techniques are uncovering a great host of viruses whose existence had never been suspected. So reported a team of microbiologists at last month's International Conference of Pathologists in Washington, D. C. The group, headed by Robert



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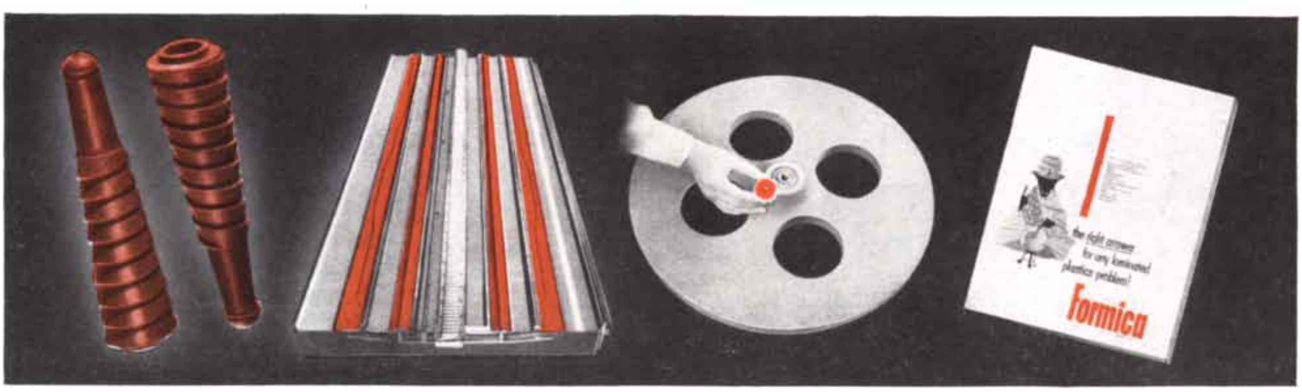

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J. Huebner of the U. S. National Institutes of Health, has found 35 new viruses in human adenoid tissue and 150 more in tonsils, throat and eye discharges and stools. The germs showed up only after bits of tissue were grown in the laboratory for long periods. In their original hosts their presence had been masked by antibodies.

The new viruses have been separated into six classes according to their immunological reactions with human and rabbit blood. Army doctors at Walter Reed Hospital later found some of the types in soldiers suffering from acute respiratory infections. It appears that a number of common, feverish respiratory illnesses may be caused by the newly discovered organisms. Immunological tests on Washington residents indicated that infection is most common in children and young adults.

John F. Enders, originator of the new tissue culture method for cultivating viruses, reported last month that he believes he has at last caged the elusive measles virus in the test tube.

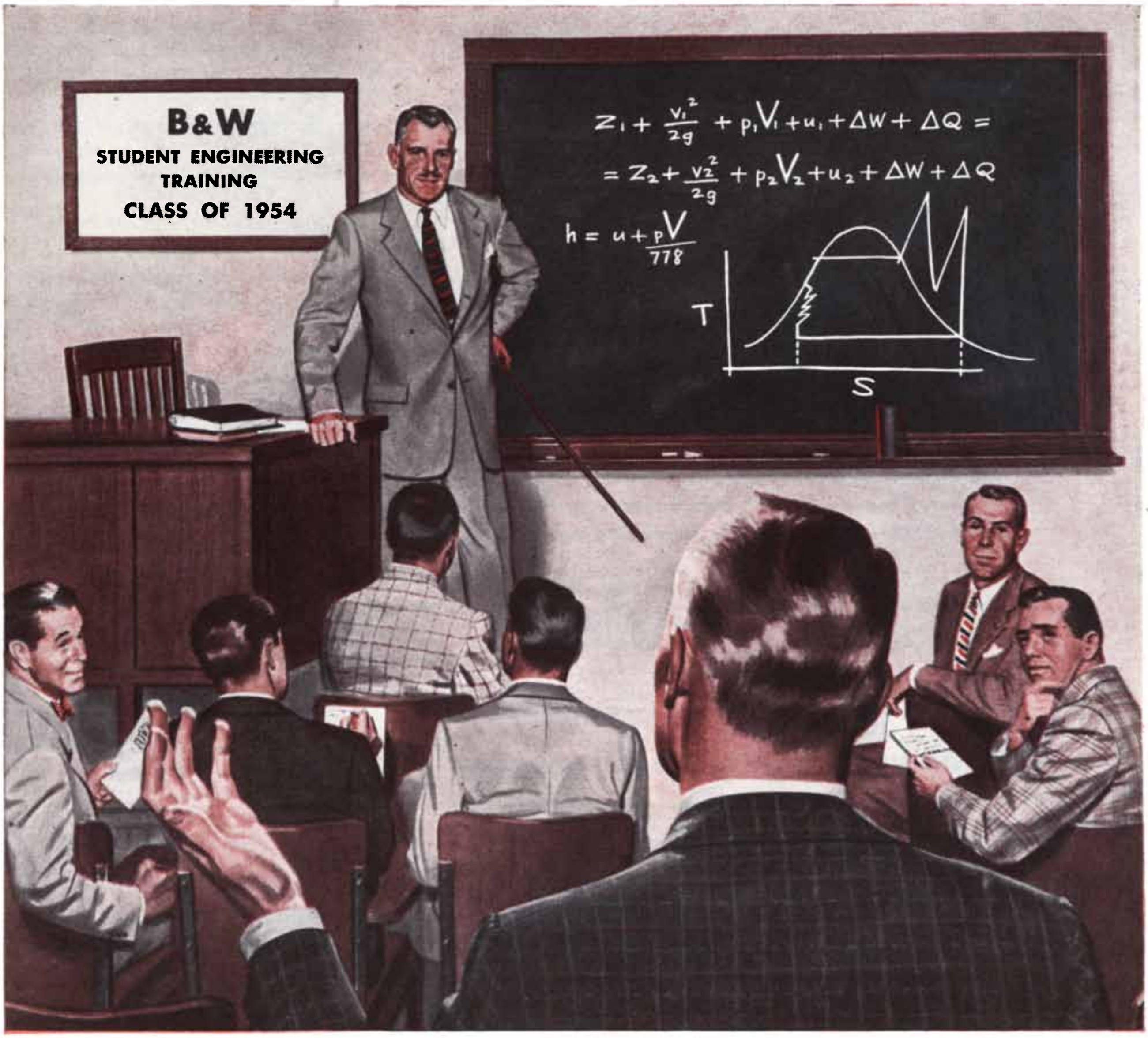
Student Bodies

How well a person uses his mind depends a great deal on the type of body in which it is housed; at least this is the conclusion of R. W. Parnell, a British physician who for a time looked after the health of Oxford University students. Applying the well-known somatotyping methods of W. H. Sheldon, he found a number of significant correlations between body build and scholastic achievement.

Parnell's subjects differed somewhat from U. S. collegians: there were no extreme endomorphs or mesomorphs and most fell in the middle range of the scale of body types. Parnell believes that the greater selectivity of British higher education weeds out the fat boys and muscle men.

He found that ectomorphs have the widest range of possibilities "for better and for worse" in scholastic work. Endomorphic ectomorphs—bony types tending more to fat than to muscle—had the highest proportion of first-honors winners, but many ectomorphs did poorly. Moderately muscular types were the most consistently good performers, and these were the "all-rounders" who were interested in sports as well as in scholarship.

Candidates for doctors' degrees in science were predominantly "central ectomorphic mesomorphs," or moderately muscular, lanky men. Oddly, this somatotype was poorly represented in the



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first-honors group of undergraduates. Parnell believes this may indicate that success in research demands different traits from success in examinations.

He suggests that somatotyping might be taken into account in admissions to college and awards of scholarships.

Volunteers

In medical and psychological research, "normal" behavior is often determined by studying volunteer subjects. Two physicians at the Harvard Medical School now report in *Science* that it is not always the normal who volunteer. Louis Lasagna and John M. von Felsinger decided to test psychiatrically a group of 56 "healthy" young men, mostly college students, who had volunteered as subjects for trials of the effects of various drugs. Rorschach tests and interviews disclosed that the group included three psychotics, 12 psychoneurotics, three psychopathic personalities, one alcoholic, six admitted homosexuals, one sufferer from severe peptic ulcer and one stutterer. A check with college guidance clinics confirmed the suspicion that this proportion of problem personalities is not typical of the general run of college students.

Many of the volunteers, Lasagna and von Felsinger concede, entered the experiments for the "kick" they hoped to get out of the drugs. But the physicians believe that other studies also may attract abnormal volunteers. They cite an investigation of sexual habits in women in which the volunteers showed more "self-esteem" and a greater tendency toward unconventional sex practices than did non-volunteers. Even a study of psychomotor performance turned up significant differences between the responses of volunteers and of students who were required to take the tests as part of a college course.

"Generalizations from data based on volunteers should be cautiously made," Lasagna and von Felsinger conclude.

Restless Scientists

Scientists with Ph.D. degrees are among the most mobile elements in the labor force, according to a study by the Bureau of Labor Statistics. They commonly change employers several times during their careers, frequently shift from one type of work to another and a surprising proportion even change their major fields. The Bureau has published its findings in a report entitled *Occupational Mobility of Scientists.* It polled about 5 per cent of the Ph.D.'s in

the U. S. in physics, chemistry and biological sciences.

The geographical mobility of scientists, says the report, appears to stem not only from conditions inherent in the type of work they do but from an innate wanderlust as well. They generally begin to move around while still students. More than 60 per cent of the Ph.D.'s took their baccalaureates and doctorates in different states.

At the time of the study 38 per cent were college teachers, 30 per cent were doing research in non-university laboratories and 21 per cent were in technical administration. Three fifths of all the scientists had worked for at least two different types of employer. One physicist in three had at some time worked in another science; among biologists the figure was one in five, and among chemists, one in seven.

The report observes that the number of scientists engaged in a particular type of activity at a given time is no indication of the number of potentially available experienced men.

Fishing for Prehistory

After a lull of a few hundred million years, the coelacanth-fishing business is looking up. Until last year only two of these "living fossils" of a 300-million-year-old family had been caught by civilized man. Since then four more have been pulled in. The latest haul was made by a French expedition organized expressly to catch coelacanths. Its four catches are now at the Natural History Museum in Paris, where J. Millot is dissecting them. Millot recently summarized his preliminary findings in the London *Times*.

The most interesting external feature of the coelacanth is its "pedunculated" fins (*i.e.*, fins attached to the body by external stems of muscle). From a similar set of fins in an extinct cousin of this fish evolved the arms and legs of land vertebrates. Millot was astonished to discover that the angle at which the coelacanth's fins are attached to its body varies widely from one individual to another, and even from one side to the other in a single fish. The French biologist points out that this great flexibility makes it easier to understand how fins of primitive fish could have swung into position to become limbs for terrestrial animals.

Millot plans to spend two years studying the insides of his fish, but he does not expect to learn much about their life habits. Their system of reproduction is still almost a complete mystery, because all the specimens caught so far are males.

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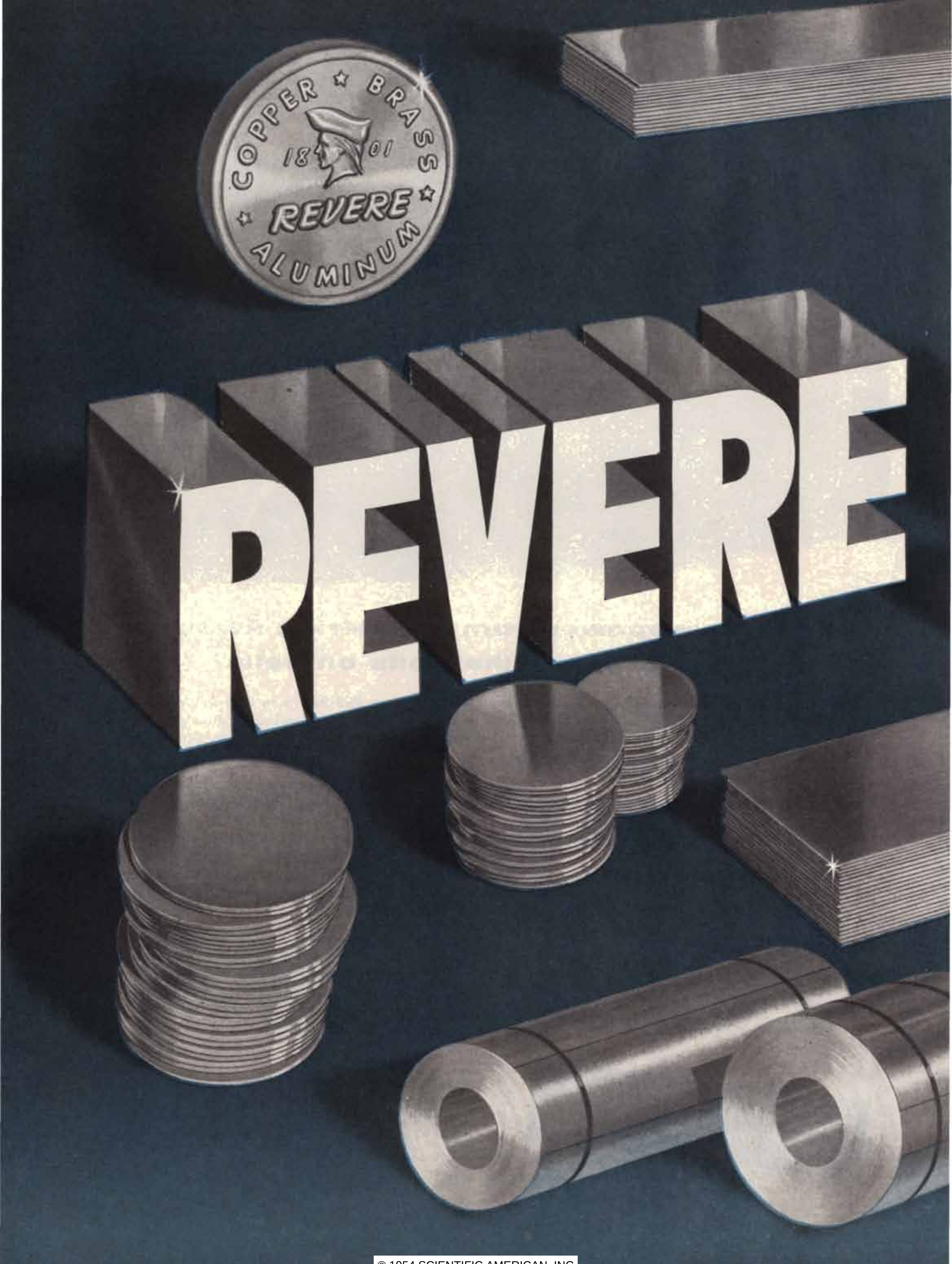
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ROMAN AQUEDUCT in the Spanish town of Segovia was built during the reign of Augustus (27 B.C. to A.D. 14). Made of granite without mortar, it is 2,700 feet long and has 119 arches from 23 to 94 feet high. Roman bridges were marked by semicircular arches.

BRIDGES

The web of modern ground transportation is only as strong as its bridges. An account of their development, with special reference to two great new bridges and the problem of bridge aerodynamics

by David B. Steinman

Bridges are an expression of man's urge to overcome barriers, to master the forces of nature, to speed travel, to link communities, to widen horizons. In many ways the story of bridgebuilding is the story of civilization. In region after region around the globe, the development of a country has awaited the building of bridges and has kept pace with progress in the art.

The U. S. has been an outstanding example. From a nation dependent on pack horse, oxcart and prairie schooner, fording streams or using crude ferries, it has become a nation on wheels. We now have 56 million motor vehicles rolling over our paved roads, parkways and superhighways. In the development of the giant automobile industry, the shrinking of distances, the speeding of travel and the knitting together of the country, bridges have played an indispensable role.

The American spirit—at once daring and practical—is peculiarly adapted to excel in such a development. With vision and initiative U. S. engineers have created the world's finest transportation system, and this has involved building many of the world's greatest bridges.

During the 19th century the principal demand for bridge construction was in the building and development of the railroads. At the turn of the century many of the railroad bridges were replaced or reconstructed to provide for the rapidly increasing size and weight of trains and locomotives. The year 1917 saw the completion of four record-breaking railroad spans: the Quebec cantilever bridge, the Metropolis truss bridge, the Hell Gate arch bridge and the Sciotoville continuous bridge.

Then came the Automobile Age. The phenomenal increase in highway traffic created myriads of bridges, including spans of unprecedented dimensions over crossings which previously had had to be left unspanned. While the U. S. has more than 90,000 railroad bridges, the number of highway bridges probably exceeds 300,000 on the three million miles of roads and highways. The aggregate investment in these highway bridges amounts to more than $3.5 billion.

Certain individual bridges have proved of key importance in the development of cities, regions and the nation as a whole. The Eads Bridge over the Mississippi River at St. Louis, completed in 1874, was an essential link in the realization of the transcontinental railroad system and "the winning of the West"; it also established St. Louis as a great crossroads.

Cities located at junctions of rivers are particularly dependent upon bridges. Pittsburgh has 16 highway and seven railroad bridges. In New York City the island of Manhattan is linked to the rest of the city and to the nation, by 15 highway bridges, over which nearly one million vehicles cross each day. Probably no bridge has had more influence on the growth of a city than the Brooklyn Bridge, completed in 1883. This connection soon doubled the population of Brooklyn, and the erstwhile village became a thriving city and an integral part of "Greater New York." Three additional bridges across the East River had to be built in quick succession; they completed the transformation of Brooklyn into the largest borough of the enlarged metropolis and created the great new borough of Queens.

Evolution of Bridges

Nature fashioned the first bridges. The fallen log, the natural arch formed by erosion, the stout vine festooned from tree to tree across a stream—these were nature's prototypes of the beam, the arch and the suspension bridge. Eventually Neolithic man began to imitate the natural structures. Some primitive genius felled a tree across a chasm, and became the first bridgebuilder. Then men learned to build multiple-span bridges by laying log beams from stone to stone across a stream, to widen this structure by placing two or more logs side by side, and later to build a bridge floor by laying branches across two separated spanning logs. In the northern glaciated countries, where timber was lacking, they used flat slabs of stone to connect the piers. In the warm southern climates they fashioned vines or creepers into ropes to form primitive cable crossings; eventually these evolved into the hammock bridge, with a woven mat floor resting on parallel cables and side ropes for railings. The hammock type was developed independently in regions as far apart as China, India, Africa and South America. The most ancient suspension bridges in China were of the sliding type, with a basket or seat transporting the traveler. In India a new idea was born: from two parallel cables the bridgebuilder hung vertical suspenders of thinner rope which carried the roadway platform at a lower level. This was the real prototype of the modern suspension bridge. India was also the birthplace of the cantilever bridge. Planks of wood, weighted down by the abutment stones, were projected from the two banks until they met in the center and connected the banks. In Mesopotamia about 4000 B.C. the true arch was born. It is probable that a Sumerian, in erecting a projection of overlapping horizontal bricks, happened to turn the bricks on end and discovered that a complete arch would stand up and support itself. It took sev-

BROOKLYN BRIDGE was the first suspension bridge in which steel wire was used for the cables and steel members for the suspended structure. Its main span is 1,595 feet long. It was opened in 1883 and remained the longest bridge in the world for 20 years.

eral thousand years for the arch idea to develop into practical bridge spans. In varied forms and materials it became the chief basis of bridgebuilding.

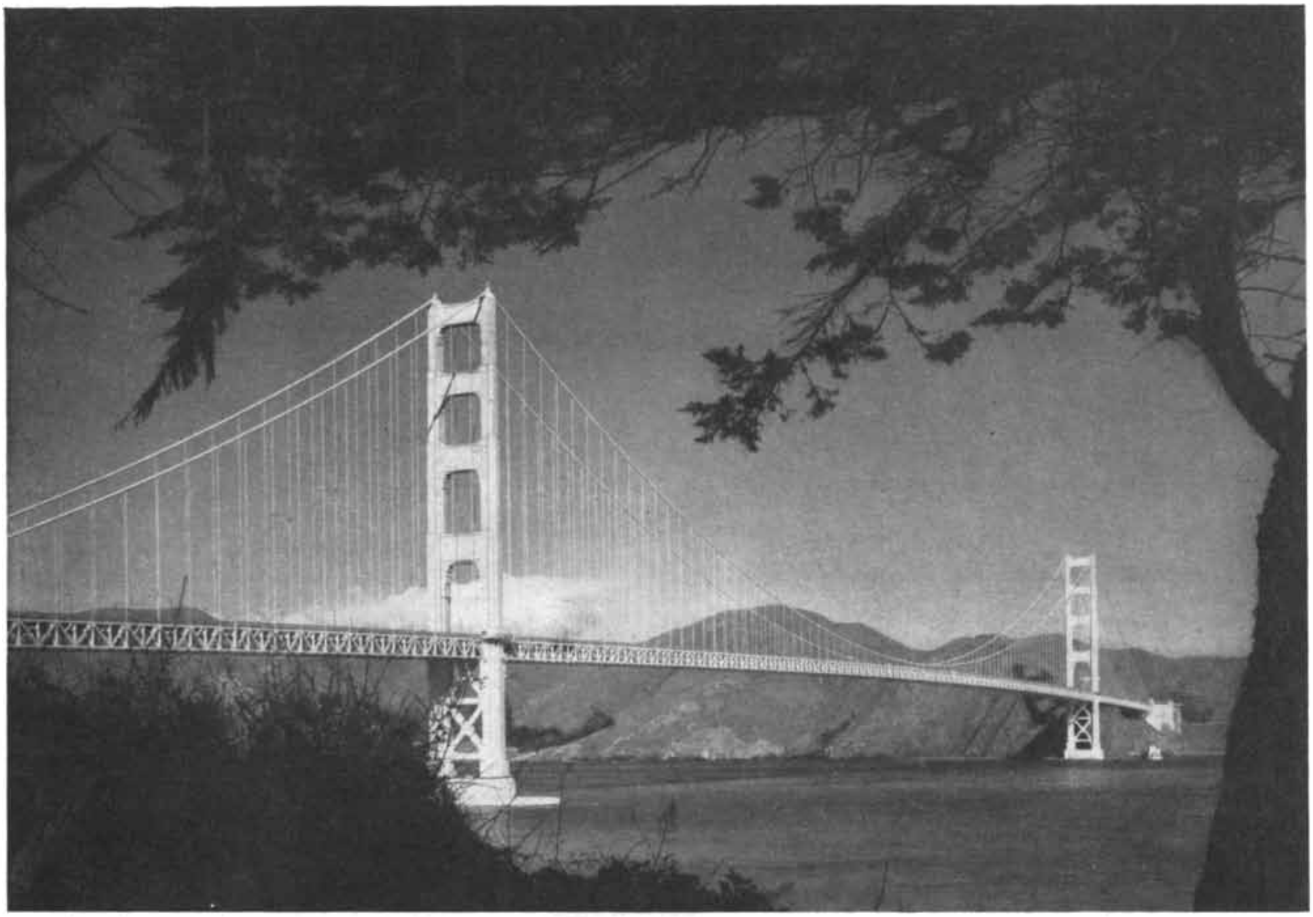
The Romans, as a warrior nation, had to bridge streams rapidly to carry their conquering armies. Caesar and Hannibal built pontoon bridges in the same manner as Xerxes had built them four centuries earlier. But the Romans also constructed other types of temporary wooden bridges. Caesar has left us the earliest detailed description of a timber trestle—his famous bridge over the Rhine (55 B.C.). Trajan's historic bridge over the Danube, built A.D. 104, consisted of a series of semicircular timber arches resting on 20 stone piers 150 feet high and 170 feet apart. Not until 12 centuries later was this remarkable span length exceeded.

Not satisfied with timber bridges, the Romans sought more permanent forms as monuments of their culture. Many of their magnificent stone arches have endured through the centuries. Between 200 B.C. and A.D. 260 they erected in Rome over the Tiber eight fine stone bridges, six of which survive, including the famous Ponte Sant' Angelo. One of the most beautiful bridges in Italy is the Ponte di Augusto at Rimini, built about 5 B.C. Other magnificent specimens of Roman bridgebuilding still stand in Spain and in France. The greatest of Roman aqueducts is the Pont du Gard at Nîmes, built A.D. 14. It comprises three tiers of semicircular arches. All Roman arches were semicircular, and massive piers were used, so that if one span were destroyed, the others would remain standing.

After Rome

In the Middle Ages the Church became the chief bridgebuilder. Travel was so disordered and dangerous at the end of the 12th century that groups of churchmen formed a "Brotherhood of Bridgebuilders" in Italy and France to give aid to voyagers. The beautiful 12th-century bridge at Avignon was built by St. Bénézet. He was a young shepherd lad when he entered the church at Avignon, interrupted the Bishop's sermon and declared that God had sent him to build a bridge over the Rhone. The construction required eight years (1177-1185). In honor of this great work, the inspired builder was later canonized. The four arches that remain have spans of 101 to 110 feet. At the same time a monk in England, Peter of Colechurch, proposed a masonry bridge to cross the Thames at London. Funds were raised by enthusiastic popular subscription. The historic structure, the old London Bridge, was started in 1176 and finished in 1209, four years after the death of its founder. For 600 years this famous bridge, weighted down by shops and dwellings, was the exciting center of London life, until the new London Bridge replaced it in 1831.

Lucerne has a famous pair of medieval bridges, the Chapel Bridge (1333) and the "Dance of Death" Bridge (1408). Both are covered timber bridges. The beautiful Ponte Vecchio at Florence, built in 1345 from a design by Taddeo Gaddi, has three spans of 90 to 100 feet. The segmental curve used for the arches was unusual for the time. Me-



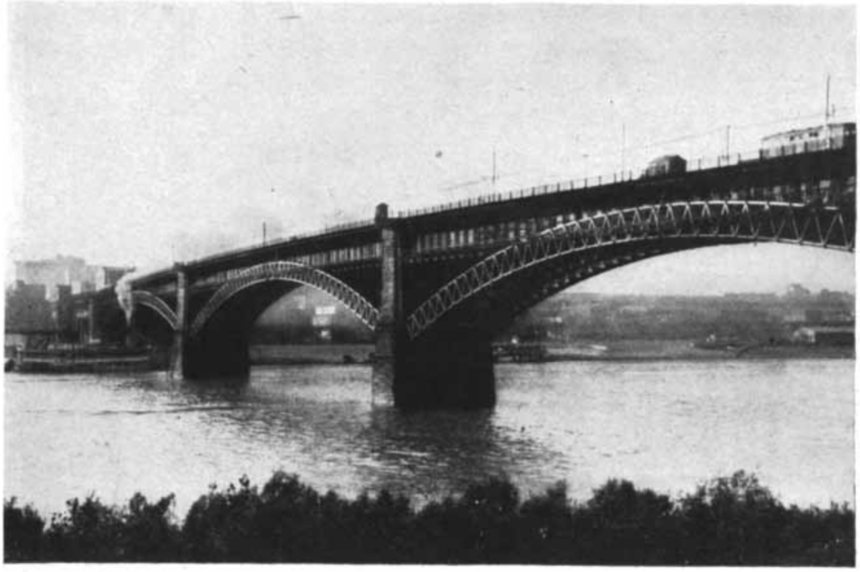
GOLDEN GATE BRIDGE is presently the longest bridge in the world, although the Straits of Messina Bridge, when it is built, will be longer (*see drawing on pages 70 and 71*). The main span of the Golden Gate Bridge is 4,200 feet. It was completed in 1937.

dieval builders generally loaded their bridges with towers, embattled parapets, chapels, statues, shops and dwellings. Occasionally they achieved spans of remarkable length. The single granite arch at Trezzo over the river Adda in Italy, built in 1377 but destroyed in 1410, was 251 feet. The world had to wait five centuries before a masonry arch of longer span was constructed (the Luxembourg Bridge of 278 feet span, built in 1903).

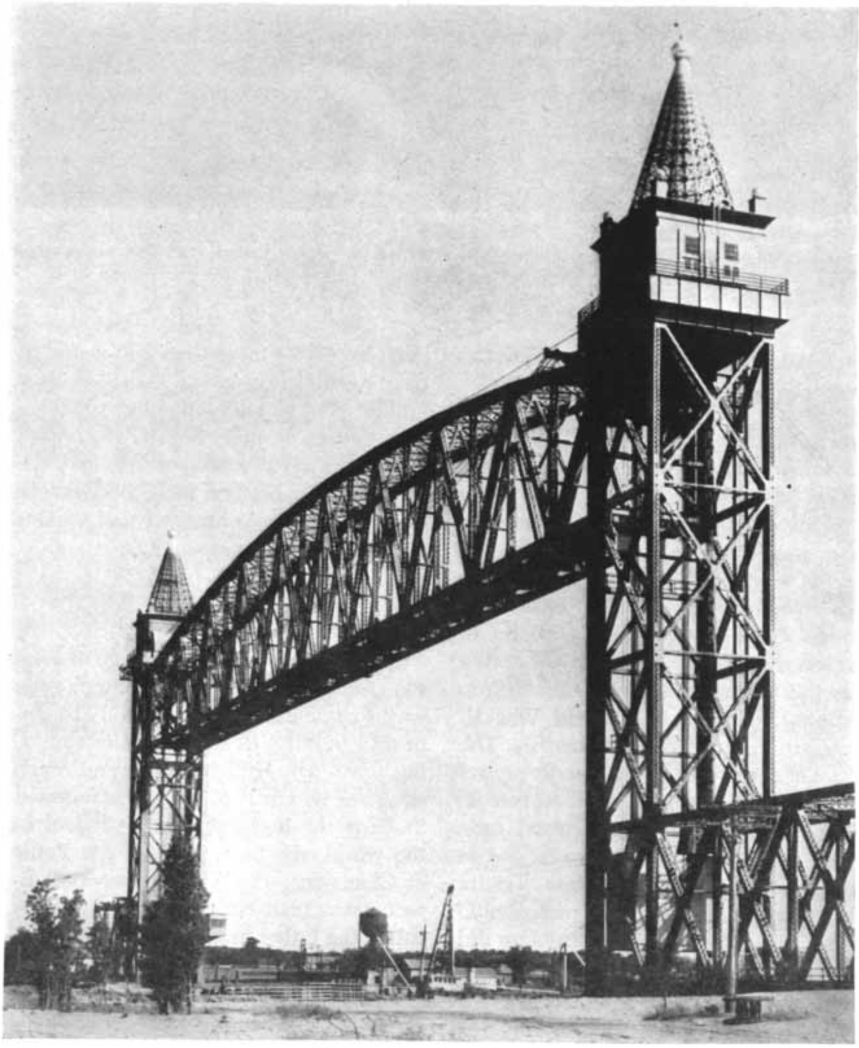
The Renaissance brought new ideas in bridgebuilding as in other fields. Leonardo da Vinci conceived portable military bridges and bascule bridges, but they took form only in his sketches. Palladio (1518-1580) was the first to apply successfully the truss—the rigid framework of reinforcing members which is a basic feature of most large bridges today. The builders of the Renaissance were able to create bridges exalting the civic pride of their community, satisfying Palladio's criterion that bridges "should be commodious, beautiful and enduring." A much-admired bridge is the Rialto Bridge over the Grand Canal in Venice. In 1587 the Venetian Senate awarded the contract to Antonio da Ponte, who was then 75 years old (but lived to build still later the famous Bridge of Sighs). The foundation piles of the Rialto Bridge were driven with a mechanical pile hammer. After keeping all the stonecutters in the city at work for two years, the bridge was completed in 1591. A Renaissance bridge even superior to the Rialto in engineering skill and in beauty of design was the Santa Trinita over the Arno in Florence, destroyed in World War II. It had three spans of white marble. The curve of the arches was the most mysterious and the most beautiful feature of the bridge. Instead of the usual ratio of rise to span of one to two or one to four, the curve of the Santa Trinita arches yielded the extremely radical ratio of one to seven. Bridge construction did its share in transforming Paris from a medieval town to a splendid Renaissance city. The first stone bridge over the Seine, the Pont Notre Dame, was built about 1505. The second, the Pont Neuf, started in 1575 and finished in 1606, has been in service more than 300 years. In the Renaissance period the bridgebuilder was at once engineer, scientist and artist. People began to regard bridges as civic works of art, and the bridgebuilder became truly a "civil" engineer—a leader in progress and creator of useful public monuments.

A Science of Bridgebuilding

In the 18th century, the "Age of Reason," empiricism in bridge design gave way to scientific analysis. In 1714 appeared the first treatise on bridgebuilding, written by Hubert Gautier, a French engineer, and in 1747 there was founded in Paris the first engineering school in the world, the famous Ecole des Ponts et Chaussées. The first teacher and director was Jean Perronet, who has been called the father of modern bridgebuilding. The greatest works of the century came from the inventive genius of Perronet. In his hands the masonry arch reached perfection. He perfected the arch curve, devised a new pier construction, introduced the balustraded parapet



EADS BRIDGE over the Mississippi at St. Louis consists of three steel arches spanning 502, 520 and 502 feet. Completed in 1874, it was the largest and boldest arch bridge of its time.



CAPE COD CANAL BRIDGE is the longest vertical-lift span in the world. Completed in 1935, it has a main span of 544 feet. This design is now used in most large movable bridges.

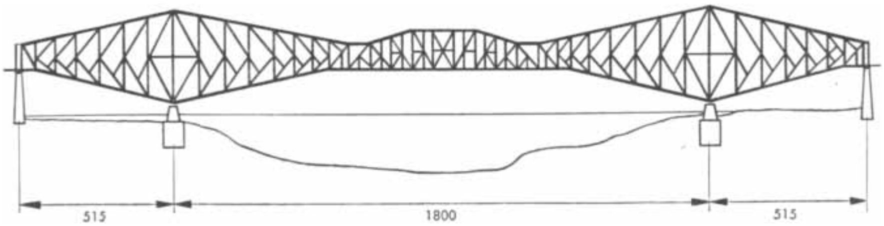
and invented construction machinery. Perronet's finest bridge from an engineering standpoint was the Pont Sainte Maxence over the Oise. The amazing slenderness of the piers was a milestone in bridge design. The bridge stood for nearly 100 years until destroyed by the Germans in 1870. He built his most famous bridge, the Pont de la Concorde in Paris, when he was 78. Perhaps no other bridge in the world has the same quality of civic dignity and nobility.

In England the greatest bridgebuilder of the time was John Rennie. Apprenticed as a millwright, he studied mathematics, was graduated from the University of Edinburgh, toured England on horseback to visit engineering works, and built his first bridge (a three-span elliptical arch) at the age of 24. In 1809 Rennie was retained to draw plans for another new bridge over the Thames (the Westminster Bridge, financed by a government lottery, and the Blackfriars Bridge had already been built to relieve the old London Bridge). Rennie's magnificent new structure was opened in 1817 with an elaborate celebration. The bridgebuilder was offered a knighthood but refused it, preferring to remain known as John Rennie, engineer of the Waterloo Bridge. Then he designed the new London Bridge. He died, however, before it could be built, and his son Sir John Rennie was selected to construct the bridge the father had designed. It was completed in 1831. This bridge consisted of five semi-elliptical arches spanning 130 to 150 feet. Perronet's segmental and Rennie's semi-elliptical arch curves brought greater span lengths, more stable arches and richer beauty. Arch construction had come a long way in its 5,000 years of evolution from the corbeled vault of ancient Mesopotamia.

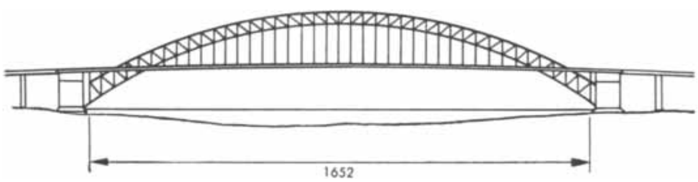
As the design of bridges evolved, so did their materials. Wooden bridges have persisted to our day, but by the end of the 18th century builders had discovered that it was a good idea to cover them to prolong their lifetime. Covered wooden bridges may be found in almost all forested countries, among them France, Germany, Norway, England, Austria, Hungary, Switzerland, the U.S.S.R. and the U. S. About 1,900 of them are still in service in this country. The first framed timber bridge in America was Colonel Enoch Hale's bridge over the Connecticut River at Bellows Falls, built in 1785. When the bridge was completed, it was heralded as the greatest achievement in American bridgebuilding, and people traveled far

FIRTH OF FORTH BRIDGE in Scotland possesses two huge cantilever spans, each 1,700 feet long. These spans were the longest in the world from 1890 until 1917, when the Quebec Bridge across the St. Lawrence River surpassed them with a length of 1,800 feet.

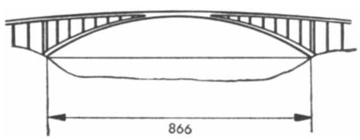
HELL GATE BRIDGE, which crosses the East River in New York, has a span of 977 feet. Here it is shown during construction in 1915. Because the water was too deep and swift to permit the erection of scaffolding, the two halves of the arch were built out from the ends.



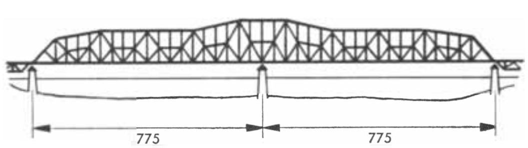
Cantilever bridge is represented by the Quebec Bridge across the St. Lawrence River



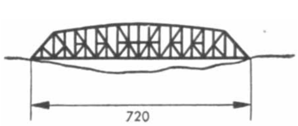
Steel-arch bridge: the Bayonne Bridge between Staten Island and New Jersey



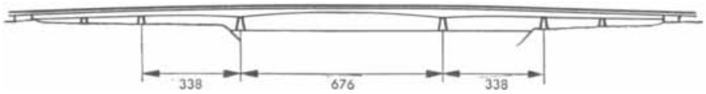
Concrete-arch bridge: the Sando Bridge in Sweden



Continuous-truss bridge: the Sciotoville Bridge in Ohio



Simple-span truss bridge: the Metropolis Bridge in Illinois



Continuous-plate girder bridge: the Düsseldorf-Neuss Bridge in Germany

to see it. The most famous timber span in America was an arch bridge called the "Colossus," built across the Schuylkill River at Fairmount near Philadelphia in 1812. This bridge, the work of Louis Wernwag, had a span of 340 feet—a truly remarkable feat in those days. After serving for 25 years, it was destroyed by fire.

Iron did not come into use as a bridge material until the 18th century. In 1779 Abraham Darby and John Wilkinson, iron smelters, built the first cast-iron bridge—an arch of 100-foot span over the Severn River at Coalbrookdale in England. This bridge is still standing. Wrought iron had already been introduced for cables in suspension bridges. In the 1850s, as wrought iron replaced cast iron in bridge construction for greater safety, many new truss types made their appearance. The famous Firth of Tay Bridge in Scotland, completed in 1877, consisted of 84 truss spans of wrought iron. On the night of December 29, 1879, many of its truss spans were blown down by the wind, and a train of six coaches crashed into the waters 88 feet below, with the loss of all passengers. During the 1870s and 1880s bridges on U. S. railroads were failing at a rate of 25 a year. Something had to be done. This need inaugurated a new era in bridge engineering and a new material: steel. The first all-steel bridge was built in 1878 over the Missouri River at Glasgow, S. D. Its builder was General William Sooy Smith, a U. S. Army engineer.

Modern Bridge Types

With steel and mathematics, the ugly iron trusses that had been introduced by the Industrial Revolution evolved into new bridge forms, forms combining strength and beauty—the modern arch, cantilever, continuous truss and suspension bridges.

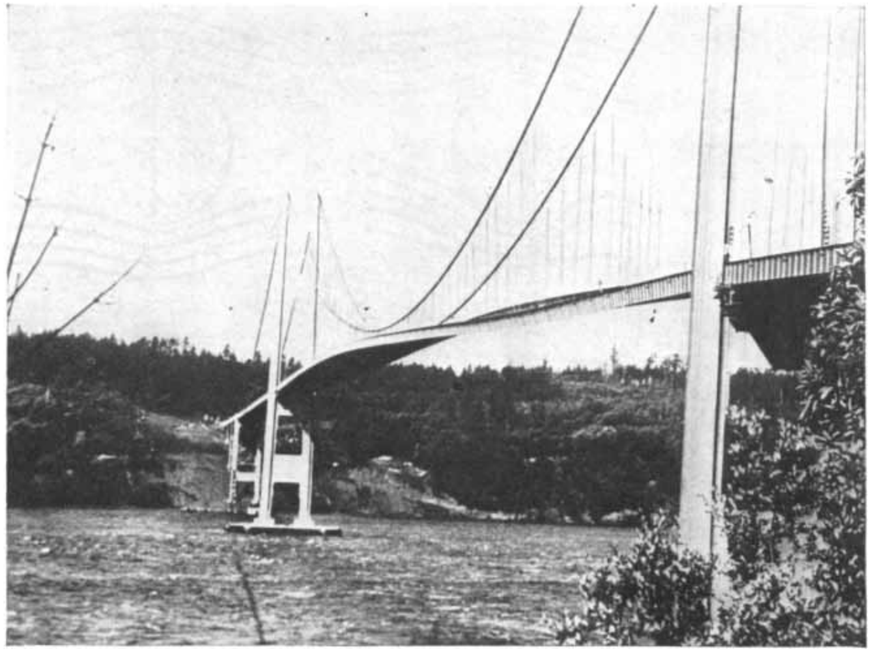
One of the first examples of the modern steel arch was the Eads Bridge at St. Louis, designed by Captain James B. Eads, the only engineer now in the Hall of Fame. With three hingeless arch spans of 502, 520 and 502 feet, it was the largest and boldest arch bridge of its day. This pioneer structure represented the first use of high-strength alloy steel in bridge construction, the first use of pneumatic caissons in the founding of large piers and the first use of tubular chord members. The bridge still carries heavy railroad, highway and streetcar loading after 80 years of service.

Steel started a competition for longer

and longer spans. In 1907 the British completed the Victoria Falls Bridge over the Zambezi River in Rhodesia; its 650-foot steel arch carries a railroad across a scenic gorge 400 feet deep. For erection of the arch a cableway was used; the first line was carried across the chasm by a rocket. One of the greatest arch bridges of all time is the Hell Gate Bridge over the East River in New York, with a span of 977½ feet. Completed in 1917, it was the crowning achievement of Gustav Lindenthal. The roadway is suspended from the arch and carries four railroad tracks on a heavy ballasted floor. The outline of the arch, framed between great masonry towers, produces a monumental composition. Inspired by the Hell Gate arch, the Australians completed in 1932 the colossal Sydney Harbor Bridge, with a span of 1,650 feet. It was their proud ambition to build the longest arch span in the world, but they were doomed to disappointment. Before their bridge was finished, the U. S. completed the Bayonne Bridge over Kill van Kull from Staten Island to New Jersey, and it was just 25 inches longer than the Australian span.

Esthetically the logical form of an arch bridge is the deck type, with the roadway carried in an unbroken line above the arch rib. The Henry Hudson Bridge, carrying the Henry Hudson Parkway over the mouth of the Harlem River at Spuyten Duyvil, is a hingeless deck-arch bridge of 800-foot span. The traffic proved so heavy that one month after the bridge was opened in December, 1936, the addition of an upper deck was authorized to double the capacity.

A cantilever bridge is generally composed of anchored trusses thrust out from the piers and connected by a shorter suspended span. A cantilever span can be erected without falsework, so that river navigation is not impeded during construction. The first modern cantilever bridge was built in 1867 by Heinrich Gerber across the river Main at Hassfurt in Germany. The world's most famous cantilever structure is the huge Firth of Forth Bridge in Scotland, with two main spans of 1,700 feet each. It was built between 1882 and 1890 by Sir John Fowler and Benjamin Baker. The steel truss members are tubular, and the massive towers and trusses are spread at the base for greater stability. The Forth Bridge held the world's record for length of span for 27 years. Then the record was taken over by the Quebec Bridge over the St. Lawrence River, but not before several mishaps. The first attempt to build this 1,800-foot span ended in a collapse on August 29, 1907, which killed 85 workers. Investigations revealed that the collapse was caused by the buckling of a compression member, due to inadequate lacing. A new design was prepared, heavier and more rigid, with the suspended span to be erected by the lifting method. In 1916 while the 5,200-ton span was being raised something gave way and it crashed into the river, with 13 more lives lost. Finally in 1917 a new span was completed and successfully jacked to the full height of 150 feet.



TACOMA NARROWS BRIDGE was photographed just before it broke up in a 42-mile-an-hour wind on November 7, 1940. The roadway can be seen twisting around its long axis.

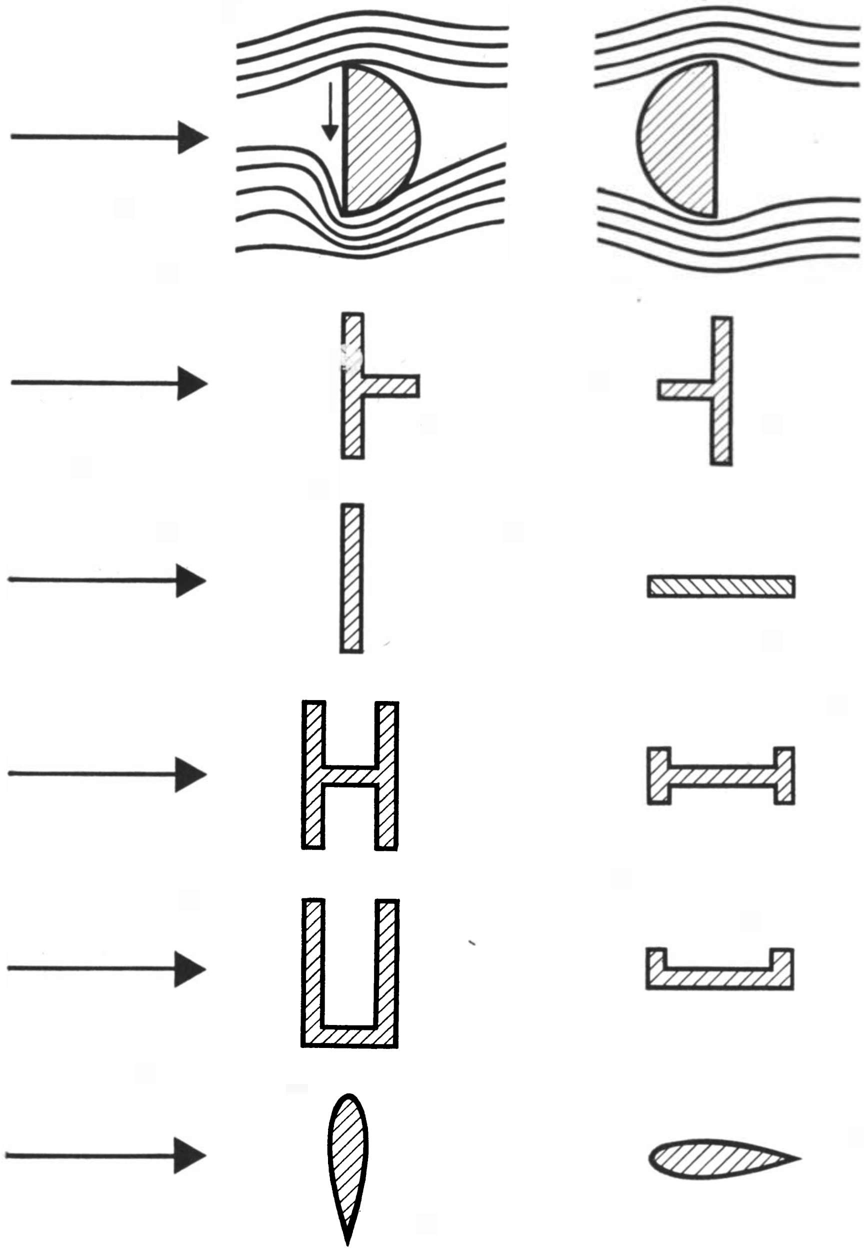
The Suspension Span

The king of all bridge types is the suspension bridge. Its greatest pioneer was John A. Roebling, who came to the U. S. from Germany in 1831 as a youth of 25. Roebling introduced new methods of stiffening suspension bridges and of stringing parallel-wire cables. In 1855 he completed the world-famous Niagara Railway Suspension Bridge, with a span of 821 feet. Made of wire and wood, it carried the weight of trains and locomotives for 42 years until it was replaced by an arch bridge in 1897. Between 1856 and 1867 Roebling built the great suspension bridge over the Ohio River at Cincinnati, with a record-breaking span of 1,057 feet.

In 1867 Roebling came to New York to design and build his crowning work, the Brooklyn Bridge. Two years later, after completing his plans, he died as the result of an accident during the final surveys. His son, Colonel Washington Roebling, carried the work forward to completion despite his affliction in 1872 by caisson disease, which left him an invalid. On May 24, 1883, this triumph of engineering was officially dedicated. It was the first suspension bridge using steel wire for the cables, also steel for the suspended structure. It is undoubtedly the most famous bridge in the world, and is generally recognized as the most artistically satisfying. Roebling taught the world how to build enduring suspension bridges. His bridges stood up when those built by his contemporaries were blown down by the wind. When a later generation of engineers overlooked the fundamental principles Roebling had preached and exemplified, disaster followed.

The Brooklyn Bridge held the record as the longest suspension span for 20 years. Then the record was successively seized by the Williamsburg Bridge (1,600 feet), the Bear Mountain Bridge (1,632 feet), the Delaware River Bridge at Philadelphia (1,750 feet), the Ambassador Bridge at Detroit (1,850 feet), the George Washington Bridge (3,500 feet) and finally in 1937 by the Golden Gate Bridge at San Francisco, which is still far in the lead with a span of 4,200 feet. The suspension bridge has displaced the cantilever as the accepted type for long-span construction.

The Williamsburg Bridge was the



FLOW OF AIR amplifies the oscillations of a half-round member with its flat side toward the wind (*upper left*) and damps the oscillations of one with its curved side toward the wind (*upper right*). The members at left are aerodynamically unstable; those at right, stable.

first large suspension bridge constructed with steel towers. Its stiffening trusses are 40 feet deep. Since it was built there has been a reversed trend toward slenderness and grace, achieved in some cases by the use of girders instead of trusses for stiffening, in others by improved trusses. A new form of stiffening truss which makes a structure four times as rigid as the conventional parallel-chord design and uses only two thirds as much steel was introduced in 1926 in the Florianopolis Bridge. This bridge crosses Atlantic waters from the mainland of Brazil to the island city of Florianopolis. It was designed by Holton D. Robinson and the author of this article. With a main span of 1,114 feet, it is the largest bridge in South America and it is the longest eyebar (chain) suspension span in the world. Another novel feature was the use of rocker towers—steel towers designed to rock at the base. Robinson and the author also introduced another type of cable construction: the rope-strand cable, composed of prefabricated, prestressed, twisted rope strands of steel wire, saving the time required for Roebling's air-spinning method. This construction has been applied in several suspension bridges built since 1929, including the 1,550-foot Lions Gate span at Vancouver, British Columbia, and the 950-foot Grand Mere Bridge in Quebec.

The George Washington Bridge, which opened in 1931 and cost $75 million, has four parallel-wire cables of 36-inch diameter. Provision was made for eight lanes of highway traffic on the original deck and for the future addition of a lower deck. The Golden Gate Bridge has two cables 36.5 inches in diameter, slung from steel towers 746 feet high. Although it is the world's longest span, it is not the world's largest bridge; the Transbay Bridge between San Francisco and Oakland, made up of a series of suspension and cantilever spans, is eight miles long.

There are, of course, innumerable other types of bridges, among them: the so-called continuous bridge, in which a beam, girder or truss rests on more than two supports, without intermediate hinges or other interruptions of continuity; the simple truss bridge; the swing bridge; the bascule bridge; the vertical lift bridge (of which the longest in the world is the 544-foot railroad bridge over the Cape Cod Canal); the "aerial ferry," which carries freight or passengers in cars suspended from a rigid span, like a traveling crane; the pontoon bridge (the world's longest is a 6,560-foot affair across Lake Washington in Seattle); the stone arch; the concrete arch, which has been developed to remarkable span lengths, the longest being the 866-foot span of the Sando Bridge in Sweden.

We cannot consider all the bridge types in detail in a single article, but I wish to tell the story of a baffling scientific problem which dramatically confronted the bridgebuilding profession only a little more than a decade ago. It has to do with aerodynamics and suspension bridges.

The Tacoma Bridge Problem

On November 7, 1940, the third longest suspension bridge in the world shook itself to pieces in a high wind and crashed into Puget Sound. The Tacoma Narrows Bridge was a new $6.4 million structure which had been opened only four months before. Its collapse was not only a riddle that called for explanation but also a warning of danger to other bridges.

The Tacoma Bridge was an extreme example of the trend toward slender, flexible construction of suspension bridges. Its stiffening girders were only eight feet deep, or one 350th of the length of the span. Despite its slenderness, the bridge was strong enough to support its own dead weight and the weight of the traffic it was designed to carry; it was also safe against temperature changes. But the aerodynamic effects of wind had been overlooked. The span was too flexible, and the shape of its cross section was such that a horizontal wind set up a vertical oscillation which became self-exciting. In the 42-mile-an-hour gale of November 7, the twisting oscillations built up so strongly that they tore the span from the cables (*see photograph on page* 67).

When we speak of the aerodynamic action of wind we mean its production of forces such as those that provide lift for an airplane. Its effect on complex structures such as bridges was until recently almost completely unknown. From theoretical and experimental studies commenced in 1938 the writer has developed a general theory of aerodynamic effects on oscillating sections which is applicable to bridges. It provides formulas which predict the stability of a design and which answer a question that has troubled engineers for a century: How much stiffening does a suspension bridge require?

The principles that govern the aerodynamic behavior of structures can be demonstrated strikingly by means of airflow experiments on a simple model. A piece of half round is mounted between a pair of light springs and its flat side is exposed to the horizontal air stream from an electric fan. If the piece is displaced slightly up or down from its equilibrium position and let go, the resulting small vibration quickly builds up into a large and violent oscillation. When the piece is reversed so that its round surface faces into the wind, any oscillation that is started promptly dies out.

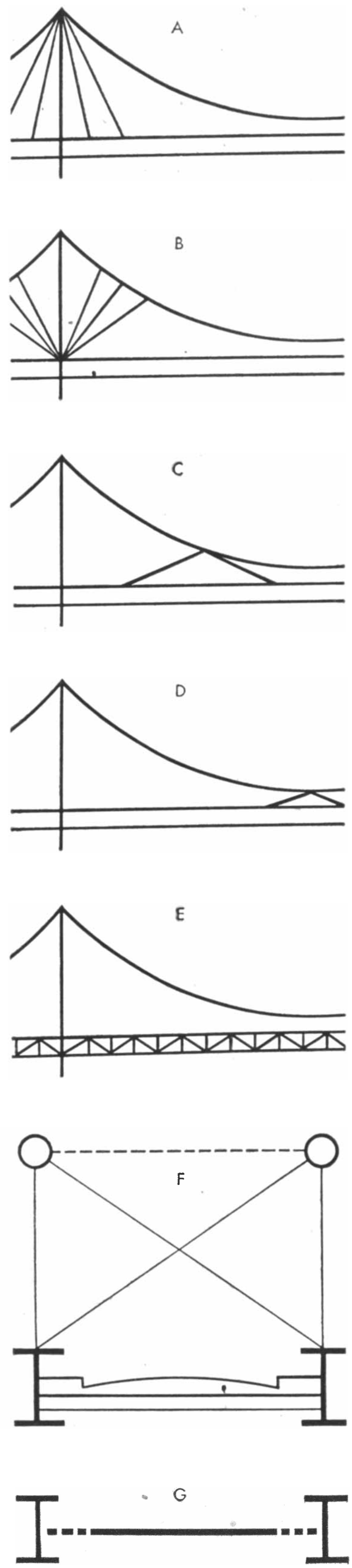
In the first case, with the flat side toward the wind, the energy drawn from the stream by the oscillating object builds up its motion (*see the upper left diagram on the opposite page*). When the flat surface is moving down across the wind, the air streaming past divides so that more flows under it than over. The result is that the flow underneath is speeded up. According to the well-known theorem in hydrodynamics known as Bernoulli's principle, the faster the flow, the lower the pressure. As a consequence of the deficit of air pressure against the bottom surface of the half round, the piece's downward movement is amplified. The same process operates when it moves upward: then the flow over the top is faster and the upward movement is amplified. Thus for an oscillating section of this form each up and down movement is amplified by energy extracted from the horizontal wind flow. The piece is aerodynamically unstable. On the other hand, in the case where the round surface faces the wind, the aerodynamic force operates against the direction of the body's initial motion, and any oscillations that may begin are damped out. This shape, in other words, is a stable one.

The case of a wide structure such as a bridge is somewhat more complicated. Because of the width of the bridge the oscillation is not uniform across its width. It takes time for the wind flow to traverse the width, and as a result the flow or disturbance of flow encounters a progressive difference of phase of the structure's natural period of vibration as it passes across. The differences include differences in velocity and even in the direction of motion. Thus the resultant motion is modified by the relative velocity of the wind. In addition, the wind builds up twisting oscillations within the structure if it is torsionally unstable.

The Solution

Strange as it may seem, this obvious basic concept of phase difference was missed by other investigators. Without it the problem could not be solved. It explains the otherwise mystifying variation of aerodynamic response at different wind velocities. On account of the phase difference factor the stability or instability of a section depends not only upon the shape and proportions of the section but also upon a function of the wind velocity. This function is the "velocity ratio" V/Nb, where V is the wind velocity, N the natural frequency of the oscillating structure and b the width of the section. The question to be decided in a given case is where the critical values of V/Nb lie. If there is no upper limit to the critical range, the structure has a potentially catastrophic instability. Ordinarily the natural damping processes in such a structure will extinguish oscillations unless the wind reaches high speeds. But in the case of the Tacoma Bridge its extreme flexibility made it vulnerable to a moderate gale.

The writer has investigated the critical values by means of wind-tunnel tests of curved models of bridge sections and measurements of pressure distributions across the width of such sections. These studies have yielded simple working



STIFFENING STRATAGEMS are floor stays (A), cable stays (B), intermediate stays (C), center stays (D), trusses (E), transverse stays (F) and roadway slots (G).

formulas for predicting all critical wind velocities for vertical and torsional oscillations and, in addition, the rates of amplification, limiting amplitudes and amplitude responses at all velocities.

A suspension bridge may be made safe in two ways. One is to stiffen the structure by bracing stays so as to prevent and to damp destructive oscillations; this can be done simply and economically by means of design specifications developed by the writer. But the more scientific attack is to apply aerodynamic principles to design bridge cross sections which are fundamentally stable. The wind-tunnel tests have produced the necessary data; they show how the form and proportions of a bridge section, with suitable openings in its horizontal width, can be designed to give it stability in any wind. It is sounder and more economical to eliminate the cause than to build up the structure to resist the effect. Many suspension bridges have had to be reinforced in recent years to make them safe, and some of these reconstruction operations have been costly; for instance, corrective measures on the Bronx-Whitestone Bridge cost $1.3 million, and on the Golden Gate Bridge, $3 million. The new science of bridge aerodynamics will make corrections unnecessary in future bridges.

Bridges of the Future

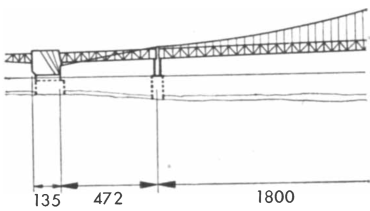
Within one generation the span length of suspension and steel arch bridges has been doubled, and the concrete arch also has reached an unprecedented length. Never before in the history of bridge engineering have such amazing strides been recorded. Length of span is a good measure of the advances in the bridgebuilding art—in design, economics, materials and methods of erection. A generation ago the cantilever type was dominant. Since then the suspension type has won supremacy: the world's seven longest spans today are suspension bridges.

A notable suspension bridge project now under construction is the Mackinac Straits Bridge in Michigan, designed by the writer. Five miles in total length, it spans the deepest water with a suspension bridge of 8,614 feet having a main span of 3,800 feet. The total cost will be $99.8 million and completion is scheduled for 1957. Still larger bridges are already in the planning stage. One of these is the Messina Straits Bridge to connect Sicily with Italy; it will have a main span of 5,000 feet and foundations up to 375 feet deep. The plans (prepared by the writer) provide for resistance to earthquakes, storms and railroad loading. A generation ago the feasibility of a span of 3,000 feet was seriously questioned. Now we can state with confidence that suspension spans up to 10,000 feet may be expected.

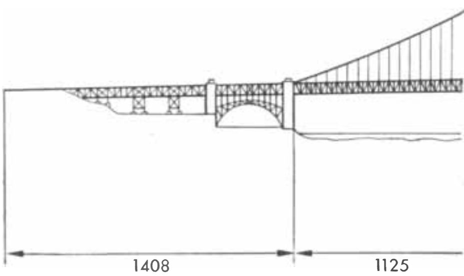
Development of long-span bridges has created an impelling need for improved bridge materials. This has taken two directions: (1) higher-strength steels and (2) lighter structural metals. The high-strength materials successfully used so far have included alloy steels, heat-treated carbon steel and cold-drawn high-carbon bridge wire. Materials with three or four times the safe working strength of ordinary steel have been developed. The principal lightweight material has been structural aluminum; it was employed in the building of several notable bridges in the U. S., England and Canada.

During the past 25 years attention has also been concentrated on the attainment of beauty in bridges. Annual awards for artistic bridges were inaugurated in the U. S. in 1928. Ponderous proportions are no longer the accepted expression of power in a bridge. Today graceful, airy spans carry thousands of tons of useful load—seemingly by magic. In span after span bridge designers have demonstrated that beauty can be obtained without sacrificing utility or economy. It costs no more to make a bridge beautiful. All it requires is a little more consecrated effort and an innate feeling for beauty on the part of the designer. A heavy, clumsy, angular structure usually represents extravagant, careless or ignorant design. A structure of graceful and inspiring lines and proportions usually represents careful and scientific design.

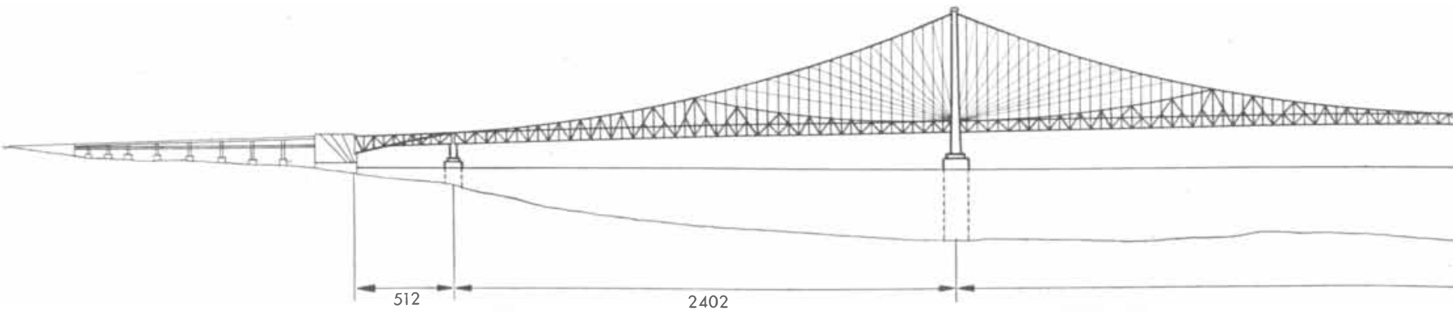
No one can remain unmoved at the



Straits of Mackinac Bridge is scheduled for

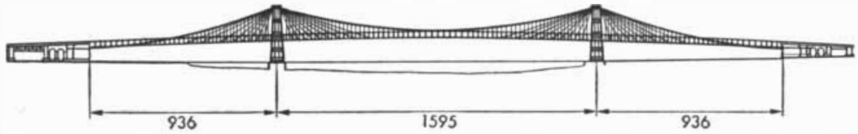


Golden Gate Bridge will have the longest

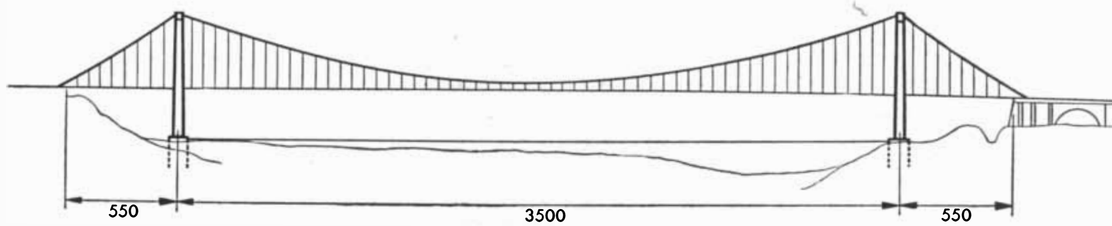


Messina Straits Bridge is now planned. It will cross the narrow neck of water between Sicily and Italy: the legendary Scylla and Charybdis.

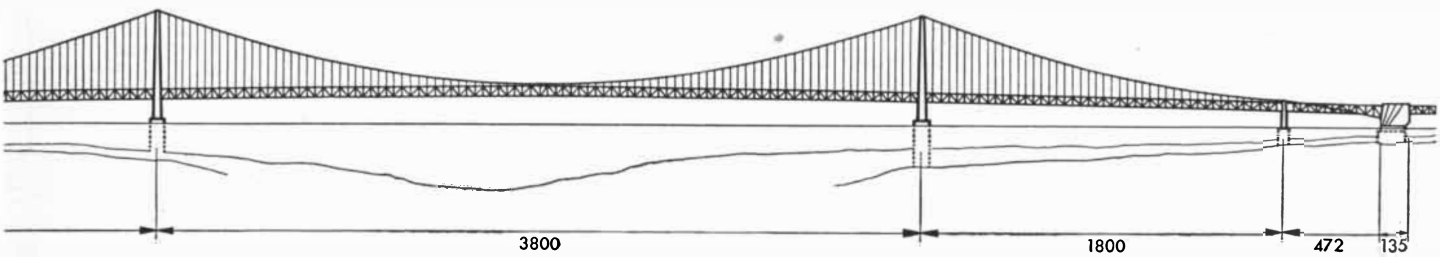
sight of a beautiful bridge. A bridge is not only a steppingstone of civilization —it is also an expression of the aspirations of humanity. The rainbow spans of tomorrow will have simplicity of form, beauty of line, grace of proportion, harmony of color and radiant illumination.



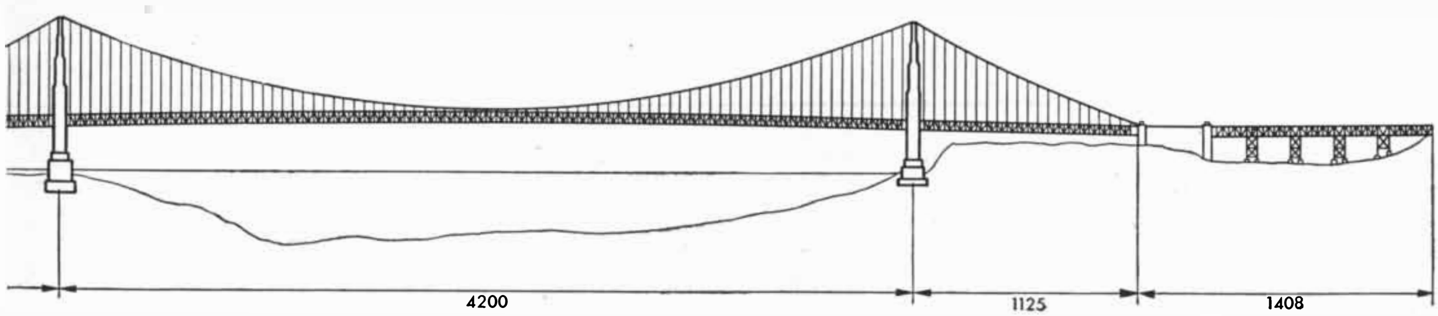
The length of present and future bridges is compared. Above: the Brooklyn Bridge



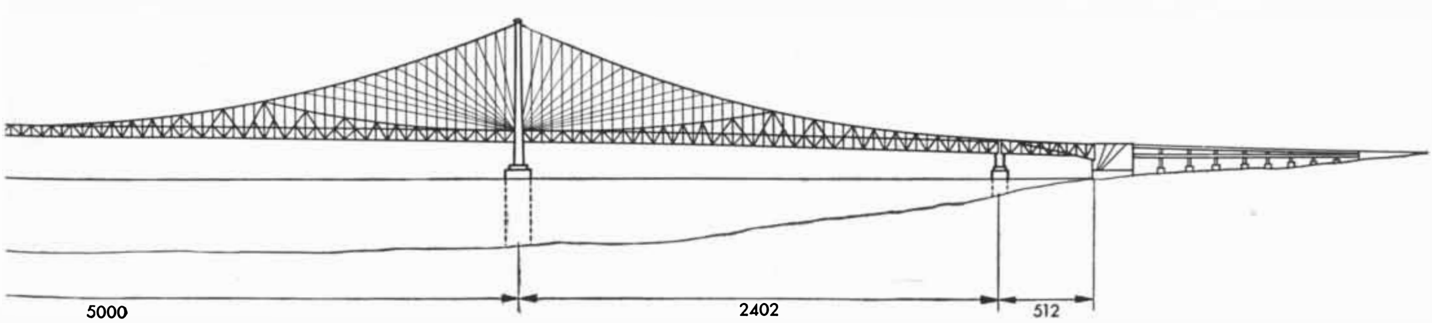
George Washington Bridge was completed in 1931. Its main span was the longest in the world until the completion of the Golden Gate Bridge



completion in 1957. It will join northern and southern Michigan, separated by the neck of water between Lake Michigan and Lake Huron



single span for some time to come. In over-all length, however, it is surpassed by the nearby Transbay Bridge, which is eight miles long



Its main piers will be sunk in water 400 feet deep. It will be stiffened by enormous trusses to withstand earthquakes and train loading

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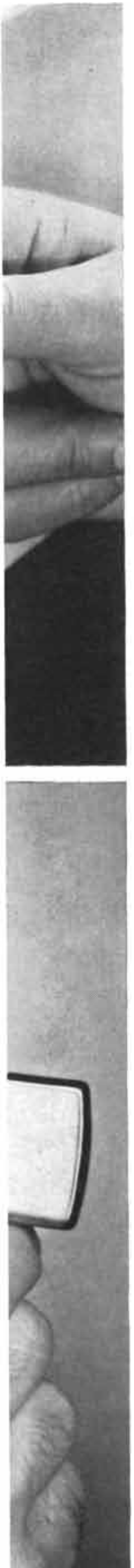

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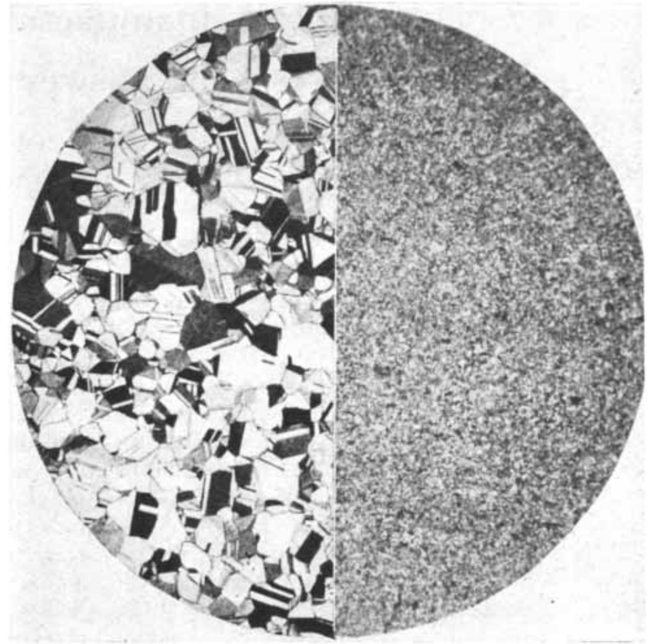

YOU CAN SEE WHY FORMBRITE'S BETTER. At the left is a 75X magnification of the grain structure of ordinary drawing brass, used for years in the production of stamped and drawn products. At the right is a 75X magnification of Formbrite. Note the superfine grain structure that gives Formbrite its superior qualities. Want to know more about this cost-saving metal? Address: The American Brass Company, General Offices, Waterbury 20, Connecticut.

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HOW ANTIBODIES ARE MADE

How do cells manufacture the molecules that neutralize foreign substances? The answer is not known, but the author discusses an hypothesis that accounts for some curious new observations

By Sir Macfarlane Burnet

English hematologists were excited last year when they discovered a woman blood donor who had *two* blood groups: about half of her red cells were group A and half group O. The physicians asked the woman if she was a twin. Considerably surprised, she replied that she was, but that her twin brother had died 25 years before at the age of three months. Here was a healthy woman who for a quarter of a century had been using red cells which "really" belonged to her dead twin. How this had happened can be explained only in terms of some rather new concepts of self and not-self in the living organism.

Our story has to do with the production of antibodies, those substances in the blood which we usually think of as protective agents formed to fight infection by an invading organism. In the simplest terms we can describe an antibody as a modified soluble protein with properties that make it stick to the type of molecule or microorganism against which it was developed. After an attack of yellow fever, for example, antibody against the yellow-fever virus may constitute something of the order of 1 per cent of the protein in the blood. These antibody molecules will immediately coat any new yellow-fever viruses that happen to enter the body and will effectively prevent them from causing an attack of disease.

Whenever any foreign material enters the body tissues, processes are set in motion to get rid of the foreign element and to insure that effective invasion by the same type of alien will not occur again. These processes are carried out by the cells producing the blood protein gamma globulin. The cells change the pattern of the gamma globulin in such a way that the molecule attaches itself to microorganisms of the infecting type, and only to that type. The different patterns allowed to blood proteins probably are almost unlimited in number, and they involve only trivial changes in the physical qualities of the molecule—*i.e.*, some relatively minor variation in the way its chain of amino acids is coiled and interlocked. In a sense these variations are analogous to those on the faces of playing cards, where a slight rearrangement of an insignificant amount of printing ink may make the difference between four aces and a four-card flush. In the body the difference is often between life and death.

In thinking about how such a reaction to foreign organic material could be called into being, we come at once on a highly important difficulty. The very same cells that are responsible for dealing with foreign bacteria are also concerned with mopping up and getting rid of worn-out and damaged material of the body itself. Aside from a few permanent cells that stay with an individual for life, practically all the body cells die and are replaced from time to time. Of the five billion red cells in every cubic centimeter of blood, nearly 50 million are removed and replaced by fresh cells every day of our lives.

Now it is clearly very important that removal of damaged or worn-out cells should not provoke an antibody response. Just how important is demonstrated by the fatal Rh disease, which in fact is due to an attack on the infant's Rh-positive red blood cells by antibodies from its mother's Rh-negative blood. These cells, though tolerated and disposed of without disturbance by the infant's own body, are treated like foreign microorganisms by the mother's blood. And indeed any expendable cell is so treated by the clean-up cells when it is inoculated into an unrelated animal.

The situation, then, is this: The scavenger cells dispose of the body's own worn-out or damaged cells without forming antibodies, but they do form antibodies to destroy an invading foreign material, be it virus, bacterium or foreign red cell. And our specific question is: How do the scavengers distinguish between the body's own and the foreigners—between the self and the not-self? The question may have much practical importance, because it appears that the capacity to recognize the difference between the body's own tissues and anything else is learned rather than inherited; if this is truly the case, something may be done about it.

This brings us back to the case of the woman with the two blood groups. Some years ago biologists at the University of Wisconsin observed that twin cattle sometimes had blood of two groups mixed together—60 per cent of each twin's cells might be of one group and 40 per cent of the other. The twins

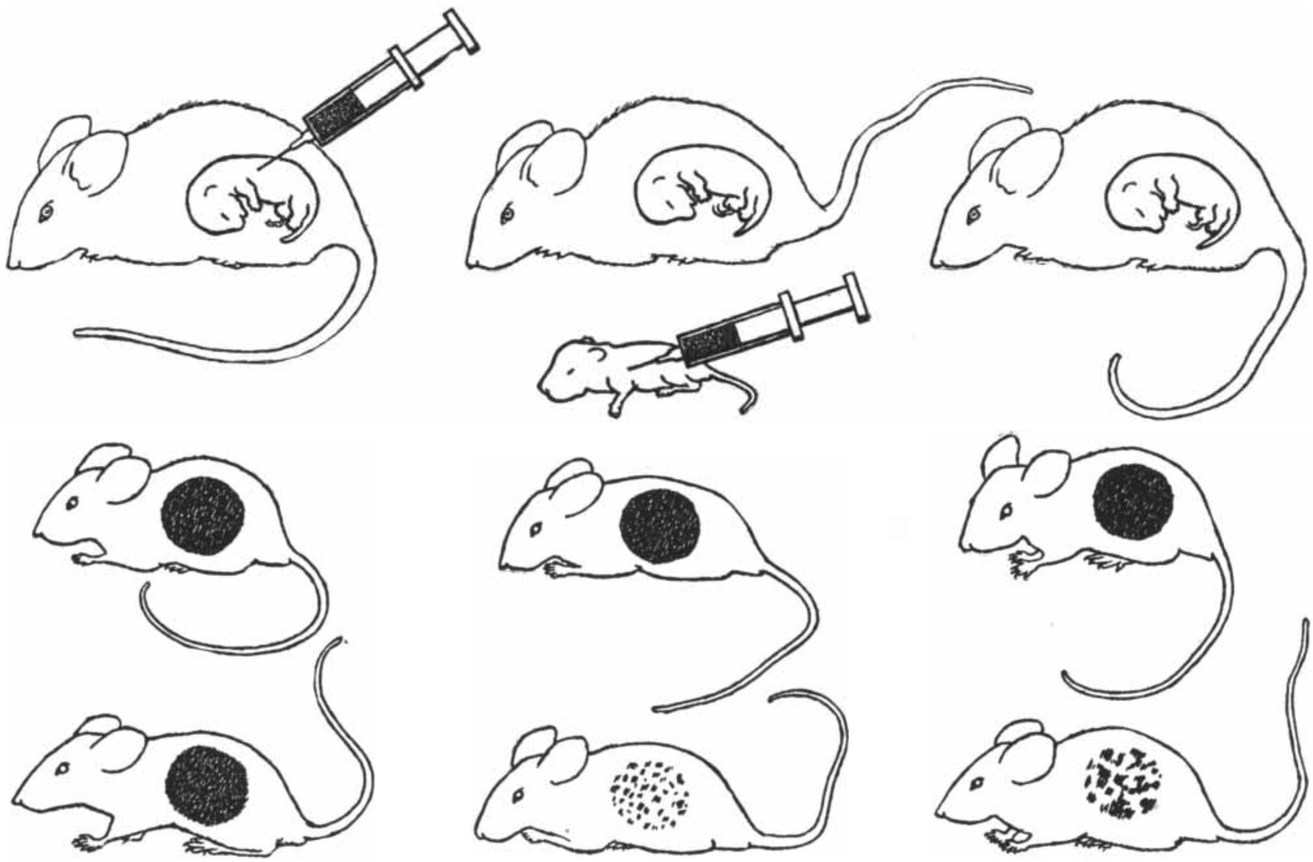
SKIN GRAFTS were utilized by P. B. Medawar and his associates to determine the period when mice could be conditioned to tolerate foreign cells. A white strain was to were never identical—they had recognizable differences in details of inheritance—yet they shared the blood anomaly. The probable answer is that they had developed a common placental circulation early in their embryonic existence and thus exchanged blood cells. Now the interesting point is this: the passing of blood cells from one to the other must have been achieved without the formation of antibody, for both twins tolerated the "foreign" cells and maintained this tolerance throughout their adult lives. In other words, it appears that during early embryonic life an animal may accept foreign cells and develop a lasting tolerance to them; its ability to recognize the difference between self and not-self does not come until later, some time before birth.

This seems to explain the mixed blood groups of the woman twin. The fact that such an occurrence is so much rarer in human beings than in cattle may be accounted for by the circumstance that two-egg human twins as embryos practically always develop separate placentas, whereas cattle often do not.

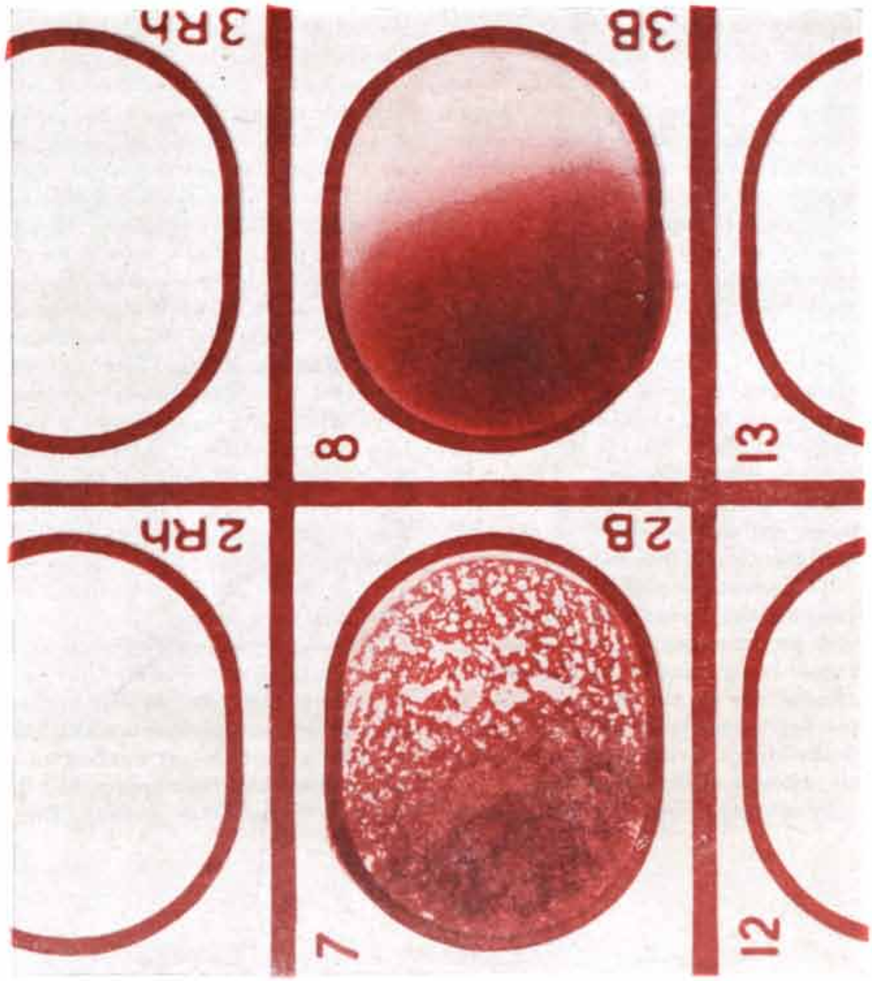
From certain virus investigations conducted at the Rockefeller Institute for Medical Research nearly 20 years ago comes another item of evidence for the idea that during embryonic life animals can develop a tolerance for foreign material. The German virologist Erich Traub observed that his colony of breeding mice, which was almost literally saturated with the virus causing the disease lymphocytic choriomeningitis, was able to pass on the virus to some of the mouse descendants without any observable effect on them. These survivors produced no antibody, and they carried the virus all their lives (passing it on in turn to their offspring). All of them appeared quite healthy. When their virus was injected into normal adult mice, however, the latter came down with the disease. Those that recovered showed some antibody and had eliminated the virus from their tissues.

Last year a group of English workers led by P. B. Medawar of the University of London succeeded in carrying out some deliberate experiments which have provided a most elegant clarification of the phenomenon. They approached the problem through skin grafting. Every surgeon knows that skin cannot be grafted from one person to another; the grafts may look healthy for a few days, but some time in the second week they begin to die and provoke an angry inflammation which leads to their complete destruction. This reaction signifies that the body has recognized the grafts as foreign cells and has produced antibody to eliminate them. Medawar and his group, however, set out to condition experimental mice to accept foreign skin grafts. They used two inbred families of mice which we shall call A and B. Their method was to expose embryos of one stock, about a week before birth, to cells of the other stock. Into each embryo of pregnant females of stock A they injected a finely minced suspension of living cells from mice of stock B. After the A offspring were born and had grown to the age of six to eight weeks, the experimenters grafted pieces of skin from B mice on them. The B skin took firmly on the treated A mice. Untreated A mice, on the other hand, completely rejected such grafts.

We have, therefore, the interesting situation that up to a certain critical



receive skin grafts from a black strain (*far left*). When a white-strain embryo was inoculated with a suspension of living cells from a black strain (*above, top left*), a skin graft from a black strain implanted six weeks after birth would "take." When a white-strain mouse was inoculated after birth and then grafted, the normal deterioration of the graft would be accelerated (*center column*). The normal deterioration is depicted in the column at right. The bottom row shows the result in each case two weeks after the graft.



RH DISEASE is an antigen-antibody reaction. In this demonstration a drop of Rh-blood antiserum is placed on each oval of the test plate. When Rh-negative whole blood is added, no reaction occurs (*top*). But when Rh-positive whole blood is added, antibodies in the Rh-antiserum combine with the cells of Rh-positive blood, causing them to agglutinate (*bottom*).

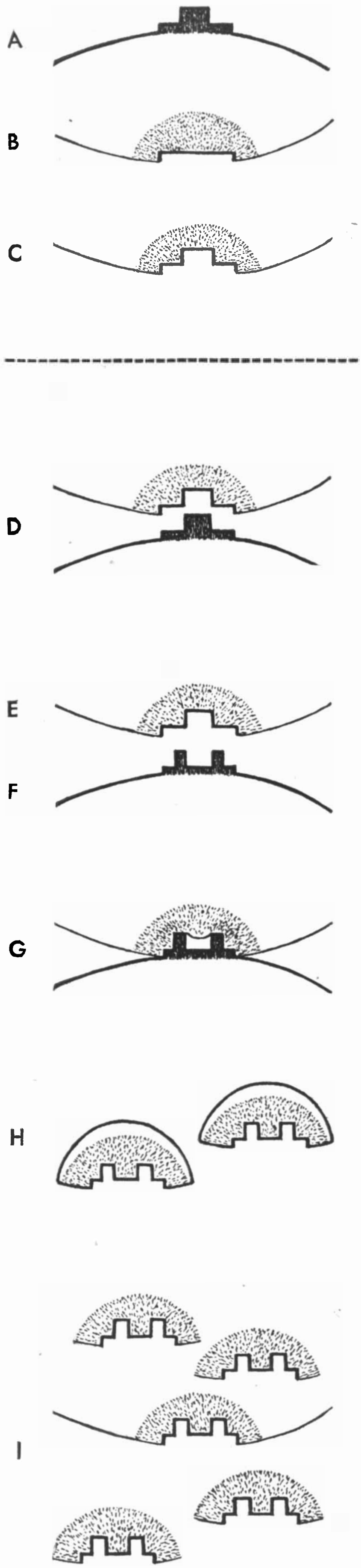
point in its development, an animal can develop an unnatural tolerance to foreign cells. In the mouse this critical point seems to be around the time of birth.

In animals such as sheep or guinea pigs, which are born at a much higher state of development than mice, there is some direct evidence that they begin to produce antibodies to foreign cells some time before birth. In human beings one can guess that the critical point comes more than one month before birth, because newborn babies respond rather well to immunization.

With the help of the new information on the early adaptability of the embryo, my fellow Australian microbiologist Frank Fenner and I suggested in 1949 a new theory of antibody production which has been called "the self-marker hypothesis." It is an untidy theory, because it postulates happenings for which there is only the slightest evidence; perhaps its only virtue—but a considerable one—is that it clearly predicted the possibility of the Medawar results.

On this theory there are in the scavenger cells of the body (technically the cells of the reticulo-endothelial system) certain structures which we call "recognition units." These units can recognize a certain fairly limited range of "self-markers," *i.e.*, molecular configurations typical of the expendable cells of the body. Recognition comes simply by virtue of a complementary structural pattern—like the lock-and-key relationship between an enzyme and the molecule with which it interlocks or between an antigen and its antibody.

The recognition units are formed and fixed before the critical point of development. They are shaped, as it were, not only to the self-markers of the body cells but also to any patterns that may be present due to an infection or accident; in other words, they may fit either a genuine self-marker or a pseudo one. The scavenger cells thereafter will ac-



cept the pseudo marker without forming antibodies.

Once the critical point in formation of the recognition units has been passed, they will react differently to any new pattern that may arrive, *i.e.*, an antigen. On our hypothesis, antigens resemble self-markers closely enough to react with recognition units. But in doing so they distort and reshape the units. This reshaping sets in train a process which is almost equivalent to the entry of a virus into the cell. The new recognition units multiply, reproducing their new specific pattern. Some of the multiplying units enter certain cells known as the stem cells of the lymphoid series—usually the precursors of lymphocytes.

In these stem cells the pattern persists, sometimes for life, though in most instances there seems to be a slow drift back to the normal self-marker pattern. When there occurs an acute stimulus to antibody production, such as a re-entry of antigen into the body, the stem cells give rise to specialized cells (known to the histologist as "immature plasma cells") which produce and liberate into the blood large numbers of antibody molecules.

As the stimulus of infection wanes and convalescence is established, antibody production drops to a lower level; all the evidence suggests that it is now being produced by the lymphocytes. It is probable that these ubiquitous, short-lived cells break down in various parts of the body and liberate fresh antibody.

Like all the blood proteins, antibody or gamma globulin generally is in a constant state of flux. Radioactive tracer studies show that the half-life of antibody is about 14 days in man. When we find, therefore, that a man who had a single attack of yellow fever 50 years previously still has antibody in his blood, we have to postulate that the cells in which the modified pattern is stored have gone on growing and reproducing, and that there is a continuing formation and breakdown of the lymphocytes which produce the actual antibody.

ANTIBODY FORMATION process proposed by Burnet and Frank Fenner is shown in this diagram. It assumes that expendable body cells have molecular configurations acting as "self-markers" (A). "Primordial recognition units" (B) are molded into "recognition units" (C) by contact with self-markers during embryonic life. In postnatal life (*below dotted line*) no antibodies are produced when a recognition unit encounters a self-marker or pseudo self-marker that had been fitted to it in embryonic life (D). But when a foreign body (antigen) of new pattern is encountered (E and F) the two adjust themselves to fit (G) giving rise to new recognition units (H) and triggering the production of antibodies (I).

It would be wrong to suggest that this picture of how antibodies are produced is acceptable to all or even most immunologists. When one looks at antibodies from the point of view of the chemist, a rather different picture emerges. This has been developed particularly by Linus Pauling of the California Institute of Technology and Felix Haurowitz of Indiana University. They regard antibody as gamma globulin which has been synthesized in contact with the actual antigen (or its significant pattern)—the antibody is stamped, as it were, with a pattern complementary to the antigen. This is in many ways the most satisfactory theory of antibody production and it has been convincingly elaborated by Haurowitz. Nevertheless it demands in the first place that the antigen must remain stored and functioning in the body as long as any antibody is being produced. What evidence there is points away from that probability. In the outstanding example where antigen can be shown to persist indefinitely there is no antibody production but an actual "immunological paralysis." A second difficulty with the orthodox theory is that it cannot explain the development of specific tolerance and the subsequent lack of immune reaction when foreign material is introduced during embryonic development.

The difference between the two approaches points up an important current issue in theoretical biology. The Pauling-Haurowitz view presupposes that the general process of protein synthesis in the cells can be described in terms of physical and structural chemistry. There are many indications that above a certain level of biological complexity this orthodox approach becomes impotent. In the fields that involve specific activities of proteins and enzymes we seem already to be relinquishing the old objective of describing the phenomena in the terms of physics and chemistry. Instead there is an increasing tendency to describe them in terms of replicating patterns which carry information or instructions from one part of a cell or organism to another. It is in line with the spirit of the times to believe that we shall soon see the conscious development of a "communications theory" of the living organism along these or analogous lines.

This perhaps is the major implication of the story of the woman with two blood groups.

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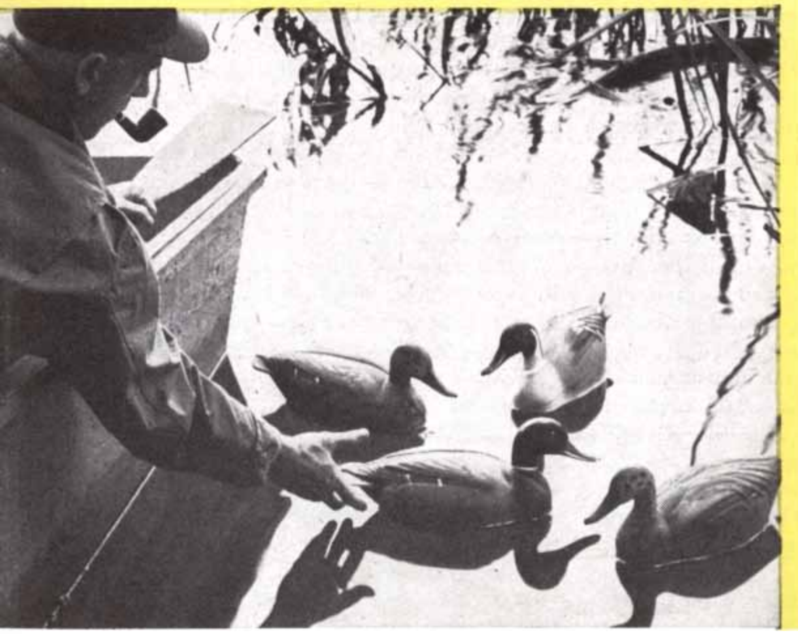

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The Curvature of Space

Just 100 years ago the young Bernhard Riemann gave his famed paper on the foundations of geometry. He discussed space of four or more dimensions, and paved the way for the General Theory of Relativity

by P. Le Corbeiller

In the spring of 1854 a young German mathematician named Bernhard Riemann was greatly worried about his future and about a test he faced immediately. He was already 28, and still not earning—he was living meagerly on a few thalers sent each month by his father, a Protestant minister in a small Hanover town. He wrote modestly to his father and brother that the most famous university professors, in Berlin and in Göttingen, had unaccountably been extraordinarily kind to him. He had his doctor's degree; now, to obtain an appointment as a lecturer (without stipend), he had to give a satisfactory lecture before the whole Faculty of Philosophy at Göttingen. He had offered three subjects. "The two first ones I had well prepared," Bernhard wrote his brother, "but Gauss chose the third one, and now I'm in trouble."

Karl Friedrich Gauss was the dean of German mathematicians and the glory of his university. In Bernhard's picture of Heaven, Gauss's professorial armchair was not very far from the Lord's throne. (This is still the general view in Göttingen today.) The subject Gauss had chosen for young Riemann's lecture was "The Hypotheses That Are the Foundations of Geometry." Gauss had published nothing but a few cryptic remarks on this topic, but he selected it in preference to the two others proposed by Riemann because he was curious to find out what the young man would have to say on such a deep and novel subject—a subject to which Gauss himself had given much thought and had already made a great, though as yet not widely appreciated, contribution.

The day of Riemann's public lecture was Saturday, June 10, 1854. Most of his auditors were classicists, historians, philosophers—anyway, not mathematicians. Riemann had decided that he would discourse about the curvature of n-dimensional spaces without writing any equations. Was that a courteous gesture on his part, or a mildly Machiavellian scheme? We shall never know. What is sure is that without equations Gauss understood him very well, for walking home after the lecture he told his colleague Wilhelm Weber, with unwonted warmth, of his utmost admiration for the ideas presented by Riemann.

Gauss's enthusiasm was justified. The young man had reached into realms of thought so new that few scientists then could follow him. But his abstract ideas were to make contact with experimental reality half a century later through the work of Albert Einstein, who saw that Riemann's speculations were directly applicable to the problem of the interaction between light and gravitation, and made them the basis of his Generalized Relativity Theory, which today controls our view of the universe.

Let us then go back 100 years and acquaint ourselves with the thoughts which Riemann made public on that June day of 1854. Before reaching Riemann's ideas we first have to cover some rather elementary background.

Everybody is familiar with the elements of plane geometry. A straight line is the shortest way between two points; parallel lines never meet; the sum of the three angles of a triangle equals two right angles, or 180 degrees, and so on and so forth. Also familiar is the geometry of figures drawn on the surface of a sphere, which obey somewhat different rules. The shortest route between two points on a sphere is called a "great circle"; this is the curve made by a cut through the points and the center of the sphere, splitting the sphere into equal halves. Two great circles always meet in two points; for instance, any two meridians of the earth always meet at the North and South poles. When segments of three great circles (for instance, one quarter of the earth's equator and the northern halves of two meridians) intersect to form a "spherical triangle," the three angles of 90 degrees add up to 270 degrees, or three right angles. The difference between this triangle and one in a plane derives from the fact that the sides of the former are drawn on a curved surface instead of on a flat one.

Now, how do we know that the surface of a table is flat and that of the earth is spherical? All early civilizations imagined the earth as a flat disk, with mountains heaped upon it like food on the king's table. Not being able to go to the moon to look at the earth, men could not see its true shape. How, then, did Greek astronomers come to the conclusion that the earth was round? By observing that the North Star was higher in the sky in Greece than in Egypt. Thus it is evident that we can recognize that a sphere is round either by observing it from a distance or, if we stand on it, by observing objects far away.

Man also could, and did, discover that the earth was round in two entirely different ways. One way was his circumnavigation of the earth. He found that while the surface of the earth had no "edge," no boundaries, its area was nevertheless limited. This is a most remarkable fact: the surface of the earth is boundless and yet it is finite. Obviously that situation rules out the possibility that the earth could be a plane. The surface of a plane is boundless and also infinite. (In common speech we consider these two words strictly synonymous—one of the many instances which prove that the sphericity of the world has not yet really taken hold of our consciousness.)

Thus mankind would have discovered that the earth is round even if it were constantly covered with a canopy of thick clouds. But suppose that he had somehow been prevented from exploring the whole planet. There is still another way in which he could have found out he was living on a globe, and that is by using the spherical geometry we have been talking about. If we look at a small triangle on the earth's surface, say one with sides about 30 feet long, it is indistinguishable from a flat triangle; the sum of its three angles exceeds 180 degrees by an amount so small that it cannot be measured. As we consider larger and larger triangles on the earth's spherical surface, however, their curvature will become more and more significant, and it will show up in the excess of the sum of their angles over 180 degrees. Thus by developing more and more precise methods of surveying and of making maps men eventually could prove the sphericity of the earth, and from their measurements they could find out the globe's radius. We shall return presently to this matter.

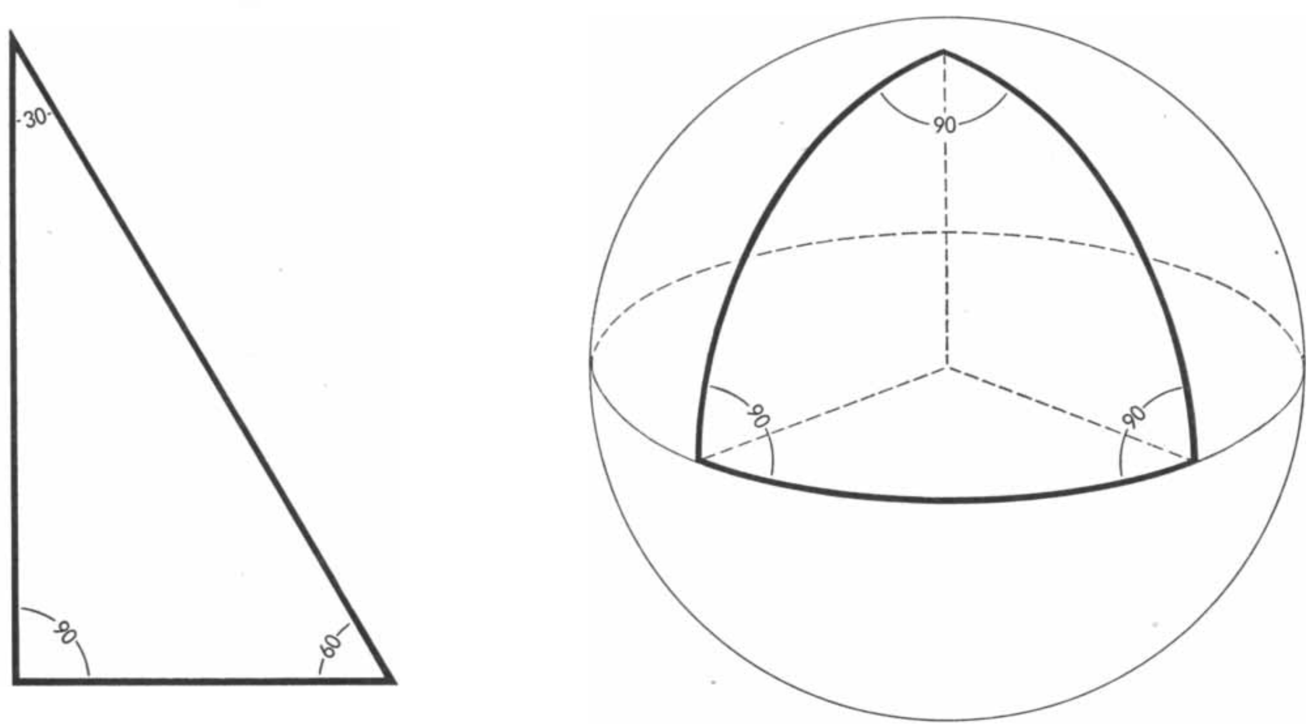
There are many types of surfaces besides those of a plane and a sphere. Consider an egg. It has a large end and a small end. A round piece of shell from the large end looks as if it were cut from a sphere; a round piece from the small end looks as if it belonged to a sphere with a smaller radius than the first. The piece from the small end looks more curved than that from the large end. Geometers define the curvature of a sphere as the inverse of its radius squared. So the smaller the radius, the larger the curvature, and *vice versa.*

If we were given a piece of shell from the middle zone of the egg, could we define its curvature? That is a little difficult, because such a piece cannot be identified with a portion of a simple sphere. The problem has been solved as follows. Suppose we lay the piece, which has the shape of a more or less elongated oval, on a table. It forms a rather flat dome. Any vertical cross section of that dome will be a curve concave downward. Every vertical cross section will look approximately like a portion of a circle, but not all will have the same radius. The section through the narrowest part of the base will have the smallest radius; the section through the elongated part, the largest. Let us call the first radius R_1 and the second R_2. Geometers then take a sort of average, and define the curvature of that small portion of eggshell as the inverse of the product R_1R_2. You can see that if the eggshell were a perfect sphere, we would be brought back to the previous definition.

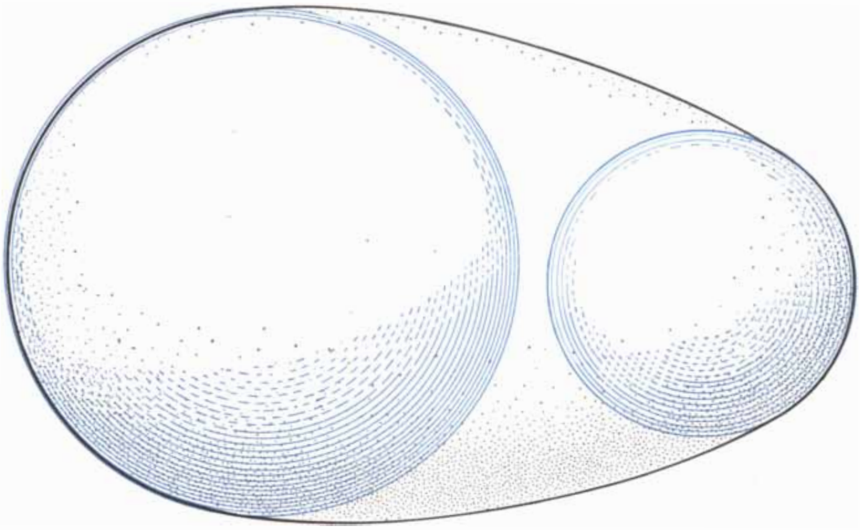
On the basis of these definitions one finds that the curvature of a small piece of an eggshell changes as we travel on the surface of the egg. It would make no sense to talk about the curvature of the whole egg; we can only talk about the curvature of a small piece.

Consider next the surface of a saddle. A crosswise vertical section cut through a saddle forms a curve which is concave downward, whereas a lengthwise vertical cut forms a curve concave upward. This makes even a small piece of the surface of a saddle something radically different from a small piece of an eggshell. Geometers say that the eggshell has everywhere positive curvature, and the saddle has everywhere negative curvature. The curvature of a small portion of a saddle-shaped surface can again be defined as the inverse of the product R_1R_2, but this time it must be given a negative sign.

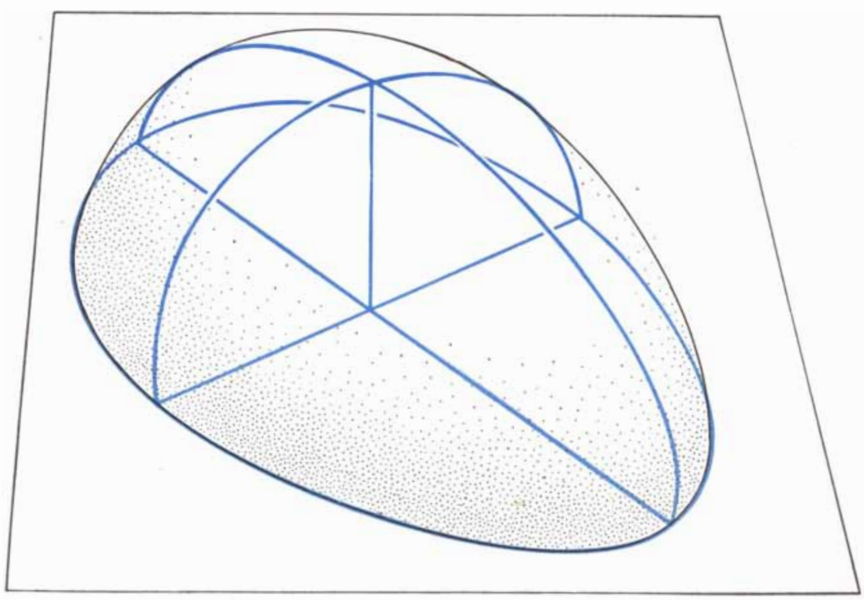
And here is still something else. Consider a doughnut. If you compare the inner half of the surface (facing the center of the hole in the doughnut) with the outer half, you will recognize that any small portion of the outer half has positive curvature, while any small por-



TRIANGLES drawn on a plane and on a sphere obey somewhat different rules. On a plane the sum of the angles of a triangle always is equal to 180 degrees. The intersection of three great circles on the surface of a sphere forms three angles adding up to 270 degrees.



AN EGG has a curved surface which looks as if the surface of the large end belonged to one sphere and the surface of the small end to another. The middle has a different curvature.



HALF AN EGG, laid on a table and cut into vertical cross sections, will yield sections with concave curves downward. These curves look like portions of circles of different radii.

tion of the inner half has negative curvature, as in the case of a saddle. Thus we must not think that the curvature need be positive or negative all over a given surface; as we travel from point to point on a surface the curvature not only can become greater or smaller, it can also change its sign.

Remember that we are engaged in taking a bird's-eye view of what was known about the curvature of surfaces before Riemann's time. What we have seen so far had been recognized in the 18th century by Leonhard Euler, a Swiss mathematician of considerable imagination and output, and had been developed by a group of French geometers at the newly founded Ecole Polytechnique. Then in 1827 Gauss, Riemann's senior examiner, added much generality and precision to the topic. He published a memoir on curved surfaces which is so jewel-perfect that one can still use it today in a college course.

Gauss started from the fact that geographers specify the location of a city on the globe by giving its longitude and latitude. They draw meridians of longitude (such as the one which unites all the points on the globe 85 degrees west of the north-and-south great circle through Greenwich) and also parallels of latitude. We may speak of the "family" of meridians and the "family" of parallels. In order to specify the location of a point on any mathematically given surface, Gauss imagined that we draw on that surface two families of curves, called p-curves and q-curves. We take suitable precautions so that any point on the surface will be pinpointed if we specify its p-coordinate and its q-coordinate.

Gauss's great insight was this. On an absolutely flat surface, if we travel three miles in one direction, then turn left and travel four miles in the perpendicular direction, we know from Pythagoras' theorem that we are at a point five miles from home. But Gauss reasoned that on a curved surface, whether egg, or saddle or what have you, the distance will be different. To begin with, the p-curves and q-curves will not intersect everywhere at right angles, and this adds a third term to the sum of the two squares in the Pythagorean equation $a^2+b^2=c^2$. Moreover, if we visualize the two families of curves as a kind of fish net drawn tight all over the surface, the angles and sides of the small meshes will change slowly as we travel from one region of the surface to another where the curvature is different.

Gauss expressed his reasoning in a famous mathematical equation. One p-curve and one q-curve pass through a given point M on a curved surface. The "quasi longitude" p and the "quasi latitude" q of point M have specific numerical values. We wish to move from point M to a neighboring point P on the surface. We first increase the value of p by a small quantity, letting q remain the same. Gauss used dp as the symbol for an arbitrarily small increase of p. We thus get to a point N, of longitude $p+dp$ and latitude q. We next increase the value of q by a small quantity, dq, letting $p+dp$ remain the same. We thus reach a point P, of longitude $p+dp$ and latitude $q+dq$. We wish to know the distance from point M to point P. Since this distance is arbitrarily small, Gauss used for it the symbol ds. In Gauss's notation, the square of the distance ds will be expressed by the sum of three terms:

$$ds^2 = E\,dp^2 + 2F\,dp\,dq + G\,dq^2$$

This equation is one of the high points in the whole of mathematics and physics —a mountain-top where we should exclaim in awe, like Faust suddenly perceiving the symbol of the macrocosm: "Was he a god, whoever wrote these signs?" It needed only two steps, one taken by Riemann and the other by Einstein, to carry us from Gauss's equation into the land of general relativity.

At any point M on our arbitrary surface, this equation is not different from a Euclidean theorem about the square of the third side, ds, of any triangle, the first two being dp, dq. That is because in the immediate neighborhood of a point the surface is very nearly a plane. But here is the novelty: Gauss introduced the functions E, F and G, whose numerical values change continuously as we move from point to point on the surface. Gauss saw that each of the quantities E, F, G was a function of the two arbitrary quantities p and q, the quasi longitude and the quasi latitude of point M. On a plane we can draw p-lines and q-lines dividing the plane into small equal squares, as on a chessboard; we have then $ds^2 = dp^2 + dq^2$, so that E is constantly equal to 1, F to zero and G to 1 all over the plane. But on a curved surface E, F and G vary in a way which expresses, in an abstract but precise manner, just those variations in the curvature of a surface that make every point different from every other.

Gauss now proved this remarkable theorem: that the curvature of the surface at any point can be found as soon as one knows the values of E, F and G at the point, and how they vary in its immediate neighborhood. Why is this theorem so remarkable? Because if we return to our fictional humanity living on some beclouded globe, not a spherical one this time but of arbitrary shape, the surveyors of any particular nation on that globe, knowing the theorem, could obtain all the information about E, F and G without seeing the stars and without going to the moon. Thus from measurements taken on the surface itself they would be able to calculate the curvature of their globe at various points and to find out whether the surface of their country was curved like a portion of an egg, saddle or doughnut, as the case might be.

Now of all the ridiculous and useless puzzles scientists like to solve, this one, you may think, surely takes the prize. Why should mathematicians find it important to describe the behavior of imaginary people in a nonexistent world? For a very good reason: *These people are ourselves.* Only it takes some little explanation to make you realize I have been talking about you and me.

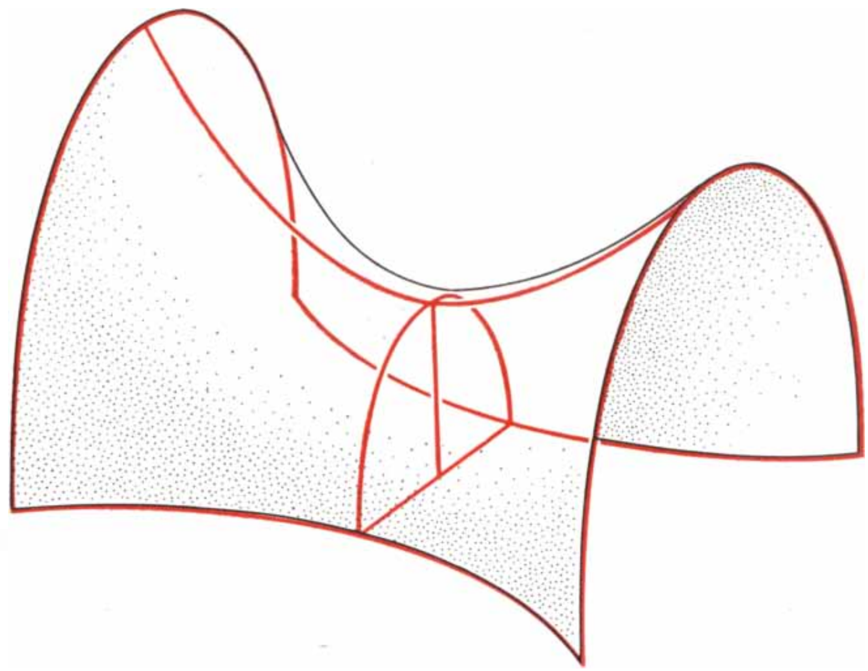
Let us imagine small bits of paper of various irregular shapes on a large, smooth sphere. These bits of paper are alive and moving: they are the people of that world, only their bodies are not volumes enclosed by surfaces but surfaces enclosed by curves. These people, having absolutely flat bodies without thickness, can form no conception of the space above or below them. They are themselves only portions of surfaces, two-dimensional beings. Their senses are adapted to give them information about the surroundings in their two-dimensional world. But they have no experience whatsoever of anything outside that world; so they cannot conceive of a third dimension.

However, they are intelligent; they have discovered mathematics and physics. Their geometry consists of two parts —line geometry and plane geometry. In physics they illustrate problems in one variable by diagrams on a line; problems in two variables, by surface diagrams. Problems in three, four or more variables they solve by algebra: "It's too bad," they say, "that for these we can't have the help of diagrams."

In the first half of the 19th century (*their* 19th century) an idea dawned upon several of them. "We cannot," they said, "imagine a third dimension, but we do handle physical problems in three variables, x, y, z. Why couldn't we *talk* about a space of three dimensions? Even if we cannot visualize it, it might be helpful to be able to talk about points, lines and areas located in that space. Maybe something might come of it; anyway, there's no harm in trying." And so they tried.

We need not carry this fable any farther; its meaning is clear enough. We are just like these people, only our bodies have three dimensions and are moving about in a three-dimensional world. Neither you nor I can visualize a fourth dimension; yet we handle problems about a particle moving in space, and this is a problem in four variables: x, y, z for space and t for time. We also handle problems about electromagnetic fields. Well, the electric field vector E at any point (x, y, z) has three projections, E_x, E_y, E_z, and it changes in space and time; that makes seven variables. Add three more for its twin brother, the magnetic field B, and we have 10. It looks as if the mathematical physicist could well use spaces of four or 10 or any number of dimensions.

Riemann in his dissertation assumed at the outset a space of an arbitrary number of dimensions. Now a lesser geometer would have found it very straightforward to define the distance of two neighboring points in that space. Don't



A SADDLE cut into lengthwise cross sections forms curves upward, while crosswise sections curve downward with shorter radii. A saddle is described as having negative curvature.

we know from Pythagoras' theorem that in a plane the square of that distance, ds^2, is equal to the sum of two squares: $ds^2 = dx^2 + dy^2$? Well then obviously in an n-dimensional space ds^2 must be the sum of n squares, the sum of all the terms similar to dx^2 which we can find. A very convenient shorthand for the expression "the sum of all the terms similar to" is the Greek capital Σ. Thus a simple-minded geometer would have written $ds^2 = \Sigma\, dx^2$. But Riemann saw farther than that. He had given much thought to the 1827 memoir of his master Gauss. He reasoned that, if we assumed that $ds^2 = \Sigma\, dx^2$, we were beaten at the outset. For Pythagoras' theorem is valid only in a plane, divided into equal little squares like a chessboard. Actually what we need to generalize is Gauss's equation, which works for any curved surface whatsoever, including a plane as a very special case. Gauss had added two things to Pythagoras' formula: (1) to the squares of dp and dq he had added the product dp dq of these two quantities; (2) he had multiplied each of these three terms by a coefficient of its own, and assumed that these coefficients *E, F, G* varied from point to point over the surface.

Let us do the same thing, then, for a "supersurface" of three dimensions, whatever that may be. We shall stretch over this supersurface three families of surfaces p, q, r or, as they are more conveniently designated, x_1, x_2, x_3. The square of the distance between two neighboring points, ds^2, should be built not only from the squares of dx_1, dx_2, dx_3, but also from their products two by two, and there are three such products: dx_2dx_3, dx_3dx_1 and dx_1dx_2. This makes a total of six terms, and we must give them six coefficients. Let us represent these coefficients by the letter *g*, with suitable subscripts. We must then write: $ds^2 = g_{11}dx_1^2 + g_{22}dx_2^2 + g_{33}dx_3^2 + 2g_{23}dx_2dx_3 + 2g_{31}dx_3dx_1 + 2g_{12}dx_1dx_2$. (The factor 2 is not indispensable, but it is esthetically satisfying to the algebraist, and Gauss had taken a fit when a young Berlin professor, Dirichlet, had committed the *faux pas* of writing a memoir which dispensed with the factor 2.) This, then, is the correct form of the ds^2 for a supersurface of three dimensions, and the six coefficients will in general vary from point to point over the supersurface.

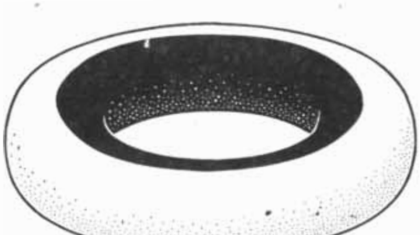
Riemann, as we have said, assumed at the outset that he had n variables to deal with, not a specific number such as three or four. He needed a name for the kind of geometrical objects he was thinking about. He noticed two things. First, a particle is free (in theory) to move smoothly and continuously from one point of a line or curve to another; it may also move continuously from one point to another on a surface or in space. Second, while studying plane geometry we think of nothing but figures drawn on a plane; that plane is for the time being our whole "universe of discourse," as logicians say. Yet the next year, as we study solid geometry, we imagine planes of any orientation in space. Any one of these planes might well be *the* plane of plane geometry which was last year's universe of discourse. It makes no difference in the geometry of a plane whether this plane exists all by itself or whether it is "embedded," as we now say, in three-dimensional space.

Putting these remarks together, Riemann coined the name "continuum" for any geometrical object, of any number of dimensions, upon which a point can continuously roam about. A straight line, for instance, is a continuum in one dimension—and it makes no difference to the geometry of points and segments on that line whether this one-dimensional continuum exists all by itself or is embedded in a plane, in three-dimensional space or for that matter in a space of any number of dimensions. The surface of a sphere or of a saddle is, as we have seen, a two-dimensional continuum; again it makes no difference whether we consider it by itself or embedded in a space of any number of dimensions.

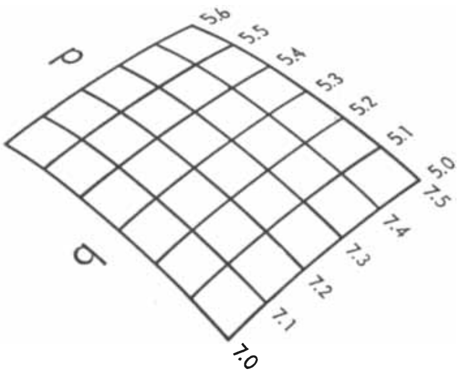
Now our space is a three-dimensional continuum. And we are bound to add that geometry in our space will be the same whether we consider that space by itself or assume it is embedded in a space of four, five or any number of dimensions. We cannot visualize what this means. Just the same, we might follow up this trail and see where logic leads us.

Such must have been young Riemann's thoughts about the year 1850. We must now try to say in a few words how far he progressed from there, and what, mainly, his dissertation of 1854 contained.

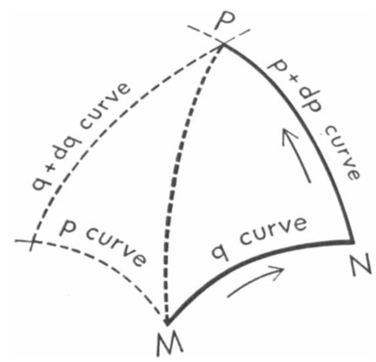
At a first reading, the outstanding result of Riemann's efforts seems to be that he succeeded in defining the curvature of a continuum of more than two dimensions. A two-dimensional continuum is a surface, and we have seen that its curvature is defined, for a small region surrounding any point of the sur-



A DOUGHNUT'S SURFACE shows positive curvature in its outer half, while the inner half has negative curvature (*black*).



LOCATION of a point on any mathematically given surface may be specified by giving one coordinate from the family of p-curves and one from the intersecting family of q-curves. On any surface but a sphere these curves will not intersect at right angles.



DISTANCE from one point *P* to a point *M* on a surface of any curvature cannot be determined by the Pythagorean rule. Gauss defined it as a function of the intersecting coordinates locating points and curvature varying on the surface from point to point.

face, by a single number—positive on an egg-shaped surface, negative on a saddle-shaped surface. If the curvature is zero at every point, the surface is a plane, and *vice versa*. Riemann showed that the concept of curvature can be generalized for the case of a continuum of *n* dimensions. Only it will not be a single number any more; a set of three numbers will be needed to define the curvature of a continuum of three dimensions, a set of six numbers for one of four dimensions, and so forth. Riemann only stated these results and made them seem mathematically plausible; their proof and elaboration would have filled a long memoir or occupied several weeks of lectures.

These considerations seem purely abstract—a completely vacuous game of mathematics running wild. However, Riemann's main object in his dissertation was to convince us that he was talking not about abstract mathematical concepts but about a question of physics which could be settled by the experimental method.

Let us return to those perfectly flat beings that live on a huge surface. Gauss's "remarkable theorem" proves that the two-dimensional inhabitants of this two-dimensional universe, provided they understood enough mathematics, could find the curvature of any small region of their universe. How could these people conceive of a curved surface, if they could not visualize a space of three dimensions? The answer is that such is precisely the power of mathematics. These people would be familiar with the concept of a curved road, contrasting with a "straight" road which would be the shortest route between two points. If then some Riemann among them had generalized this notion, *in a purely algebraic way*, into a theory of the curvature of a continuum of *n* dimensions, their surveyors would be able to calculate from a formula given by Riemann a certain number which, they would find, would change slightly from country to country. Thus they would have measured the curvature of their two-dimensional universe without being able in any way to visualize what that could be.

Such, of course, is exactly our situation regarding the curvature of our own universe, and we must return to Riemann's work to form some idea of how he came to define it.

Riemann suggested that if all the numbers which defined the curvature of an n-dimensional space were zero, this space should be called flat, for that is what we call a surface whose curvature is zero. Now if we divide a three-dimensional space into equal little cubes, as a chessboard is divided into equal little squares, then ds^2 is simply the sum $dx^2 + dy^2 + dz^2$, with *dx, dy, dz* representing the three sides of each little cube. That space is a "flat" space, just as a plane is a flat surface. In other words, what our intuition tells us is that space is flat—in the sense given to that word by Riemann.

Is it really so? That the small portion of space in our neighborhood should appear flat is only to be expected. It may well be that space is actually flat, not only in our vicinity but away into the realm of the farthest nebulae. On the other hand, it is equally possible that space is ever so slightly curved. How could we ever find out? Riemann's answer was: *from experience*. That is the revolutionary message which, very quietly but very firmly, he brought to the scientific world.

Euclid and Kant had unconsciously accepted the intuitive notion of space as flat. Riemann declared that this proposition should not be asserted without proof, as self-evident; it was only a hypothesis, subject to test by experiment. To start with we could make three hypotheses about our space: that it had constant positive curvature, or constant negative curvature or no curvature at all (*i.e.*, that it was flat, or Euclidean, as we now say). Which of these hypotheses was correct was for astronomers and physicists to find out. Such was the meaning of Riemann's cryptic title, "On the Hypotheses That Are the Foundations of Geometry," which had, how very rightly, aroused the curiosity of Gauss.

There are many other important things in this dissertation of Riemann's, such as a very clear-sighted appreciation of the possibility that we may have to adopt eventually a quantum theory of space—something our physicists are just now rather gingerly trying out. But the point we have presented here—the appeal to experiment in order to find out a possible curvature of space—is, we believe, the most important one.

Riemann wisely made no attempt to suggest what specific experiments should be made. Looking back from the vantage point of our post-Einsteinian knowledge, we realize they were very difficult to discover. One might have expected them to lie in the domain of classical astronomy, of measurement of angles between stars, but that doesn't cut deep enough. Einstein showed that gravitation had a great deal to do with the matter and that Riemann's provisional hypothesis of a space of constant curvature had to be abandoned in favor of local variations (*e.g.*, the curvature in the neighborhood of the sun or of Sirius was greater than in empty interstellar space). He also showed that time had to be brought in; in other words, a four-dimensional space-time was what had to be investigated experimentally. And thus it came about that in the three experimental checks on Einstein's theory obtained in 1920, space, time and gravitation were seen to be indissolubly mixed.

Riemann's contention that the geometry of the universe was just a chapter of physics, to be advanced like any other by the close cooperation of theory and experiment, was thereby fully justified. So also was Riemann's faith in his master, Gauss. The more we gaze upon Riemann's and Einstein's truly gigantic pyramids of thought, the more we admire how much was invisibly contained in the short, unassuming formula written by Gauss in 1827.

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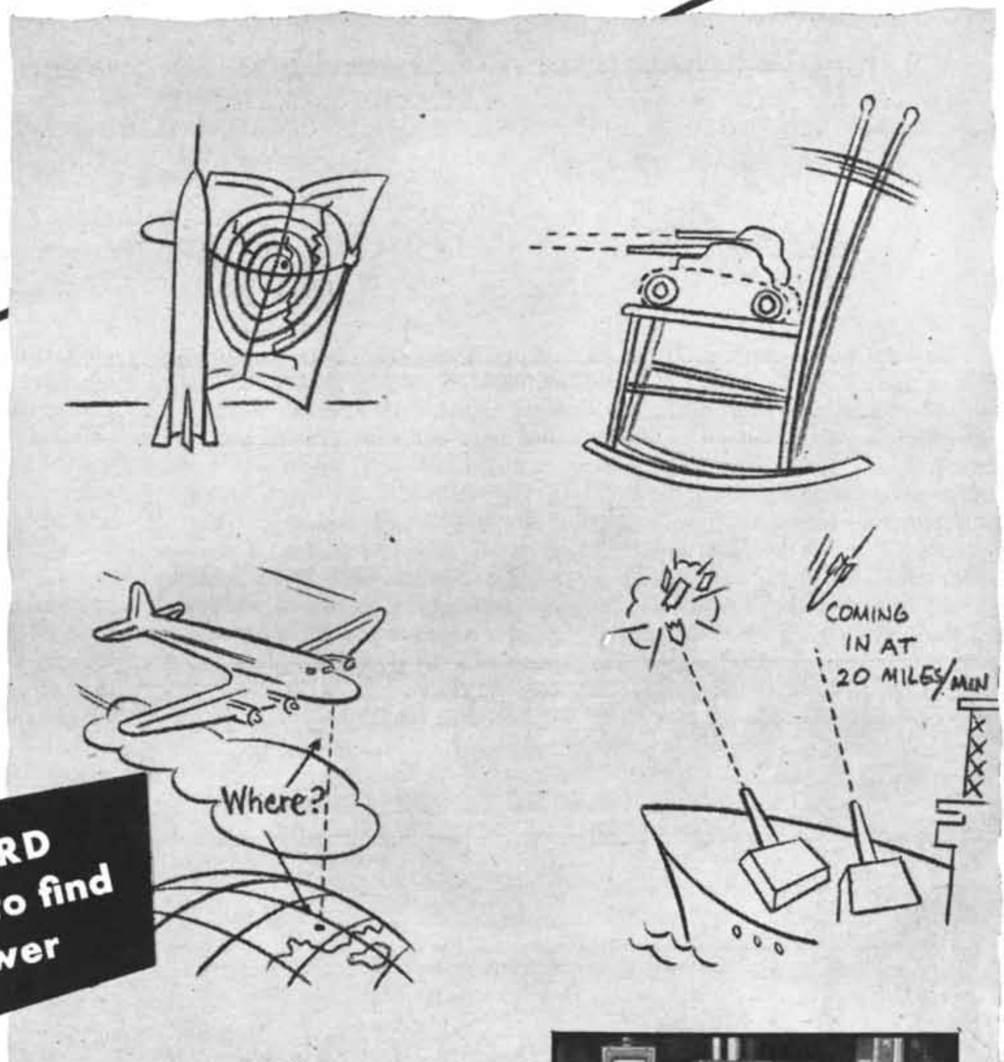

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SUICIDE

In the U. S. it causes 20,000 deaths a year, 10 times as many as those due to poliomyelitis. Its psychological and social factors are studied in the hope it can be prevented

by Don D. Jackson

Suicide is not a minor affliction of mankind. The statistician Louis Dublin estimates that about 310,000 members of the human race take their lives each year, and no one knows how many more attempt to. In the U. S. the suicide rate, some 20,000 per year, is more than 10 times the death rate from poliomyelitis. Yet hardly any systematic research is done on the causes of suicide, and the prevailing views on the subject are still unbelievably naive—witness the irrepressible newspaper cliché: "He is believed to have shot himself as a result of overwork." The moral confusion of opinion on suicide, which has always been torn between considering it a sin and a self-evidently rational act (since no man in his right senses would want to die while life was worth living), is still perfectly reflected in the laws of England, where a person of unsound mind may destroy himself with impunity, but the suicide of anyone of "sound" mind is regarded as a crime (*felo-de-se*) punishable by penalties against the deceased's estate.

Not until the 19th century was any attempt made even to keep statistics on self-homicide. A few scholars then began to study it from the sociological point of view. The man generally regarded as the father of research on suicide was Emile Durkheim of France, who in 1897 published his classic *Le Suicide*. Durkheim arrived at some conclusions which still hold good: he dismissed climate and certain other "extrasocial" influences as causes of suicide and suggested that a major factor was lack of sympathetic acceptance of an individual by his social group.

PSYCHODYNAMIC FACTORS affecting suicide include the idea of regaining a loved one through death (*left*), childhood self-punishment as an attempt to gain love (*middle*) and the feeling of displacement in the mother's affections by the younger sibling.

Our understanding of the psychodynamics of suicide of course began with the work of Sigmund Freud; his brilliant pupil Karl Abraham also contributed to it with his studies of depression and the superego (conscience). According to psychoanalytic theory, a depressed person, prevented by his conscience from expressing hateful or murderous wishes toward a loved object (originally the mother), turns them against himself. He has tremendous guilt feelings and feels responsible for all sorts of sins, crimes and wrongs which realistically do not exist. If he goes so far as to commit suicide, his self-destruction is in reality a strike against the hated and loved object as well as against himself. Most suicides occur during an emotional depression. It may be said that suicide is an impulsive urge which comprises all the elements of a depression within the single brief act.

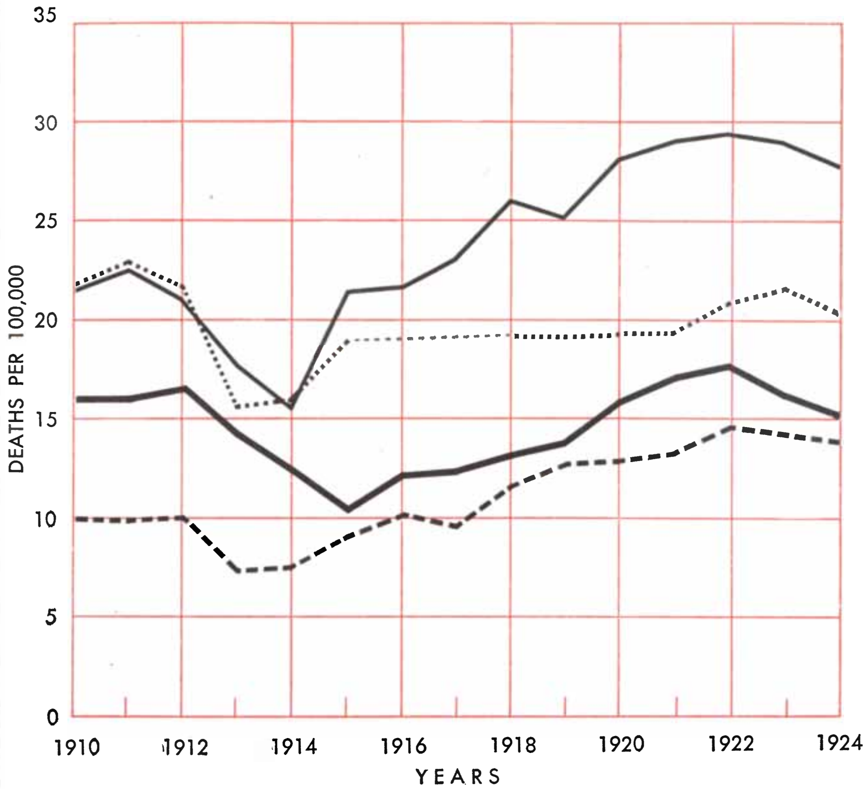
In recent years a number of psychoanalysts, notably Karl Menninger and Gregory Zilboorg, have taken a special interest in the problem of suicide, but all authorities admit to feeling rather discouraged by the difficulty of learning much about this complicated subject. To speak of the "death instinct" does not explain anything, and the concept of the death instinct itself seems to be in the throes of death. Not every depressed person commits suicide, or even thinks seriously of doing so. To understand what may have motivated a given individual to suicide, one would have had to study him psychiatrically for months or years; what psychiatrists have learned about the subject has come from patients who express suicidal urges, who have attempted suicide, or, occasionally, those who have actually committed suicide during treatment.

Suicide usually is the result of the combination of a conditioned personality and a triggering external stress. The situation is not unlike the shock reaction of an allergic person to an antigen: the individual has been sensitized to the particular antigen, and if he happens to encounter it in his environment, it may set off a severe reaction. The potential to react is not evident; on the surface a person with suicidal tendencies may be no different from his neighbors. And of course some individuals are much more resistant to stress than others. At one extreme, suicide may be committed by a psychotic who is under no actual stress but feels that the world is coming to an end; at the other extreme, a cancer victim suffering unbearable pain may end his life; in between, a neurotic person under some daily emotional strain may also commit suicide.

If we describe suicide as an attempt to escape from an unbearable situation, we can say that in nearly all known cases this unbearable situation is the experiencing of the loss of love. As a natural consequence of a feeling of sudden loss of love, the individual hates those who seem to be denying him. Because of the strength of the mechanism of guilt in our culture, the hateful or aggressive feelings are internalized and directed against the self. If the person had an aggressive parent, this process of internalization is strengthened by the individual's need to be like the parent (so-called identification). At the same time, the individual's self-punishment is an attempt to gain love; he seems to be saying: "Can't you see I will do anything—even die—if you will only love me?" We see the same tendency in little children who spank their own hand and call themselves bad because the hand took the forbidden piece of candy. The superego, which is intimately involved in the act of suicide, is an outgrowth of the child's awareness of parental approval and disapproval.

Children seldom commit suicide, but when they do they illustrate the under-

SOCIOLOGICAL FACTORS affecting suicide include political sacrifice or reaction to the radical change of structure of one's life (*left*), lack of acceptance, as among immigrants (*middle*), and economic disaster (*right*). All involve anticipation of rejection.



NATIONAL PATTERNS are evidenced by the suicide rates over extended periods. The rates plotted here are for Germany, France, U. S. and England, respectively from top to bottom. It is apparent that the rate declined in each of the four nations during war years.

lying motives more clearly than adults. Thus an adolescent girl, who experienced a sudden fear that she might kill her mother during the night, attempted suicide when the mother did not take the fear (wish) seriously. A 10-year-old boy whose father had been killed during the war hanged himself after quarreling with his mother about her new suitor, whom he hated.

The idea that through death one is joined with the loved object also seems to play a part in suicidal motivation, as does the fantasy that one will make a new start, that is, the good self will be reincarnated if one destroys the bad self. The wish to join the love object through death, as for example in *Romeo and Juliet,* is strengthened if there is identification with a dead or absent parent. It appears that persons who commit suicide have, more often than not, at least one dead or absent parent. Further, it seems that often people who attempt suicide were abnormally jealous of a younger sibling. Frequently there is a history of the individual's having run away from home, as if he preferred to leave rather than be left and was searching for the "real" parents.

There is a phenomenon known as "anniversary suicide"—an urge to kill oneself on the anniversary of the death or departure of a loved one. The impulse may also come when the circumstances of an early psychic trauma are repeated, or when they are evoked during psychiatric treatment. Thus a young man who was expressing hatred toward his father to the analyst attempted to drown himself when the therapist went on vacation at that point; it developed that the patient had once been severely punished by his father for running away when a new baby brother was born. Psychiatrists have long been impressed with how frequently men commit or attempt suicide when their wives become pregnant or deliver a child. More striking still, such an attempt is likely to occur when the new child comes in the sequential position that corresponds to that of the father among his own siblings.

It seems that the unbearable feelings of guilt that usually precede suicide are most commonly evoked by a sudden feeling of rejection, which accentuates the unacceptability of the person's unconscious hatred. It is as if the individual is saying: "They want me to die because I hate."

To summarize this brief account of the psychodynamic basis of suicide, it seems that suicidal individuals have major problems in regard to dependence and hostility, arising from childhood difficulties which usually involve severe rejection by one or both parents. If, in addition, a parent has died or has been absent for a significant period, the child's feeling of rejection and loss is increased. As long as such an individual lives in a situation in which he is continually accepted, his conflict may not break out into the open. But if he encounters an experience producing a marked feeling of rejection, such as divorce, a loss of prestige or the like, he may no longer be able to repress the conflicts.

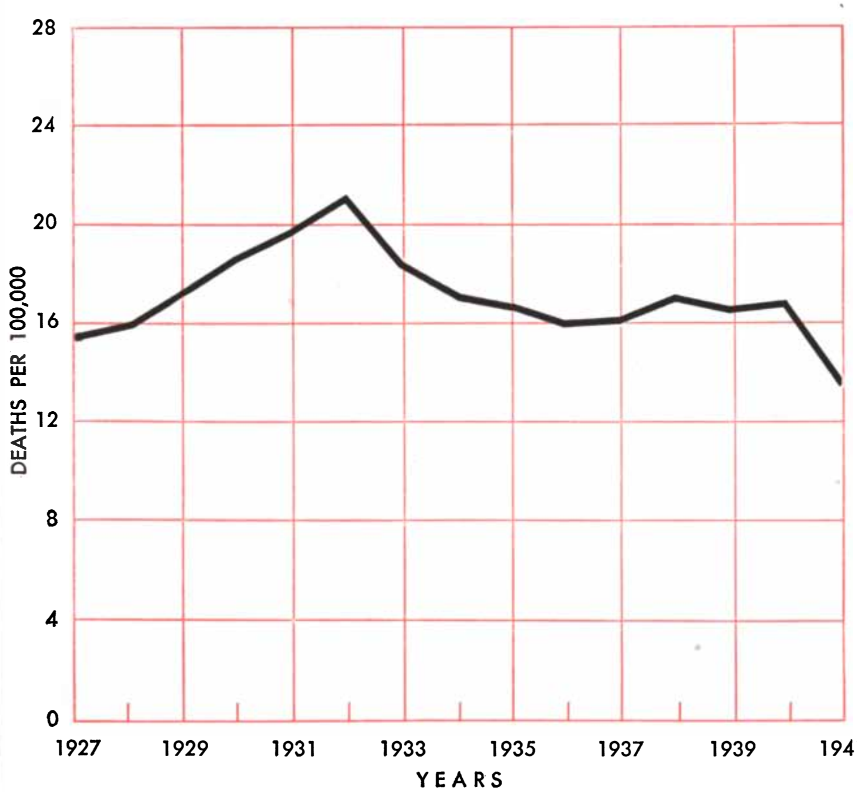
Of course there is a great deal more to the story of suicide. We need to study the sociological factors. Wars, postwar readjustments, economic depressions, religion and social organization all play their parts. A considerable amount of sociological data on suicide has been collected; some of it is summarized here. They make clear that suicide rates vary with the country and the time. Suicide declines during prosperity and rises during a major economic depression, though not in any spectacular manner (the supposed wave of Wall Street suicides during the crash of 1929 turns out to be only a ripple statistically). In general, the so-called epidemics of suicide are a myth; for example, in 1927 the U. S. press heralded an outbreak of suicide among college students, but actually there was no unusual rise among persons of this age group, only aroused public notice.

Suicide rates among the various groups of society show a fairly well-defined pattern in U. S. statistics. The rate generally rises with age; among males it is about four times as high after 60 as before the age of 20. Male suicides outnumber females about three or four to one (although the rate of unsuccessful attempts is higher among females). The rate is highest among divorced persons, lowest among the married. Professional people commit suicide more commonly than nonprofessionals; white collar workers, than laborers; officers, than enlisted men. Negroes have a lower suicide rate than whites. Suicide is more common in cities and towns than in rural areas; geographically the rate is higher in the Western U. S. than in the Eastern—for a decade after the turn of the century San Francisco had the highest suicide rate in the world. Where the homicide rate is high, the suicide rate is apt to be low; this is especially striking in Italy, where the northern part of the country has comparatively few homicides and many suicides, while the reverse is true in Sicily. Curiously, both in the U. S. and Europe suicide exhibits a seasonal and even daily ebb and flow: it is highest in the spring, and in the shorter cycles there is a peak at the beginning of each week and one at the beginning of each day.

Ireland, which has an astonishingly low suicide rate (about three per year per 100,000 population), illustrates the social factors that minimize suicide. It is a predominantly rural and Roman Catholic country; the suicide rate is generally lower among Catholics than Protestants. There are few divorces in Ireland, and the family enjoys high social status. The people's passionate loyalty to their country is renowned. On the other hand, they have little ambition for leadership in power or in commerce.

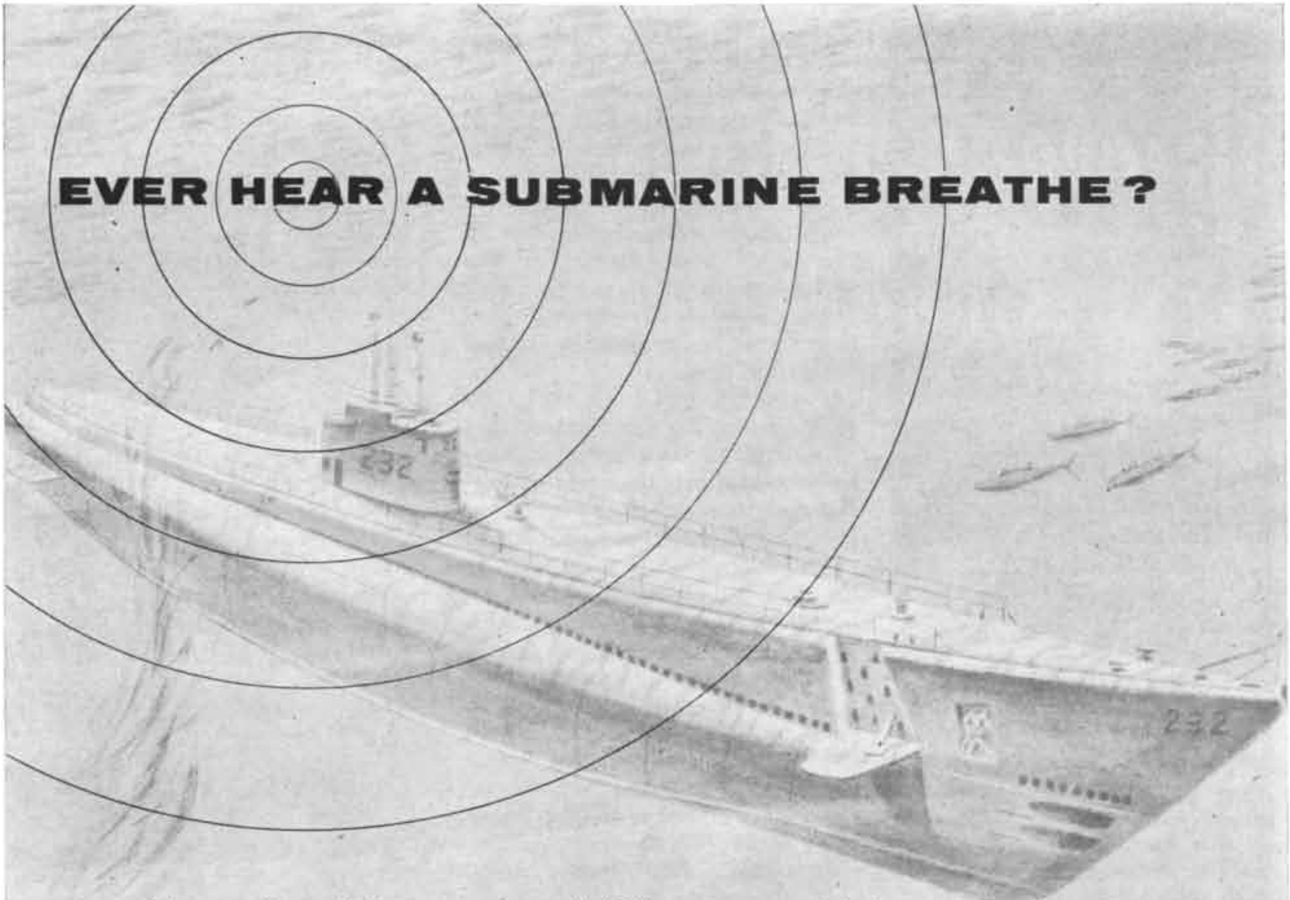
As a matter of fact, it can be stated that in any community where there is no marked striving for leadership or personal prestige, and where group pressure is strong, the suicide rate tends to be low. This is true of a small rural community, where the sameness of interests and religion makes most individuals feel accepted. In a country such as the U. S. the problem of acceptance may account for the higher suicide rate among men than among women. Men usually are expected to strive for prestige more aggressively—and are more apt to suffer frustration—than "those who sit and wait." In contrast, in those countries where females are disprized (China, Japan, India) women have a high suicide rate; in India in the early 1900s it was higher than among men despite the ban on suttee (self-cremation on the husband's funeral pile). In certain primitive cultures the elderly males are encouraged to commit suicide when they have outlived their usefulness; their self-destruction is accompanied by great honor, prestige and ceremony. The Tschuktschi of northern Siberia appoint a son, friend or neighbor to stab or strangle an old man whose usefulness is done. Old women remain valuable as midwives or menials. Even in our own culture the single, elderly woman can generally find more acceptance and use for her limited abilities than a man in the same position.

Primitive peoples, it appears, have a low suicide rate. Their reasons for self-destruction, however, follow the same pattern as civilized peoples': guilt feelings over violations of taboos, the loss of love and so on. The relation between hostile feelings and suicidal impulses is perhaps best demonstrated by the "running amuck" of the Malays. Here the wish to kill is followed by a



NEW YORK STATE'S RATE of suicide over a significant period indicates the short surge upward during a period of severe economic depression and the slope downward in wartime.

EVER HEAR A SUBMARINE BREATHE?



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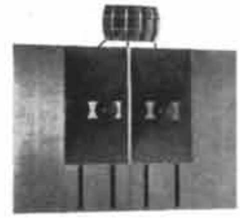

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ceremonial suicide. In our own country we frequently see suicide following murder or attempted murder. Psychiatrists are well acquainted with the soldier who becomes depressed and suicidal when he returns to civilian life. A classic example is an aircraft gunner in the late war: he felt at home as long as he was a member of a fighting team where he had an acceptable outlet for his hostile and aggressive impulses, but after his discharge from service he attempted to jump off a bridge.

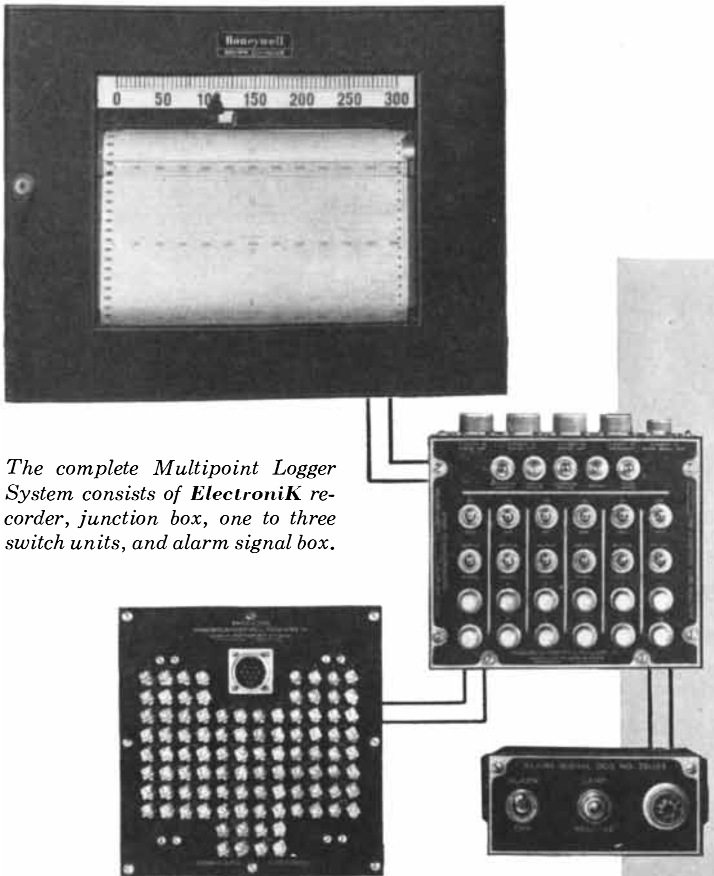
This writer has great limitations in interpreting sociological data, and has presented only the barest outline of the available sociological studies of suicide. Indeed, the social statistics do not mean much unless they are related to the individual's emotional make-up and personal relations. For instance, it is misleading to say, as Durkheim did, that marriage tends to reduce suicide, for the higher suicide rate among single and divorced persons probably is due to the fact that such individuals tend to be less mature emotionally than those who marry successfully. Again, many people resist any impulse to self-destruction in spite of painful, disfiguring or fatal disease, while others commit suicide as a reaction to success! The latter paradox is not hard to understand in the light of individual psychodynamics, for the drive to succeed may be rooted in an urge to outdo a hated parent. The son of a hostile father may feel "now he will hate me for being better than he is."

It is not uncommon for an emotionally disturbed person to have the thought that someone on whom he is dependent would be justified in a desire to kill him. This thought tends to occur in situations where the person feels he is a nuisance or is making the other unhappy (although he may be in no way responsible for the other's unhappiness). Invariably such a person felt rejection in early childhood. If he becomes strongly attached to someone, he is apt to feel: "I cannot live without you, but I hate you for making me need you so much." A rejected child who grows up into a dependent adult has no choice: he cannot give up the loved object and must endure the torturing emotions. There is a terrible yearning and helplessness, a fear and expectation of being hurt by rejection or abandonment. The individual maintains a precarious balance by means of the fiction that he will be loved "if"—if he is "good" or gains power in some way. ("I can show them that I don't need them," or, "They will realize some day how they should have treated me.") As long as the balance is preserved, the hostile elements are not noticeable. The individual is aware only of hurt feelings, helplessness and a passion to be loved. However, if the false hopes are dimmed by overt rejection, as happens in divorce, or by a failure that increases the expectation of rejection, the hostile elements break through and may become conscious. The major situations in which suicide tends to occur can be classified roughly in two groups: those involving outright rejection and those involving anticipation of rejection because of a change in one's status. Divorce, an unhappy love affair, discharge from a job, illness or an accident (punishment by an act of God) are examples of the first kind of rejection; a loss of prestige, a subjective failure or unacceptable sexual feelings exemplify the situations that lead a person to expect rejection. Obviously there is no clear dividing line between these two groups, since it is simply a matter of emphasis whether one feels rejected or expects it.

Suicidal feelings embrace these elements: a wish for recognition and attention through being missed, an atonement for guilt, a wish to be born again blamelessly, an urge to join a dead or lost loved object, a longing for sleep, a religious aspiration for Heaven, a running away from an intolerable situation, an act of self-punishment which at the same time lays the blame at another's door (*e.g.*, hara-kiri). Whatever the immediate motive or occasion, the roots of suicide always lie in a childhood conflict. The triggering event may be trivial. Often the attempt at suicide has a histrionic air: a girl who read in the morning paper of her former boy friend's engagement scattered pictures of him about her bedroom, decked herself in a bridal-like nightgown and took sleeping pills while lying in a bower of white gladiolas.

Suicidal thoughts are common: of an unselected group of 100 college students who were interviewed, 50 per cent said they had had such ideas at one time or another. It is when these ideas become a preoccupation that they signal danger. The Rorschach test has disclosed some interesting signs of dangerously suicidal tendencies: individuals with such tendencies do not use color in their responses; they tend to reject some cards; their responses lack spontaneity, and their interpretations seldom invoke movement, especially human movement.

Significantly, patients who are suddenly relieved of symptoms of illness by treatment with ACTH or cortisone some-



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It's fast: the *ElectroniK* Logger steps from point to point at a maximum rate of one point per second.

It's alert: warns of overheat or other danger spots . . . operates an alarm whenever any point exceeds a preset maximum . . . alarm circuit remains energized until manually reset.

It's versatile: can be stopped to indicate any single point continuously . . . can automatically recycle through or omit any group of 24 points.

It's economical: does the work of up to eight conventional instruments . . . costs considerably less per recorded point.

The Multipoint Logger System is supplied for 48, 96, or 144 points in ranges to fit your specific requirements. Your nearby Honeywell sales engineer will be glad to discuss ways your project can utilize this new system. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA: Write for new Bulletin 1570, "Multipoint Logger System."**

H HONEYWELL

MINNEAPOLIS **Honeywell** BROWN INSTRUMENTS

First in Controls

times attempt suicide. Unbearable as their physical symptoms have been, they were more bearable than the unconscious conflicts and hostile feelings toward the persons on whom they had been dependent.

Finally, I should at least mention the case, familiar in 19th-century novels but rare in real life, of those people who seem to waste away because they want to die, and also the phenomenon of accident-proneness, which in a sense is partial suicide. One family that was studied psychiatrically exhibited a remarkable concatenation of apparently suicidal expressions: the mother had a chronic, fairly incapacitating illness for which no organic cause was found; the father was accident-prone and had broken his leg three times; one daughter was hospitalized for depression; the other daughter committed suicide.

In this sketchy and admittedly superficial attempt to discuss some of the elements of suicide, I have had to pass over some complicated psychodynamic factors, such as homosexual wishes, incestuous feelings and pregnancy fantasies. These are special expressions of the same general picture: to wit, that an individual, generally in a sociological setting that complements his interpersonal difficulties, attempts suicide when he experiences specific rejection (real or illusory) in a situation which mimics an earlier traumatic one. The essence of the interpersonal difficulties is a strong feeling of loss of love, with consequent hateful and murderous feelings. The specific rejection is experienced at a time when the person's psychic economy is already strained to the utmost by the notion that he is unacceptable and by strong guilt feelings. In seeking death he seeks expiation and reincarnation.

This basic thesis is supported by clinical observation and by sociological data. The stronger the cohesive forces of a society and the more acceptable the dependency wishes of individuals, the lower is the suicide rate. The more benevolent the authority toward whom the individual looks (be it parent, President or Pope), the less his superego drives him toward self-destruction. The strict superego has been called "alcohol-soluble". Evidently for most of us the idea that things will get better serves as a protection against impulsivé self-destruction.

As Franz Kafka wrote: "Only our concept of time makes it possible for us to speak of the 'Day' of Judgment by that name. In reality, it is a summary court sitting in perpetual session."

WHICH "150" fits *your* oscillographic recording need?

4-CHANNEL

As a graphic example of the design idea that has brought new versatility to industrial recording, a Carrier Preamplifier (A) is shown above in position to plug into a Driver Amplifier in framework with Power Supply (B) which are normally already in place in the Basic Cabinet Assembly.

The identical design principles of the four-channel system are provided in the two-channel, the only difference being the number of channels.

Sanborn "150" Recording Systems that put to use the original design concept of amplifier interchangeability (illustrated at the left) start with either a four-channel or two-channel standard Basic Assembly, to which the user adds whatever selection or combination of preamplifiers (A) are needed for his recording problem. The standard Basic Assemblies comprise a metal Cabinet, Recorder, and a built-in Driver Amplifier and Power Supply (B) for EACH channel. Presently available Preamplifiers are: AC-DC, Carrier, DC Coupling, Servo Monitor, Log-Audio, and Low Level Chopper.

Advantages common to ALL Sanborn Recorders are: inkless recording (by heated stylus) on plastic coated strip chart paper, and in true rectangular coordinates . . . high torque galvanometer movement . . . time and code markers . . . numerous paper travel speeds.

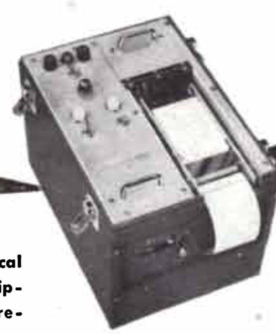
2-CHANNEL

"150"
COMPLETE FOUR-CHANNEL SYSTEM FOR USE WITH ANALOG COMPUTERS

This "150" system consists of a Cabinet Assembly, a four-channel Recorder, and *two* dual channel DC Amplifiers. Each amplifier is complete with a common power supply. Each measures and records two separate single-ended signals, at sensitivities between one and one hundred volts per centimeter. The *two*-channel version of this system will comprise Cabinet, *two*-channel Recorder, and *one* dual channel amplifier.

"150"
SINGLE-CHANNEL RECORDER

A compact, lightweight unit for use when only one channel is required — provides permanent, inkless recording in *true* rectangular co-ordinates; *five* paper speeds (5, 10, 25, 50, 100 mm/sec.); *extra* stylus for either manual or remote timing and coding marks. Designed for simple, patch cord connection to *any* of the several "150" preamplifiers (plus driver amplifier and power supply), available soon in portable metal cases.



Ask, also, for a copy of the *Right Angle* — a Sanborn publication devoted to oscillographic recording in industry.

Catalog and technical data on all "150" equipment available on request.

SANBORN COMPANY
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Trade in the Ancient World

The seaborne commerce of Rome was unsurpassed until relatively recent times. Evidence for this marine traffic comes from many sources, including the newly stimulated underwater archaeology

by Lionel Casson

I built five ships, loaded them with wine—worth its weight in gold at the time—and sent them to Rome. . . . Every one of my ships went down. . . . Neptune swallowed up 30 million sesterces in one day. . . . I built others, bigger, better and luckier, loaded them with wine again, plus bacon, beans, perfume, slaves. . . . When the gods are behind something it happens quickly: I netted 10 million sesterces on that one voyage.

The time is the first century and the speaker is Trimalchio, the famous character of Petronius' *Satyricon.* Petronius is, of course, exaggerating—but not much. In Roman times there was a fortune to be made in the export and shipping business. M. Porcius, a wealthy wine shipper who worked out of Pompeii, made enough money to contribute half the cost of building a public theater for his town, capable of seating 1,500 people. Sextius Fadius Musa, who shipped wine out of what is now Burgundy, set up a large trust fund whose annual proceeds were to go for a huge feast to be celebrated on his birthday forever. Archaeologists have found hundreds of wine jars stamped with his name in France and Italy, testifying to his far-flung activities. On Delos, a tiny island in the middle of the Aegean Sea, shippers so fattened on the lucrative perfume, spice and slave trade that they were able to establish orphanages and other charitable institutions, erect temples, put up statues and carry out all sorts of public improvements. Not only the shippers but also the bankers who financed them grew rich. Even Cato the Elder, that dour Roman farmer, was not averse to investing in the oriental trade.

The Mediterranean in a very real sense made one world of the Roman Empire. The sea was the heart and around it the provinces stretched in a wide arc. The arteries were the shipping lanes, the largest leading from points on the perimeter to the huge capital at Rome, and later at Constantinople. Over them passed the great ships, leaving on regular schedules to carry the thousands of bushels of wheat, the jars of oil and wine and salt fish. Both large and small vessels transported luxury goods ranging from Chinese silks to Athenian statuary.

To piece together the details of this ancient commerce the investigator must do without the wealth of detail available to the modern economic historian. He has no sets of national statistics, no annual records of boards of trade and the like. His bible is a voluminous geography written by an observant Greek named Strabo who lived around the turn of the first century. Strabo traveled widely in the Mediterranean, described the industry of each area and frequently added a brief sketch of its commercial history. A good deal of miscellaneous information comes from Pliny the Elder, a high official of the Roman Empire in the middle of the first century who spent his leisure time compiling a sort of encyclopedia which is a storehouse of all sorts of facts and a good many fancies. Once these two sources and minor ones like them have been exhausted, the researcher must seek the help of archaeology. Greek and Latin inscriptions that have survived on stone add nuggets of detail: a dedication to one of the Roman emperors found in the port of Rome records that it was erected by "the shippers of Africa"; a tombstone of a merchant unearthed in Asia Minor proclaims that the deceased rounded Cape Malea 72 times in his trading voyages to Rome; a decree of the Senate and Assembly of Athens announces the grateful thanks of the city to a shipper who had brought in a boatload of grain during a serious shortage. The best representations we have of ancient vessels come from the graves of merchants who had a sketch of the craft to which they owed their fortunes inscribed on their tombs. Findings of Egyptian pottery in Crete, of Syrian glass in Italy, of Italian dishes in southern France and so on enable us to trace many lines of commerce. We can reconstruct the wine and oil trade from clay shipping jars, stamped with the place of origin, which excavators have unearthed at dozens of sites. A new and fruitful source of information is underwater archaeology. Divers, working under the direction of archaeologists, have carried out the delicate and in some cases dangerous task of investigating ancient wrecks and of identifying their cargoes. Although the first of the marine excavations was begun in 1907, virtually nothing more was done along these lines for the next 40 years. Since 1950 a dozen new wrecks have been located, and two have been seriously excavated. Present indications are that this will soon become an important phase of archaeology.

Obviously marine commerce began long before Roman times. On the tomb of Hatshepsut of Egypt is inscribed the story of a trading venture directed in 1500 B.C. by this first great queen known to history. Hatshepsut sent a fleet of merchantmen from Thebes on the upper Nile via the Red Sea to the Somali coast to bring back a huge cargo of incense. Though this story has long been known, another bit of evidence came to light 50 years ago. A group of Egyptian peasants looking for firewood stumbled upon a papyrus which turned out to contain a diary dating from about 1120 B.C. kept by an individual named Wenamon. Wenamon was a special envoy whom Pharaoh Ramses XI sent to buy lumber from Byblos in Syria, and the diary records the events of his trip. Moreover, his story indicates clearly that it was not the first time that lumber had been shipped along this route; the traffic had been going on for centuries.

Not long before Wenamon's time the Trojan War had taken place. Some historians and archaeologists see in it a struggle between Greeks and Trojans for possession of the Dardanelles, which controlled the water route between the Aegean and the Black Sea. In Homer's poems describing the conflict we see, too, something that was always to plague the shippers of the Mediterranean: piracy. The Greek raid that ended in Achilles' famous retirement to his tent was nothing more than a piece of piratical brigandage.

By the fifth century B.C., when Athenian civilization reached its height under the rule of Pericles, a pattern of trade on the sea began to emerge. The average Greek town was virtually self-sufficient. Large cities such as Athens and Corinth, on the other hand, were getting too big to be fed by the produce of the surrounding countryside and had to start importing. Three staples formed the basis of trade: grain, wine and olive oil. Then as now the Crimea and Sicily produced a large grain crop and ships unloaded thousands of bushels each year at Piraeus, the port of Athens, taking in exchange Athenian olive oil or gaily painted pottery dishes and other kitchenware. Greek islands off the coast of Asia Minor, such as Rhodes and Chios, annually produced thousands of gallons of both cheap and choice wines that were sold all over the eastern Mediterranean; the distinctively shaped jars in which they were carried have turned up in practically every archaeological excavation in the area. Where today the cash crop of Egypt is cotton, in ancient times it was grain, and she joined Sicily and the Crimea in feeding Greece and the Greek islands.

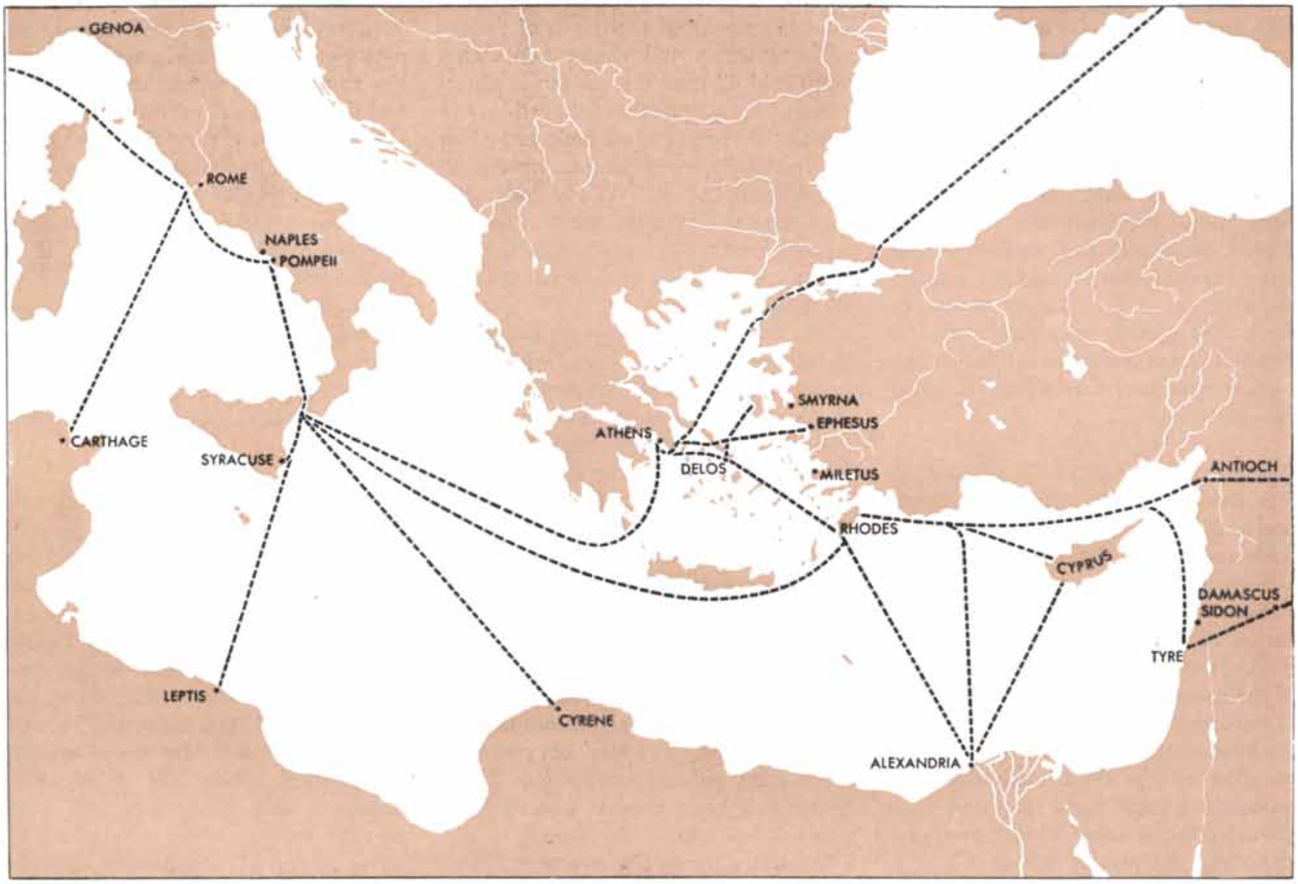
An economic iron curtain closed off the western Mediterranean, which was under the sway of the great commercial empire of Carthage. All North African grain, Sicilian wine, Spanish silver and Italian iron carried there traveled in Carthaginian bottoms. The Carthaginian navy maintained a hawklike police system, and any trespassing ship was sunk.

The great changes that followed in the wake of Alexander the Great about 300 B.C. transformed this picture. In the eastern Mediterranean the focus shifted from Greece. There arose, stretching from the Balkans around the sea to Egypt, a series of powerful monarchies which maintained lavish courts and huge armies. The shippers now had more to do than merely supply a handful of large Greek centers. Here were armies needing supplies in bulk and a nobility which could afford luxuries. An immensely varied and genuinely international trade was the result.

In the west Rome had broken the power of Carthage and started her massive movement toward the east. By the middle of the first century B.C., when Caesar was conquering Gaul, the whole of the sea came under Roman domination. It was then that the Mediterranean became one world, and the city of Rome emerged as its biggest customer. If the Roman populace wanted bread and circuses, they had to be supplied from abroad. Thus one of history's greatest merchant marines came into being, for everything from the grain to the gladiators and lions was brought to Rome by ship.

The international maritime trade now took on the form it was to have for the first 400 years of the Christian era. The great shipping lanes were marked out from all parts of the Mediterranean to Rome. The bulk of the trade was still grain, oil and wine. Ironically we have relatively little information about this thriving period. The historians Thucydides, Polybius and Livy noted military and political events but not economic statistics. But every now and then, through some accident, a revealing figure is preserved. We happen to know, for example, that each year Rome imported at least 15 million bushels of

ARRIVAL of a great cargo vessel in the port of Rome is recorded on a second-century A.D. relief. The owners offer sacrifice on the stern as the lighthouse is passed. The protecting gods and goddesses, including Neptune and Bacchus, and the Emperor are represented.



TRADE ROUTES at the height of the Roman Empire are indicated on this map. There were other routes, but these were the most important. From France and Spain to Rome went wine, oil and minerals. From Carthage and Leptis went grain and oil; from Syracuse and Cyrene, grain. Alexandria sent grain, papyrus, incense and other oriental products, and received wine from Rhodes. Athens was scoured for works of art. Smyrna, Ephesus and Miletus shipped wine to Delos and Athens. Rhodes sent wine to Athens and all the eastern Mediterranean. From India went spices and jewels and Chinese silks overland to Seleucia, thence via Antioch or Damascus.

grain from North Africa and Egypt. For more details, however, we must turn to the evidence brought to light by excavations. Thus it is known that, before Caesar overran Gaul, the Gauls imported wine from southern Italy. Recently, with the help of divers, French archaeologists examined the wreck of a Roman ship outside the harbor of Marseilles; they found that it was loaded with several thousand jars of wine, which probably came, sometime around 200 B.C., from vineyards that once flourished on the slopes of Mount Vesuvius. More Italian archaeologists enlisted the aid of one of Italy's best-known salvage experts to investigate a wreck that came to light a number of years ago near Genoa. This ship was carrying more than 3,000 jars of wine—over 20,000 gallons—and was very likely making its way from southern Italy to Gaul when it went down. But by 100 A.D. or so the pendulum had swung the other way, and Roman shops were selling French, Spanish and Greek vintages. We can tell that thousands of gallons of wine and oil now came to Rome from North Africa, France and Spain, for today there is a good-sized hill on the outskirts of the city called Monte Testaccio—"Mount Potsherd"—which excavation has shown is composed entirely of broken oil and wine jars from these countries. This mound stands beside the site of wharves where for 400 years stevedores unloaded these commodities.

Shipping bulky and cheap cargoes like grain, oil and wine was, as we have seen, an essential trade; many, like Trimalchio, made fortunes at it. But the really big profits lay in a more risky form of commerce. By 250 B.C. a market for luxury goods had come into being. Wealthy men in great Mediterranean centers like Rome, Alexandria, Antioch or Marseilles wanted exotic woods, ivory, oriental rugs and tapestries for their homes, and perfumes, silks and rare table delicacies for themselves and their wives. To meet the demand fixed trade connections were opened with the Far East. Indian merchants entered the picture as middlemen for Chinese silks and Far Eastern spices and as prime suppliers for India's own products: ebony, beryl, pearls, cinnamon and, above all, pepper. The trade was brisk: it is common to find Roman coins in excavations in southern India. Even a manual was available for the use of merchants who operated in these areas. Like the Coast Pilots issued by our Hydrographic Office, it gave detailed information on harbors, markets, wind and weather conditions and so on. The manual has fortunately been preserved and, as a consequence, this phase of ancient commercial activity is one of the best documented of all.

Each year camel caravans made their way overland from India to Seleucia (now Baghdad), then west to Antioch or, through Damascus, to Tyre where the goods were loaded aboard ship. Alternate and somewhat safer routes lay by sea. Ships worked from the west coast of India up to the head of the Persian Gulf, where their cargoes were transferred to camels that joined the caravans at Baghdad. Another route, favored because it was practically all by water, was in the hands of Alexandrian merchants. Each year a fleet of ships left from the Red Sea for the west coast of India and brought their cargoes back to a tiny Red Sea transshipment point called Myos Hormos (Mussel Harbor). Here the goods were transferred to camels and carried the relatively short distance overland to Coptos on the Nile, from which point they were barged down river to Alexandria for transshipment. Profits were tremendous, but so were the risks. There were mountains, deserts and bandits along the caravan routes, and squalls, shoals and pirates in the Red Sea. The trip—eight months at the least—was depressingly long.

The shipper who was willing to give up a portion of his profit in exchange for a somewhat safer and quicker return went into the perfume and incense trade. Frankincense was burned daily on hundreds of thousands of altars all around the Mediterranean. Most of it came from the southern coast of Arabia, namely Yemen and the Hadhramaut. Hundreds of vessels loaded up Arabian incense, added perfumes and ivory and other products from nearby Somaliland and carried their cargo to Myos Hormos, from which point they followed the same route as the shipments from India.

A particularly profitable form of ancient commerce was the slave trade. It rose to its height between 300 and 50 B.C., when the ancient world was rent by practically continuous war; it died only when the Roman Empire finally imposed peace. The Greeks and the Romans had long made a practice of selling their prisoners of war into slavery. When this source began to run short, pirates stepped in to bolster the supply.

Piracy had plagued the Mediterranean for centuries. The Egyptian scribe Wenamon tells of being chased by pirates off the coast of Syria. Piracy had surely existed from long before the time of Wenamon, and the Mediterranean was not safe until 1815, when the U. S. Navy finally quelled the brigands of North Africa. For several centuries the pirates were held down fairly well by the excellent navies first of Athens and then of Rhodes. But when Rhodes lost its power about 150 B.C. the pirates broke all bounds. Establishing headquarters on the southern coast of Asia Minor, they set themselves up in what amounted to organized business. Not content with abducting men off ships they would descend on coastal towns and carry off whole populations. Most of the victims were brought to the island of Delos for sale. Strabo estimated that the slave market there could handle over 10,000 slaves a day.

The pirate nuisance came to a head when particularly daring gangs raided the coast of Italy and kidnaped for ransom wealthy ladies and Roman officials traveling along the highways. The authorities decided that this was enough. A special command was proposed, Cicero delivered a speech urging its adoption, and Pompey the Great was put in charge. Within a year (67 B.C.) the seas were free of pirates.

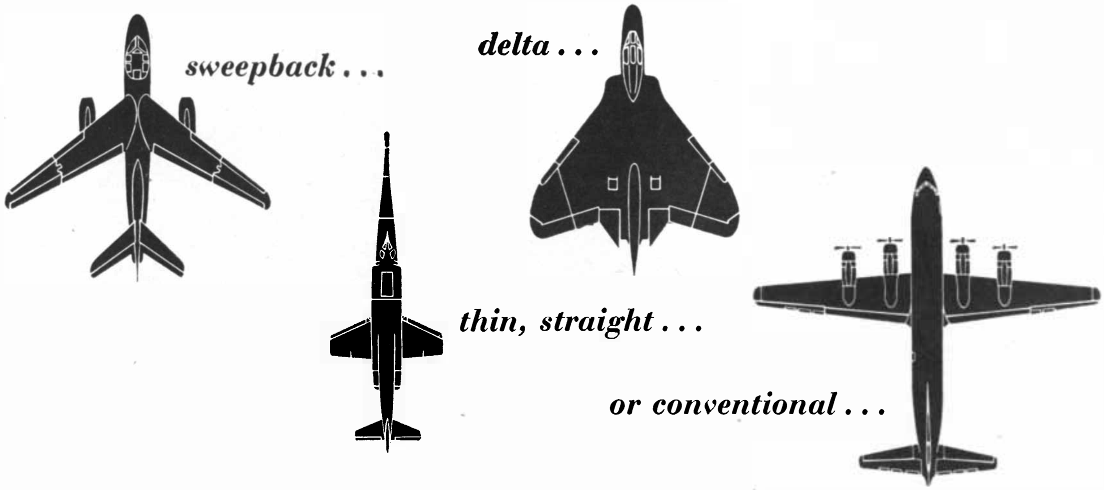
The scope of sea-borne commerce in the ancient world was so vast that it is hard to realize the handicaps under which the Greek and Roman sailors worked. They had no compass, but in the clear air of the Mediterranean, where by day islands may be seen from miles away and at night the stars are rarely obscured, this was not as serious a lack as it might appear. They used clumsy steering oars instead of the stern rudder that was to be invented in the Middle Ages. The bulk of their cargo had to be moved in the summer months, when the Mediterranean was calmer than in winter. They even had to build most of their own harbors. Although the Mediterranean has many coves suitable for small vessels (and also for pirates), it has few large-scale natural ports. Alexandria, Piraeus, Syracuse and Marseilles were excellent natural ports, but the list stops about there. Rome's harbor near Ostia, which from A.D. 50 handled more goods than any other in the empire, was completely artificial. So was the harbor built for Antioch, in Syria, a great transshipment point. Archaeologists have found protective jetties at almost every known ancient seaport. Around the site of the great port of Tyre divers have succeeded in tracing massive underwater moles which once embraced the city's harbor.

The ships were slow and clumsy, but they were safe. The emperors of Rome, with the vast facilities of the Roman navy at their disposal, often preferred to travel by private merchant sailing ship. "When you go to Palestine," Emperor Caligula once said in effect to the young prince Herod Agrippa, "don't travel by galleys and the coastal routes, but take one of our direct Italy-Alexandria merchant ships." The average merchantman ran about the size of a large harbor tugboat of the present day and carried between 150 and 250 tons of cargo. But on the major runs, such as the grain trade between Egypt and Rome, ships almost 200 feet long and capable of transporting 1,200 tons were employed. These ships were about the size of a 19th-century U. S. frigate—only slightly smaller than a large modern ferryboat. They could take tremendous loads. Thus in 1585, when Pope Sixtus V's architect Domenico Fontana moved an Egyptian obelisk from one point in Rome to another, he was hailed as a brilliant engineer. Actually he was much less impressive than the engineers of Caligula. In 40 B.C. they took the obelisk and its base from its original site in Heliopolis near Cairo, loaded its 500 tons aboard the biggest ship available, added 800 tons of ballast to steady her, sailed it successfully across the sea, transferred it to a river barge to bring it up the Tiber and erected it at the point where Fontana found it. This was only one of several obelisks that were successfully transported across the Mediterranean to Rome.

The cargoes of a Roman ship were

WINE JARS were removed from the hulk of a Roman ship which sank off the harbor of Marseilles about 200 B.C. They are of Italian origin, and each holds over seven gallons.

Name any type of modern wing

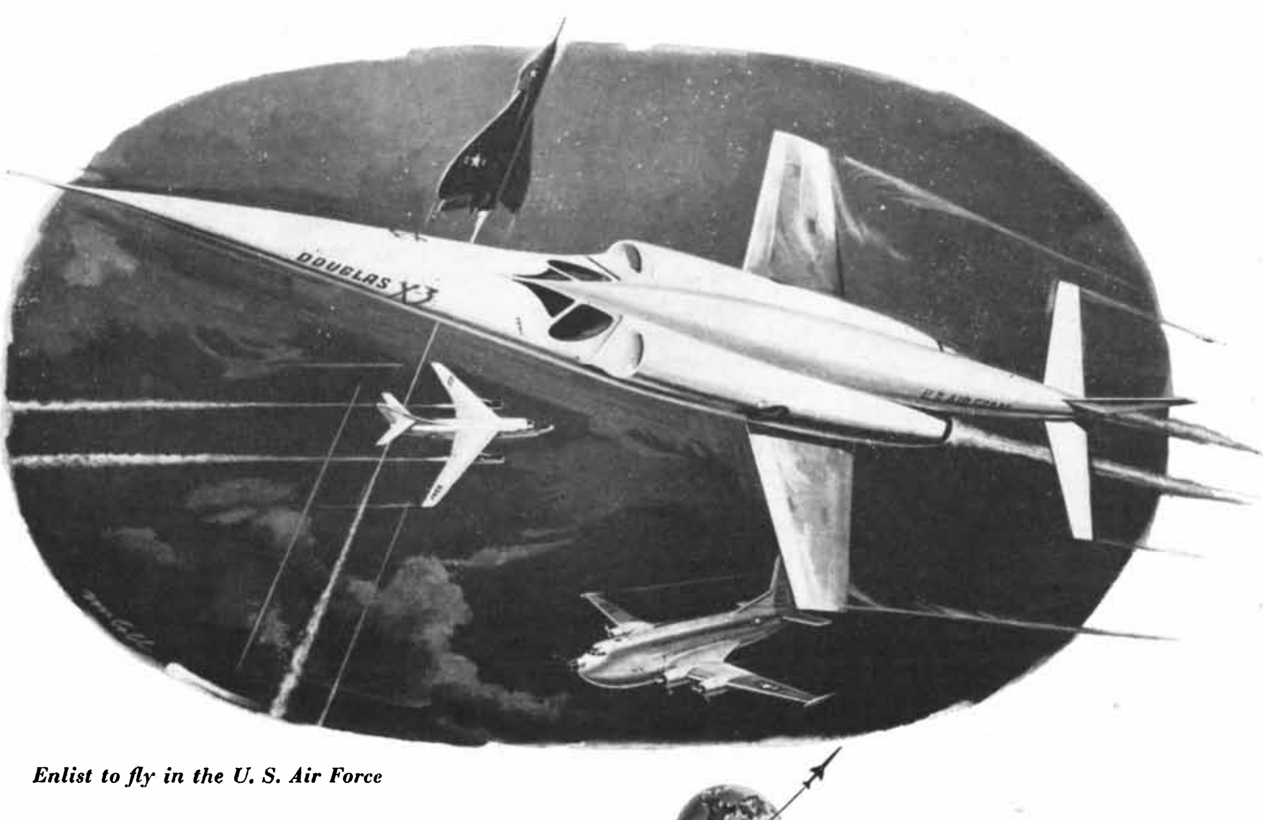


it has been built and flown by **DOUGLAS**

What is the ideal wing planform? Obviously, there can be no all-inclusive answer, for wings—like power plant or size—are designed to meet certain specific tactical requirements.

Thus a sweptback modified delta lets the Douglas F4D Skyray, first carrier plane to hold the official world speed record, come in *slow* for carrier landings. The broad conventional wings of a Douglas C-118A Liftmaster contribute to the range and lift a cargo carrier needs—while the Navy's carrier-based A3D Skywarrior bomber flies at near-sonic speed on sleek, tapering, sweptback wings. Again, the experimental stilleto-shaped Douglas X-3—though bigger than a DC-3 transport—has a wingspan smaller than a DC-3's tail.

Correct design of airframes to meet intended use contributes to Douglas aviation leadership. Building planes to fly farther and faster with a bigger payload is a basic Douglas concept.



Enlist to fly in the U. S. Air Force

Depend on *DOUGLAS* **First in Aviation**

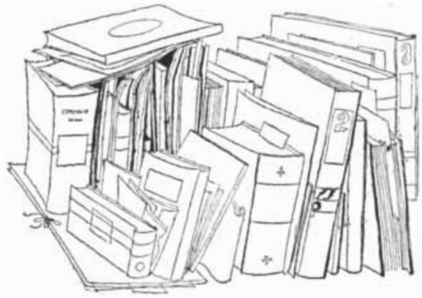
TEMPLE COLUMNS, prefabricated in sections, were raised off St. Tropez by archaeologists. They were on a ship probably bound from Rome to Gaul in the second century A.D.

stored not only in the hold but also on deck. Grain was carried in sacks, but most other commodities—oil, wine, salt fish—were packed in heavy pottery jars. A typical jar had a capacity of seven to eight gallons and weighed, when empty, upwards of 50 pounds. Passengers lived and slept on deck—as many still do today in the mild Mediterranean climate. The largest ships carried more than 600 passengers on a long journey. The vessel in which St. Paul was wrecked in A.D. 62 had only 270 aboard, but he was traveling late in the year toward the end of the sailing season.

At Rome and other cities where harbor facilities were poor, large ships unloaded onto small harbor craft, which carried the cargo either to docks or upriver to the city itself. The organization of a busy harbor was just as complicated then as it is today. Ships were given permission to enter, were assigned berths, had their cargoes checked against the manifests, took on a return load under equally careful supervision and left only after receiving clearance from the harbor master. By a quirk of fate, an actual cargo manifest over 2,200 years old has been preserved. Apollonius, an official of Ptolemy II around 250 B.C., had as secretary a certain Zenon, who apparently was the kind of man who never threw away a piece of papyrus. By great good luck his voluminous files were discovered, preserved for two millennia in the dry soil of Egypt. One of the documents is the cargo list of a small coastal vessel which had loaded up at a Syrian port to discharge at Alexandria. The vessel arrived carrying the following goods. Table wine: 63 jars (probably holding seven gallons each); two half-jars. Dessert wine: 10 jars. Olive oil: two jars; one half-jar. Vinegar: two jars. Honey: seven half-jars. Dried figs: 10 jars. Nuts: one jar; three baskets (2½ bushels). Seeds: one basket. Cheese: one jar. Wild boar meat: 10 jars. Venison: two jars. Goat meat: two jars. Rough sponges: one basket. Soft sponges: one basket.

The economic story this list tells is clear. Here was a shipment of imported table delicacies. From the wharves of Alexandria they would make their way to the markets, and from there to the kitchens of the court or of the local shippers and industrialists. Foreign foodstuffs were not the only luxuries that the wealthy of Alexandria and elsewhere brought in to enhance their mode of living. They imported works of art on a large scale as well. Forty-odd years ago a shipwrecked vessel was discovered off the coast of Tunisia loaded with marble statuary and prefabricated temple columns from Athens. Some of the finest Greek bronzes we have today were fished up from a wreck discovered by sponge divers off the east coast of Greece.

The intensity of all this traffic and the number of ships involved in it were unsurpassed until comparatively recent times. The sea-borne commerce of Roman times never died out entirely. The massive trade in staples came to an end when there was no longer an empire which needed them, but there was still a demand for silks and spices and perfumes. Commerce in these precious commodities lived on to furnish the vast wealth of the Genoese and Venetian republics of later days.



BOOKS

Can the various ways of studying the human animal be synthesized in a science of man?

by Marston Bates

THE HUMAN ANIMAL, by Weston La Barre. The University of Chicago Press ($6.00).

Can we have a comprehensive science of man? A few anthropologists possibly believe that anthropology does, or should, cover the whole spectrum of human activities susceptible of scientific treatment. But when we look over the organization of a university, we find all sorts of other labels or departments that also apply to the scientific study of man—sociology, psychology, economics, history, geography, physiology and the whole constellation of medical sciences. None of these will admit to being mere branches of anthropology, whatever the anthropologists may say. And we cannot think about the study of man without becoming involved with the humanities as well as with the sciences, without looking at philosophy, literature and the arts as well as at sociology and economics.

Man, the human animal, is lost in this jungle of lusty and self-important disciplines. Weston La Barre, an anthropologist, has set out to find him, braving the tangles of biology, the swamps of clinical psychology and the hard thorns of linguistics. It was a bold adventure. Whether he found the human animal or not, I am not sure. He came out at least with an interesting and challenging book which will surely be helpful to all other searchers.

La Barre and his search represent a preoccupation of our times. "The whole trend of 20th-century science is plainly toward integration," as he points out. As specialization developed in the 19th century, it became clearer and clearer that each specialty was only some fragment of a larger whole, meaningless as a thing-in-itself. "It is as if we had cut up the subject of man like a meat pie. But . . . scientists [now] realize that the whole is a large circle and not a small triangular wedge—and that there are solid meat, hot potatoes and gravy in all the slices."

The biggest problem of synthesis, perhaps, is to relate the biological and social aspects of man, because the biological and social sciences have had quite separate histories and remain separate areas of study in our universities. We have built, with sciences like biochemistry, serviceable bridges for the transport of ideas between the physicochemical world and the world of life, but we have not yet found a firm structure for communication between the life sciences and the sciences concerned with the social and cultural aspects of the human animal. La Barre devotes himself explicitly to this problem.

Properly enough he starts out with the amoeba, and manages a rapid survey of evolution "From Amoebas to Mammals" in his first chapter. I do not like the way he treats evolution, though I would be hard put to find anything to label inaccurate. Partly the problem is vocabulary. La Barre begins by stating that "living organisms are different from machines" because they "have *purposes.*" Now La Barre knows all about language and the problems of meaning, and he is using the word "purpose" in his own way and for his own reasons. But there it is, tripping me up constantly as I read, as he develops his argument that "we may view evolution as the gradual unfoldment and increase of organisms' purposes." My reading progress is further impeded by the author's decision to use "know" in a rather special sort of way, so that he can say that "an organism's 'knowledge' is its environment."

I suppose the author thought this vocabulary helpful in the development of his thesis that there is an essential continuity of all living phenomena from the amoebas to man. But the result is an undue stress on the discontinuity between living systems and inorganic systems. La Barre is willing to write that "a plant root knows down from up" but I doubt he would be willing to write that water knows down from up. To me it seems unfortunate to stress the continuity from the organic to the cultural at the expense of the continuity from the inorganic to the organic; both continuities are important. Inorganic evolution, organic evolution, cultural evolution—the three are different enough at one level of investigation; but at another level are there not problems of universals that underlie all three?

I am bothered more, however, by what La Barre himself calls the "animal series fallacy." He is trying to get from the amoeba to man, and from this point of view it may be inevitable to look at evolution as a graded series of "improvements." If the author were trying to look at interrelations among organisms within a rain forest or a coral reef, his picture of adaptations might be quite different, and he would certainly be unable to generalize so neatly about protozoa, coelenterates, insects, mammals and the like.

I am, of course, accusing La Barre of not having written his book the way I would have written it—which I suppose would be called the fallacy of misplaced authorship, a common enough fallacy of reviewers. If he wants to start his book with amoebas, that is his privilege, and I must admit that he manages to get from the amoebas to the primates, and from primates in general to anthropoids in particular, quickly enough. By page 69 he has arrived at *Homo sapiens.*

Yet the anthropoids—chimpanzees, gorillas and gibbons—keep on bobbing up all through the rest of the text. It seems to me that the anatomical similarity of the anthropoid apes to man has led psychologists to lay altogether too much stress on ape behavior in their search for the biological basis of human behavior. The paleontological evidence increasingly indicates a long separation between the ape line and the human line; the human family is perhaps closer to the extinct australopithecine man-apes than to the apes now living.

To be sure the apes, like man, have the family as a basic organization unit. But I wonder whether the key to human behavior does not lie in the capacity for forming larger groupings; whether the immediate ancestors of man were not social, in this sense, long before they

were human. The apparent evidence of clan groupings among the australopithecines would give this some support. In that case, relations among individuals in those social primates would have far more relevance to possible primitive human behavior than would interindividual relations among present-day apes. For understanding the beginnings of man I would look not to Ray Carpenter's study of the gibbon but to his study of the howler monkeys, which live in clans that include several cooperating adult males in each basic social unit. I can only wish that, in discussing evolution, La Barre had not made the evolution of social behavior seem quite such a neat, single-track affair but had taken time at least to glance at the social canines and the social monkeys.

But this is indeed rewriting La Barre's book for him. He has given an excellent discussion of the biological peculiarities of man, and of the bearing of these peculiarities on the eventual development of the extraordinary phenomenon that we call culture. Each biological reader may well find a different sort of special interpretation to quarrel with—but this is generally the sign of a good synthesis.

By the time La Barre gets to the discussion of human races, I find myself cheering at almost everything he says. This carries on through most of the latter half of the book. The race chapter is followed by one on L. Bolk's theory of human evolution through "foetalization," or prolongation of the immature period. This theory has much appeal for me, if only because I like to think of man as a sort of ape that has lost the possibility of growing up into the deadly seriousness of the adult state.

The second half of the book, mainly on culture, starts appropriately enough with an analysis of language. The author's Freudian slant, which gives a characteristic perspective to his whole book, comes out neatly in his opening paragraph on language: "For reasons that are plain in the baby's long dependence on the mother, man is libidinally a very mouthy mammal. For the human mouth is not only the means of eating as it is in other animals; it is also, in the beginning, the organ of human interindividuality between mother and child. It is very appropriate, then, that the mouth should additionally—through the astonishing invention of language—have become the main organ of human interindividuality finally and permanently."

Taking off from a discussion of vocalization among the anthropoids, La Barre makes much of the "phatic" aspects of language in man. (It is good to see that useful but neglected adjective put to work; it comes from the Greek word meaning "to show," and is roughly translatable as "demonstrative.") "Nothing is more infuriating to some people," says La Barre, "than a spouse who does not keep up even a reasonably intermittent flow of phatic reply, but holds to an unpermitted and thoroughly suspect emotional privacy. And at a really successful party, after the second drink any initial pretense at intellectual commerce begins to collapse into phatic nudges, pats, punches, pawing and verbal face-making. Nor is anyone fooled into believing that an exchange of polite opinions about the weather between two thoroughly sober people has any real concern with or bearing upon current or proximate meteorological events: in this, people are taking the temperature and assessing the humidity of the interindividual weather, not the earthly."

La Barre is mainly concerned here with symbolization and with the ways in which man's thinking is channeled by the structures of his diverse languages. He does not pretend to say anything new, but he does give what seems to a nonexpert an excellent summary of the concepts and insights which are coming from the developing studies of linguistics and symbolic logic. This provides a firm basis for his final discussion of the peculiarities of the human animal.

More and more we are coming to realize that the problems of the nature of the mind are the problems of symbolic thought, that the problems of the nature of reality are in large part problems of the fit between our symbols and that reality. The philosopher, the poet, the scientist—and the psychotic—are all caught in traps created by their symbol systems. The discovery or invention of symbolization has given man his power, his glory, his mind, his soul, his escape from the chains of instinct and of directly adaptive response. It has also been the cause of most of his ills—material and spiritual. "The ability to know things that are not so is an extraordinary and unique peculiarity of man among animals and arises out of the profoundly interindividual nature of his being." (This incidentally demonstrates the point of La Barre's peculiar usage of "know," which allows him to carry over from plants and amoebae to man.)

This ability of man "to be spectacularly wrong, and wrong over long spans of space and time" leads the author to an interesting comparison. "Qualitatively," he writes, "there is no discernible difference in content between a culture and a psychosis. The only objective or operational criterion is quantitative: the number of their respective communicants. This is no doubt an alarming statement —thus to equate cultures with psychoses. . . . But cultures and psychoses are identical in these ways: qualitatively, in being symbol-systems; functionally, in being anxiety-allaying; and also operationally, in being mere hypotheses to be tested by reference to the real world."

This search for an understanding of culture through an examination of its pathological aspects is pursued at some length, and with thought-provoking consequences. "We mean it quite seriously when we say that schizophrenic, poet and scientist are all part of a human continuum. The schizophrenic is systematizing and symbolizing some part of his real experience, not less than are the poet and the scientist." Only "the schizophrenic is oriented relatively to the 'inside,' the scientist to the 'outside' of his organism." They thus can be strung out along a subjective-objective continuum. "The scientist's theory more and more approaches or parallels reality, but—because of the inherent nature of symbolic systems—never quite touches the coordinates of reality."

In examining the roots and the idiosyncrasies of human culture, La Barre devotes his penultimate chapter to an analysis of animism, the tendency to attribute a "soul" to everything, as one of the oldest and most influential of man's culture traits. He looks into its basis in the universal human experiences of birth, death, dreaming, seeing, memory, thought, conscience and language, and he shows how the whole body of animistic beliefs still remains formidably entrenched in our thinking, despite our gradual development of more adequate systems of understanding. The author concludes: "For all its alterations and retailoring, the soul-hypothesis is nevertheless a garment ill fitting modern man. As physics, metaphysical animism is a poor explanation of the nature of things and of such energies as heat and light. As a statement of the facts of life, it is bad embryology. And as an explanation of the nature of life and death, it is bad biology. As a religion, it is a useless narcissistic protest against the fact (and the probable blessing) of metazoan death. In dealing with mind, memory, volition and dreams, animism is a poor approximation of a useful psychology. As a comprehension of man's possession of hands, brains, culture, language, the family and human interindividuality, it is wholly inadequate anthropology. Psychiatrically it expresses the inveterate homoerotism of the Greek tradition

in philosophy. And as philosophy, it is certainly very bad grammar."

In his last chapter, for which he borrowed from the atomic physicists the title "Three Minutes to Midnight," La Barre looks at the problems facing the human animal in the contemporary world. He rejects the fatalistic thesis of the "culturologists" that culture has achieved an existence independent of the culture-bearing man. Culture, he admits, often seems to behave as though it were a thing-in-itself. But his whole book is an exposition of the ways in which man's cultural nature is derived from his biological nature, and in this, somehow, he finds faith and hope. I share the faith and hope that La Barre expresses in this last chapter, where he rejects the tyrannies of all substitute fathers, whether in the form of a personal dictator or a dictatorship of ideas. But I am not sure whether his arguments—or my rather different reasoning toward the same end—represent logic or merely wishful thinking.

The book ends with a plea for democracy in the American sense; for federation rather than force as a way of solving the political problems of the world; for the cultivation of *aretē*, which "connotes manliness, wholeness, integrity, purpose, moral clarity, decision and self-responsibility," rather than *hubris*, "a sometimes arrogant pride in our great but limited power."

La Barre has given us a very interesting and thought-provoking book. I suspect that he has addressed his book to the scientific and scholarly community. Each scholarly reader will surely find many places where he wants to quarrel with the author—but each reader's quarrel will probably be slightly different, which to me means a good book.

I found the writing uneven. Much of the prose is clean and effective for conveying the author's thought, but in some places it becomes clogged with adjectives, and I found myself yawning as I read. Occasionally the author tends to be "cute," as when he tries to describe cultural differences between Yankee and Shawnee Americans in terms of two hypothetical GIs named Joe Blow and Joe Blow-Snake. This method may be effective in a lecture, but in cold print I found the mixture of slang and academic jargon rather silly.

The book is full of neat, quotable remarks. "What you don't know *will* hurt you." "Animism is a fallacy with many progeny, many of them misshapen." "The absolute length of time some fragment of 'the wisdom of the ages' has lasted is in itself no measure of objective truth: a paranoiac's beliefs do not become true for having become chronic."

In a final section called "References and Reading" La Barre makes many intriguing suggestions for further reading, some of them far from obvious. This method of giving documentation by means of a running text which is interesting reading in itself seems to me excellent, and I wish it were more generally adopted.

I started this review with the question: Can we have a science of man? I think so, and I think La Barre has made a major contribution toward its development. He has attempted particularly to relate concepts of biology, social anthropology and clinical psychology to the origin and development of culture. This is only one aspect of the science of man. It is far from representing the whole pie, but it is a much larger and more representative slice than that provided by any of the conventional disciplines. If we keep on trying these different slicing methods, we may presently be able to arrive at a better comprehension of the rounded whole.

Certainly we need this comprehension. If we cannot develop an understanding of ourselves that will enable us to solve the problems of living peaceably together on this shrunken planet, all the rest of our science becomes explosive menace. I am sure that La Barre has no faith in science as a white magic that can solve all our problems. But clearly he shares the faith that, as a way of achieving a better fit between the symbols of our thought systems and the outer world of reality, science can help mankind achieve the humanity that surely lies within its grasp.

Short Reviews

THE DRAMA OF ALBERT EINSTEIN, by Antonina Vallentin. Doubleday and Company, Inc. ($3.95). Mrs. Vallentin is a Polish journalist and biographer whose writings include lives of Leonardo da Vinci, H. G. Wells and Heinrich Heine. She has known Einstein and his family for many years and in this book draws an affectionate portrait. Her account does not go very deep; it often breaks down into a rather disconnected recital of incidents and foibles. Nevertheless, like almost everything written about this remarkable man, her book is enormously readable. Einstein is exhibited in his peasant stubbornness and independence, his courage and Spinozan gentleness. He is not an intellectual monster, as was Isaac Newton. His great passion is to understand the go of things;

he is, as his wife acutely observed, more of a practical man in scientific matters than a dreamer. Mrs. Vallentin's book brings out vividly Einstein's unhappy experiences in Germany, his dedication to pacificism, his irony, his humanity, which is puzzlingly mixed with detachment and a stern Hebraic ethic: "Well-being and happiness never appeared to me as absolute aims. I am even inclined to compare such moral aims to the ambitions of a pig." And of course there are anecdotes in these pages which, if not told for the first time, still retain their charm: for example, the story of the French Minister of War Painlevé at a cabinet meeting reading surreptitiously under the table a paper on field theory received that morning in the mail from Einstein.

GOVERNMENT AND SCIENCE, by Don K. Price. New York University Press ($3.75). In these lectures a former official of the Bureau of the Budget and deputy chairman of the Defense Department's Research and Development Board examines some of the principal aspects of the relationship between the Federal Government and science. Price is primarily interested in how science can receive financial support from the U. S. Government and yet maintain its independence, that is, avoid becoming an instrument of politics. He shows that the issue of government support versus government domination is no longer as clear-cut as it was even at the end of the war. Government administrators, he says, have come to realize that science requires special handling: scientists, in exchange for princely largess, are prepared to make concessions both as to conditions of work and the direction of their research. As for those who run the universities, their attitude toward the acceptance of Federal funds is perhaps best expressed in the celebrated limerick:

There was a young lady from Kent,
Who said that she knew what it meant
When men took her to dine,
Gave her cocktails and wine;
She knew what it meant—but she went.

Price's book brings into clear and objective focus many issues which have either been distorted by sentimentalism about the purity of science and the selflessness of scientists or disingenuously concealed by those who pretend that what is good for the future of jet propulsion is good for all of us. On the other hand there is a deceptive blandness about this book; it skirts some of the most troubling underlying issues, such as the effects of government influence on science as a creative quest and the questions of ethical responsibility which today confront the many scientists engaged in weaponeering.

THE MECHANISM OF ECONOMIC SYSTEMS, by Arnold Tustin. Harvard University Press ($5.00). Professor Tustin, head of the department of electrical engineering at the University of Birmingham, describes his book as an exposition of the "remarkable analogy that exists between economic systems and certain physical systems." These physical models, notably the automatic control systems developed for aircraft and for chemical plants, promise to shed much light on the interaction of economic forces and to make useful predictions possible [see "Feedback," by Arnold Tustin; SCIENTIFIC AMERICAN, September, 1952]. The methods of analysis of the theory of control systems have been applied to problems of economic stabilization and "the prevention of unwanted oscillations" of the business cycle. Tustin applies the notions of feedback, harmonic components and so on to the "problems of economic fluctuation and economic regulation," and he suggests how the very complex behavior of economic systems might be reproduced by mechanical analogues or computers. His book is mainly for economists and engineers, but several chapters are of general interest and can be read without special training.

AERODYNAMICS, by Theodore von Kármán. Cornell University Press ($4.75). A leader in the science of aerodynamics here presents a brilliant review of the principal problems that had to be solved to make the airplane what it is today. Von Kármán is a masterly expositor; he explains the difficult principles of aerodynamic theory so lucidly that any reader with an elementary understanding of why airplanes fly can follow him. And he makes his account even more palatable with delightful biographical anecdotes and details: how Lord Rayleigh investigated aerodynamics by studying the swerving flight of a cut tennis ball; how aircraft designers discovered that the modern airfoil is almost identical with the cross section of a trout; how a "former elevator boy," Robert T. Jones, made a number of brilliant aerodynamical discoveries; how von Kármán himself studied wing-stalling by slowing sea gulls in flight to stalling speed with tantalizing offerings of bread; how a U. S. sergeant translated the title of a von Kármán paper in German from "Resistance of Slender Bodies" to "Resistance of Undernourished Bodies"; how the great German pioneer in wing theory, Ludwig Prandtl, borrowed many of his ideas from the Englishman Frederick Lanchester and failed to acknowledge the debt. Weakness of memory, as von Kármán points out, is not a rare thing among inventors. Sir Francis Aston once said of J. J. Thomson that if you told him an idea on Wednesday, he shook his head; on Thursday he still would not accept it; but on Monday he would come to you to propound the same idea, finishing with: "Now, do you understand the problem?"

THE GEOMETRY OF RENÉ DESCARTES, translated by David Eugene Smith and Marcia L. Latham. Dover Publications, Inc. ($2.95). A facsimile edition of the masterpiece in which Descartes gave the first complete statement of the principles of analytical geometry. It is written, as one student has observed, in a "contemptuous vein"; Descartes was apparently more interested in showing what he knew than in instructing beginners. He concluded the work with an ironic paragraph: "I hope that posterity will judge me kindly, not only as to the things which I have explained, but also as to those which I have intentionally omitted so as to leave to others the pleasure of discovery."

HERACLITUS: THE COSMIC FRAGMENTS, edited by G. S. Kirk. Cambridge University Press ($9.50). About Heraclitus the Ionian, who came from Ephesus, little is known. There is reason to believe he was at his prime about 500 B.C. He was a sage and a mystic, given to dark sayings about nature and death and to paradoxical sentiments such as: "Mortals are immortals, and immortals are mortals, the one living the other's death and dying the other's life." He was also very abusive, with a fine gift for withering those who bored him: once, asked why he was silent, he is reported to have replied, "That you may babble." It is said that he finally withdrew from the world and lived in the mountains "feeding on grasses and plants." He died miserably at the age of 60. Most of the handed-down details of his life are probably mythical, but there is no doubt there was such a man, and his contempt for others may have led his biographers to subject him to every possible ignominy. Kirk's meticulous work translates about half the extant fragments of Heraclitus' writings. They exhibit the philosopher's views on the mingling of opposites, on the physical changes effected by fire, on astronomy, on war. Some of his sayings sound distressingly current: "War is the father of all and king of all, and some he shows as gods, others as men; some he makes slaves and others free."

THE PAPERS OF THOMAS JEFFERSON, VOLUME VIII, edited by Julian P. Boyd, Mina R. Bryan and Elizabeth L. Hutter. Princeton University Press ($10.00). The correspondence in this volume covers the period from February to October, 1785, during which Jefferson was in France and succeeded Benjamin Franklin as Minister to the Court at Versailles. Besides the letters having to do with his official duties, the collection includes Jefferson's endlessly entertaining and informative correspondence with friends about contemporary happenings and conditions on both sides of the Atlantic. He discusses books and gossip, his horse-trading ventures, his opinions on agriculture and animal magnetism and the proper design of the new state capitol at Richmond, the trousseau of the 10-year-old Portuguese Infanta, the melancholy fate of Monsieur Pilâtre de Rozier, who with a companion tried to cross the Channel in a balloon of "inflammable air" but crashed and was "crushed to atoms." As a homesick American, Jefferson entreats Eliza House Trist to write him "all the small news . . . about persons and not about states . . . who die, . . . who marry, who hang themselves because they cannot marry, etc., etc." To Abigail Adams, a favorite correspondent, he reports that the Queen "has decided to wear none but French gauzes hereafter," and that Cardinal de Rohan is a "debauchee and a booby." To a French officer friend Jefferson imparts his views on Americans: "In the North they are cool, sober, laborious, . . . chicaning; in the South they are fiery, Voluptuary, indolent, . . . candid. . . . In Pennsylvania . . . the two characters seem to meet and blend to form a people free from the extremes of both vice and virtue." There is also a charming letter to Mrs. Trist from Jefferson's daughter Martha, who accompanied her father. She says: "Pray write me very long letters by every occassion. I should be very glad to write for papa, but I am sure that he could not have an occupation which gives him more pleasure than that."

ON THE SENSATIONS OF TONE, by Hermann L. F. Helmholtz. Dover Publications, Inc. ($4.95). This classic on physiological acoustics, now reprinted in

Alexander J. Ellis' celebrated translation, is an "unexhausted treasure." Helmholtz, says Henry Margenau in his introduction, was one of the last great universalists of science. He was able to take "a full synthetic view of nature . . . to unify the practice and teaching of medicine, physiology, anatomy and physics, and to relate these sciences significantly and lastingly to the fine arts." The publisher has done a fine job in making this scarce and important book available.

COMMENTARY ON THE EFFECTS OF ELECTRICITY ON MUSCULAR MOTION, by Luigi Galvani. Burndy Library ($6.00). An English translation of Galvani's classic work. Margaret Glover Foley is the translator; I. B. Cohen provides notes and a critical introduction; John F. Fulton and Madeline E. Stanton add a bibliography of the editions and translations of Galvani's book. This is a well-made, nicely illustrated volume.

Notes

BIOLOGICAL EFFECTS OF EXTERNAL RADIATION, edited by Henry A. Blair. McGraw-Hill Book Company ($7.00). A report on work done at the University of Rochester during the war.

ATOMIC AND FREE RADICAL REACTIONS, by E. W. R. Steacie. Reinhold Publishing Corporation ($28.00). This is a two-volume second edition, greatly enlarged and almost entirely rewritten, of an authoritative monograph by the president of the National Research Council of Canada on the rates of elementary organic reactions in the gas phase.

A TREATISE ON ELECTRICITY AND MAGNETISM, by James Clerk Maxwell. Dover Publications, Inc. ($4.95). An unabridged reprint of Maxwell's great work on his theory of electromagnetic phenomena. It is a most attractive book bargain.

THE THEORY OF THE PHOTOGRAPHIC PROCESS, by C. E. Kenneth Mees. The Macmillan Company ($21.50). A revised and largely rewritten edition of an excellent handbook surveying the literature of photography.

THE ANALYSIS OF MATTER, by Bertrand Russell. Dover Publications, Inc. ($3.95). This well-known work, first published in 1927 and now reissued, deals with the logical analysis of physics, physics and perception and the structure of the physical world.

THE AMATEUR SCIENTIST

About the eye of the snake and, by curious coincidence, a telescope like a gigantic eye

Conducted by Albert G. Ingalls

Last March D. F. Munro, an amateur herpetologist of Manhattan, Kan., told readers of this department about his discovery of a strange eye-movement in copperhead snakes. If you look a copperhead straight in the eye, he explained, you will observe that the snake's slit pupil stays vertical when the animal tilts its head up and down—as if the eye were under the control of a gyroscope. *Herpetologica*, the official journal of the Herpetologists' League, credited Munro with a "scoop" for this observation.

The observation also excited the curiosity of Henri Morgenroth, a consulting engineer of Santa Barbara, Calif. He wrote: "Munro's item has cost me a lot of sleep. Why should this varmint need gyroscopic eyeballs when other animals don't? Or, if others have them, which species do—and why? If Munro or your readers can shed any light on this puzzle, I wish they would speak up.

"If I remember Norbert Wiener's book *Cybernetics* correctly, he had a lot to say about the terrifyingly complicated apparatus that translates an image on the retina into the code of memory. Among the many transformations that signals from the retina have to undergo before they find and are matched with their twins in the memory (that is, for recognition to take place) is a step which, in effect, levels these signals regardless of the angle at which we hold our eyes.

"Since the copperhead needs gyro-controlled eyeballs, this species of snake must lack at least this one processing apparatus in the signal's path from the retina to the memory.

"It seems to me that this would represent a major design difference between the brain of the copperhead and that of animals with eyes which make no provision for perpendicularity control. Certainly you would not expect a difference of this magnitude among closely related species. Consequently other snakes must have the same eyeball control.

"Could it be that this characteristic has escaped observation because it is much harder to detect in the case of eyes with round pupils? If this suspicion makes any sense to you, why not ask one of our herpetological friends to attach or paint little markers on the pupils of other snake species and take a look?"

Munro reported that he had already examined snakes with elliptical pupils. "Without exception," he wrote, "the eye keeps its vertical position when the snake tilts its head. This observation, incidentally, casts some doubt on my original supposition that the eye accommodation evolved in pit vipers is an essential for accurate striking. Snakes that do not strike also have the gyro-control. Incidentally, you cannot attach markers to the eyeball of a snake for observing eye movements. The eyeball is protected by an immovable window, part of the snake's skin, which is cast when it sheds."

"I could not shake off the suspicion," Morgenroth went on, "that if snakes lack one or possibly more of the major complications in the picture-recognizing department of the brain, this deficiency and consequently the copperhead's 'crutch' of a gyro-controlled pupil must also exist in animals farther down the evolutionary ladder, including fish. It is just not conceivable that snakes should be distinguished from all other members of the animal kingdom by such an extraordinarily special brain design. Yet it is not easy to suppose that such a thing should have escaped notice.

"It should be said that today's snakes are a fairly recent product of evolution. Historical geologists tell us that during a long dry period some millions of years ago the snake's ancestors burrowed underground to escape extinction and that their eyes retrogressed to barely more than light-sensitive buds. When life on the surface became possible for them again, they faced the necessity of reinventing the eye. Hence in many details of design snakes' eyes are unique. Nevertheless it seems reasonable to suppose that the limited brain mechanism which requires a gyro-eye might be shared by some of the snake's evolutionary kinfolk.

"With the objective of locating one of these, I undertook a scientific expedition to the goldfish tank at a local five-and-ten-cent store. Quite a number of these little fish, I discovered, carry spots on the periphery of the pupil which are easy to watch as the fish gazes at you while swimming up and down the glass wall of the aquarium. After watching them for a while I saw that, sure enough, the fish eyeball always kept the same position relative to a vertical line regardless of whether the fish pointed its nose 60 degrees up or 60 degrees down.

"Then I invested 50 cents in a baby turtle, selecting one with two little black stripes on the tissue surrounding the pupil. I found that the turtle's eye moves in precisely the same way as the copperhead eye illustrated in your March issue! The maximum angle of turning down, as the head points up, appears to be about 70 degrees. As the head is turned down, a limit is reached at about 10 degrees. If the animal is tilted farther down, it compensates by raising its entire head. The eyes seem unable to follow a sudden tilting. The lids close for about a second, as if the unanalyzable image has to be excluded until the eyes level off.

"It seems just not possible that all this has never been discovered before. Was Dr. Munro's observation really a scoop? If it was, and if what I have just reported has not been known, then I hereby lay claim to being the first man who ever really looked a fish straight in the eye!"

Before conceding that distinction to Morgenroth, it seemed appropriate to consult a professional biologist and learn just who was scooping whom. Charles M. Bogert, curator of amphibians and reptiles at the American Museum of Natural History, decided that Munro's report on the copperhead's eye movements was in fact a scoop, though a San Diego herpetologist had once noticed, but not published, such movements in rattlesnakes.

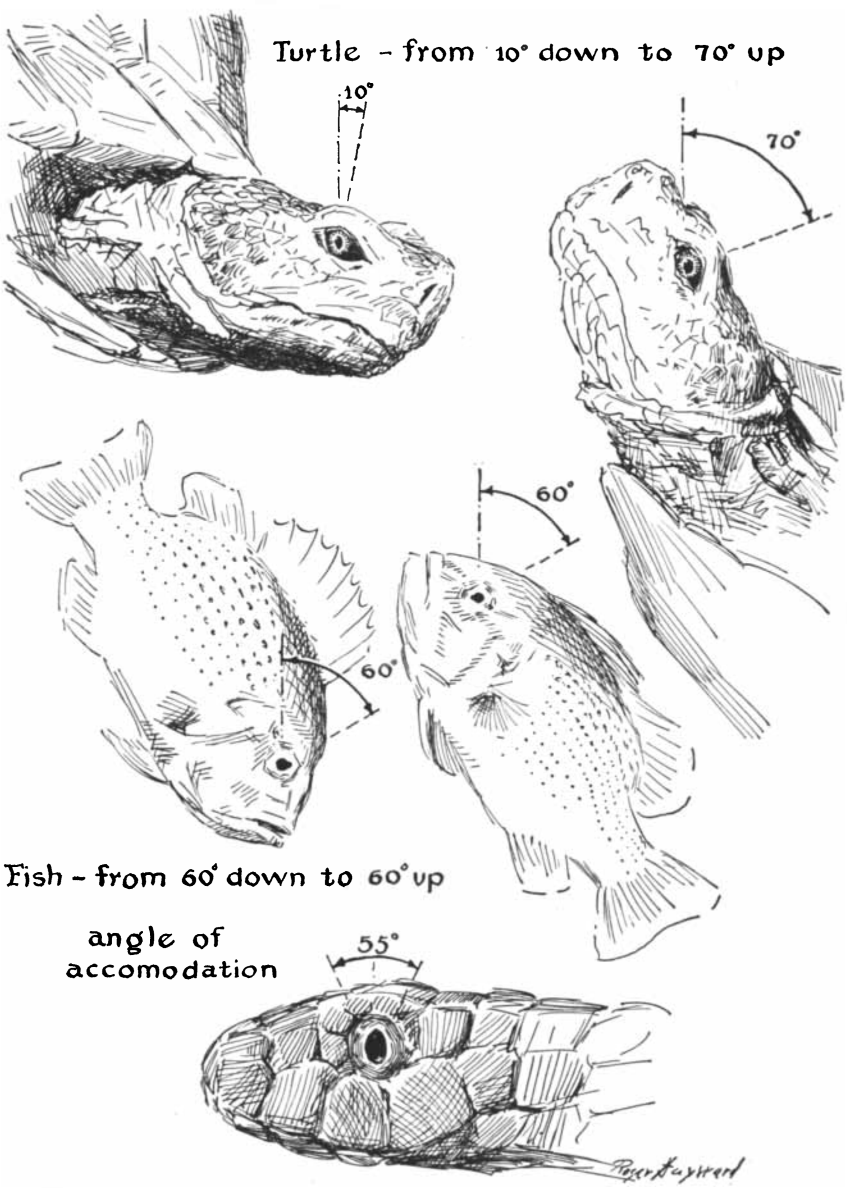
Morgenroth, however, "is not the first man to look a fish straight in the eye," says Bogert. A number of ichthyologists have noted "wheel" movements in fishes' eyes. But they have not gone much further than merely to note the phenomenon; there has been little or no attempt to explain it.

Morgenroth, though a little disappointed to learn that the discovery is not new, makes bold to offer some conjectures as to why fishes and reptiles have gyro-controlled eyes.

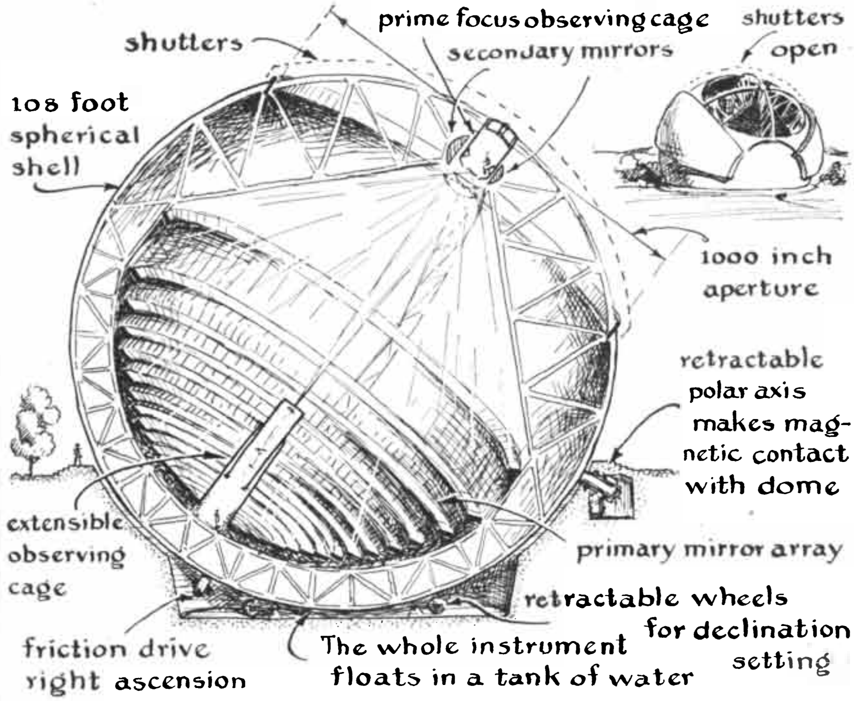
"First," he writes, "let us agree on some terminology. We'll distinguish between eyeballs with two degrees of freedom (2F) and eyeballs with three degrees of freedom (3F). Offhand, it might appear that an animal with 3F eyes would require no level-correcting beyond that afforded by the eyeballs themselves, whereas animals with 2F eyes must accomplish this level-correcting somewhere in the visual cortex.

"Now let's see how this internal level-correcting works in an animal with 2F eyes, such as the human animal. When you lean your head sideways, everything seems to stay nicely vertical. The correction still works, though not perfectly, when you look at an object upside down. But now comes the surprise: you cannot readily recognize the printed word upside down! Here is quite a contradiction. We seem to possess an internal level-correcting mechanism which works pretty well for most objects but not for written or other coded images.

"Only one explanation appears possible: we animals with 2F eyes do



The ever-vertical pupil, not only in snakes but also in a turtle and a goldfish



The 1,000-inch "big eyeball" telescope

not, in fact, possess an internal level-correcting mechanism. Rather, what we do is make a mental correction for objects which we have seen frequently in various angular positions. We cannot recognize writing upside down because we do not ordinarily learn to read it that way.

"As Wiener has pointed out, we become so familiar with ordinary geometrical shapes in their countless sizes and perspectives that we are not normally aware of perspective distortion. Wiener believes that this explains why it took man a long time to learn how to draw a picture with the distortions as they appear on the retina. Learning to recognize perspective distortions and to draw pictures accordingly was a complex deductive process.

"We possess no skew-corrector in the circuitry linking the retina and the visual cortex. Rather, the correction of a picture seen from a skewed position is made through the cooperation of our senses of equilibrium and the 'group scanning' (discussed in *Cybernetics*) of our sets of experiences as stored in the memory.

"Group scanning explains why mammals and possibly many birds can do without a level-correcting mechanism. Why, then, do reptiles, fishes and possibly other animals need 3F eyes? It seems to me that the line between the two kinds of eyes is drawn exactly at the point of evolutionary demarcation which separates animals that learn by experience from those whose visual experiences are largely inborn—a subject on which the Gestalt psychologists have had so much to say. Reptiles and fishes come out of the egg as diminutive adults. A greater part of their visual experience must be born with them; without ever having learned to distinguish food or enemies by sight-experience, they must be able to interpret the picture correctly at the very beginning.

"It is hard enough to understand how evolution succeeded in storing visual experiences in the memory in a hereditary way. It would be still harder to understand if we had to assume that this hereditary storage was in the same form as the higher animals' learned angular experiences. The problem of explaining the hereditary storage of visual experience certainly is simplified if the picture has to be memorized in one position only. Gyroscopic eye-control makes this possible.

"The limited observations and experiments seem to support me pretty solidly up to this point, and I hope others who enjoy looking their fellow animals in the eye will find some interest in matching their observations against this conjecture. Pending their reports, I cannot resist the temptation of adding something highly speculative which, despite the present rudimentary state of cybernetics, may still be permissible.

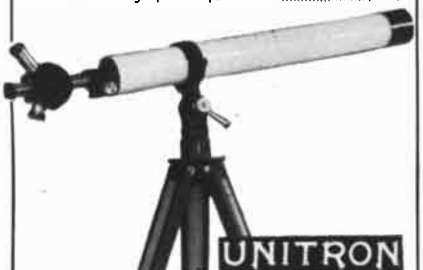
"We have seen that animals with 2F eyes use group scanning of the memory storage for corrections of level and of distortions. Now it is not too farfetched to assume that reptiles and fishes, lacking the facility of group scanning, are just about blind as far as recognition of geometric shapes goes. Their seeing may be restricted to the recognition of colors and light changes—that is, movements. They may react to a mass, shapeless as it is, according to whether it grows larger or smaller, approaches or recedes.

"As Munro concluded, the always-vertical pupil of the snake's eye appears to have uses beyond that of gauging distance and direction. Certainly the snake benefits from its gyro-controlled eye steadiness in estimating a strike. On the other hand, my little turtle does not strike, yet it has wheel eyes. Why? Evidently there are answers in each case which lie in the animal's specific pattern of behavior.

"It is fun to speculate on how the 3F eye may affect the behavior of various animals. For instance, compared to the agility of a dolphin or a seal, the average fish is a stiff, sluggish performer. The restrictions on its body movements may well be due to the fact that it cannot move its eyes to see beyond a certain angle. Or consider those strangely long and mobile necks of prehistoric reptiles; it seems permissible to suspect that the main factor in the formation of those necks was the necessity for carrying the head on an even keel, rather than any advantage in reaching for food.

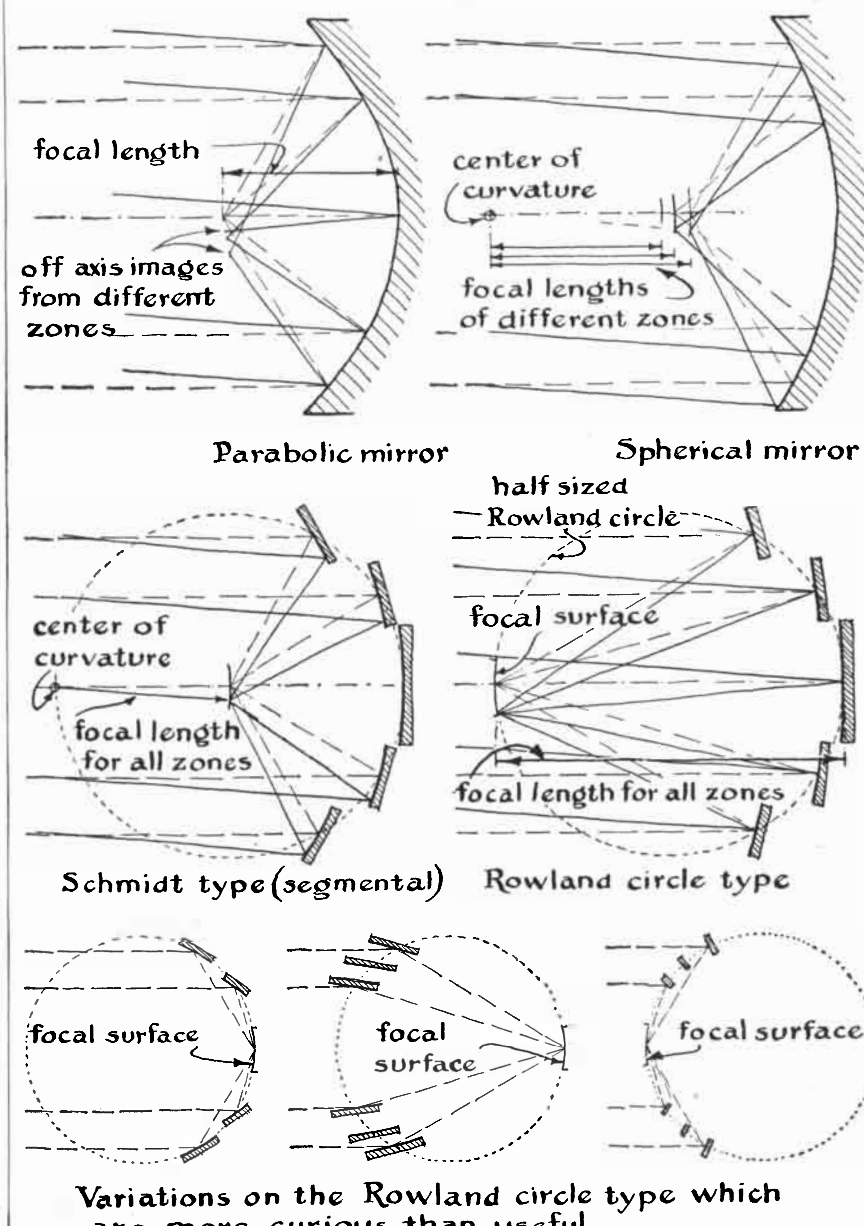
"A little higher up the ladder of evolution, observe the head movements of birds. I have not yet managed to look one squarely in the eye; I hope our friends in ornithology will do so. Birds in general have not yet achieved the independence of head-carrying that mammals possess. A grazing horse or cow can keep on watching its surroundings while it feeds, but a feeding pigeon has to interrupt its peckings for food every moment to resume the watching position. The obvious inability to watch and feed at once represents a major decrease in survival value. It enormously reduces the chances of catching food and creates an interval of hazard while getting it. This does not mean that birds must possess the wheel-eye movement. It does suggest, however, that the development of the neural mechanism responsible for Gestalt perception, as discussed by the cyberneticists, must have taken a decidedly different turn in birds from that in mammals."

This department's illustrator, Roger Hayward, who on several occasions has illustrated here other people's pro-



posals for huge telescopes, this month proposes a giant reflector that should end all giants. It has the shape of an immense eyeball with a 1,000-inch aperture [*see the illustration on page 118*]. Within its sphere, 108 feet in diameter, are arrayed rings of circular shelves like the tiers of seats in a football bowl. On these seats are hundreds of thin mirror "tiles" (tesserae), each approximately three feet square and spherical in curvature. All have a common center of curvature at the top of the telescope. The sphere, floating in a pool of water, can be rotated in any direction. It may be clamped in declination by the electromagnet shown at its right, and thereafter a submerged truck-tire drive will move the tremendous eye in right ascension in synchronization with the turning of the earth.

The optical inspiration of Hayward's super-giant reflector is the famous lighthouse-lantern lens invented by Augustin Jean Fresnel. This kind of disk, with a sawtooth profile on the side toward the light source, is familiar today in railroad and traffic signal lamps. Hayward anticipates the objections that his "big eyeball" would have serious trouble with diffraction at the edges of its many composite mirrors and would be limited in resolving power to that of any one of its component mirror tiles. Against this he points to several compensating advantages: an immense gain in light-gathering power, speed as great as $f/1$, freedom from coma, and reduc-



Theoretical approach to the "big eyeball" tion of astigmatism to no more than that of a single one of its composite mirrors. Hayward writes:

"Ever since the days of Fresnel there has been intermittent interest in optical systems composed of many small elements arranged in a convenient manner. In the case of the lighthouse lantern the object is to project the most light in a horizontal direction. Resolving power is of almost no interest, while the scattering of light by the many edges in the glassware is offset by the gain in speed.

"In the recent proposals in this department to build large tessellated mirrors, the over-all figure of a paraboloid has been merely approximated. Most reflecting telescopes have their primary mirrors in the form of paraboloids of revolution. This figure is ideal for a star on the mirror axis, but stars not on the axis have their images distorted so that they appear as comets flying toward the axis. This defect, called coma, is associated in part with the fact that the images formed by different zones of the mirror are different in size. In the drawing at upper left in the panel on the opposite page one can see how the images of a star which is, say, five degrees off the axis fall on the focal surface at different distances from the axis, indicating the different sizes of the images formed by the various zones of a paraboloidal mirror.

"The Schmidt system overcomes this defect by using a spherical mirror for a primary, with a correcting plate the size of the full aperture to eliminate spherical aberration. However, a Schmidt correcting plate 1,000 inches in diameter would be pretty hard to make, since it would have to piece together a number of sections of glass, which would be difficult to match optically. Yet similarly hard to take would be the aberrations of the spherical mirror if the correcting plate were omitted. The drawing at the upper right in the same panel shows how the images of a field of stars would be distributed over a multiplicity of focal surfaces with different focal lengths. A plate could be placed at only one of these focal distances, and all the others would be out of focus.

"However, each individual zone of a spherical mirror has a good focus over a considerable field. Therefore, if one were to construct a series of concentric spherical zones it would be possible to arrange them so that they would have a common center and were so graduated in radius of curvature that their images would fall on the same surface and all have the same size. The drawing at the left in the middle row shows an array of such surfaces. Of course for a large instrument such as we are considering there would have to be more than the three zones shown in the figure.

"Another approach to the problem is indicated by the drawing at the right in the middle row. The physicist Henry A. Rowland, of ruling-engine fame, pointed out that the equal conjugate foci of a small part of a spherical mirror lie in a circle whose diameter equals the radius of curvature of the mirror. He applied this principle to the spectroscope, but in the case of the telescope one focus would be at a star—that is, at infinity—and therefore the circle with which we are concerned would be half this size. If we arrange a series of mirrors around a Rowland circle so that their foci are at a point on the same circle, then their images will all have the same size and the focal surface will be concave.

"This leads to four solutions: the one at the right in the middle row and the three in the bottom row. The three at the bottom are more curious than useful. The remaining one has the most promise and is the one embodied in the big eyeball telescope.

"In these four schemes the focal surface is spherically concave; in the one that resembles the Schmidt system, it is spherically convex. In this one a knife-edge test at the center of curvature of all the mirrors would serve to line them up and could be carried on while observations were in progress. In all five systems the mirror elements might need astigmatic surfaces to cure rather considerable astigmatism unless the individual mirrors were rather small. The problems associated with holding them in position and keeping them that way are not simple, although the weight need not be large compared with any comparable single mirror.

"If we assume that these technical details are capable of solution, it would be fun to imagine what sort of mountings would be required if the extremely radical systems were really exploited (there would be no advantage in moderately radical instruments). The ultimate speed for the first of the last four systems, which may be thought of as a Schmidt with every ring of mirrors at the neutral zone, is $f/0.5$. In practice, allowing for the light losses due to obstruction by the supports for the observing cage, an equivalent of $f/0.6$ might actually be accomplished. The other schemes, with the focus lying in the mirror circle, would be limited to $f/1$, which might have to be shaded to an equivalent $f/1.2$ to accommodate all practical considerations.

"To give an idea of the tremendous light grasp of these really fast optical systems we might take the 100-inch telescope as a yardstick. The focal ratio is 5, and the limiting exposure is about 40 minutes, at which time the fogging of the plate due to the light of the night sky prevents further recording of faint stars. At $f/1.2$ an exposure of 138 seconds would accomplish the same, and at $f/0.6$ only 35 seconds would be required. With speeds like this, the telescope could even be held still and the film moved across a slot to keep pace with the moving image. The width of the slot would determine the exposure. For so short a time manual guiding of the plate would hardly be necessary. Photocell guiding would be quite feasible because of the extreme brilliance of comparatively faint guide stars at this focal ratio."

Pitch-polishing laps for telescope mirrors can be brought into contact with the glass and kept that way by channeling the lap into facets. The channels give the pitch a space into which to flow in settling to contact. To carry the same idea further and assure better and quicker contact, each facet may be subfaceted with smaller channels by the use of onion sacking obtainable at grocery stores. However, if the sacking is cold-pressed into the pitch, the pitch will tend to flow up and around each of the meshes and lock the sacking in. A correct method, as used professionally by F. B. Ferson, is to dip the cold lap in nearly boiling water for an instant, lay the sacking, previously wetted, upon it, press it in flush by hand and strip it off before it can become locked in. Then dip the lap in hot water and apply it to the mirror long enough to flatten the tops of the subfacets without closing the little channels.

There are two kinds of onion sacking. Each is square-meshed but one is coarse, like strong wrapping twine, and the other is finer, like coarse sewing thread. The coarse kind makes deeper, longer-lasting channels. Wash it thoroughly before use.

E. B. McCartney of Minneapolis uses a woven square mesh embedded in sheets of cellulose acetate which is listed in mail-order catalogues for admitting ultraviolet radiation into hen houses. This is easier to handle than onion sacking, can be used against dry mirrors and makes a perfectly square pattern, though this has no actual importance. However, its channels are not so deep.

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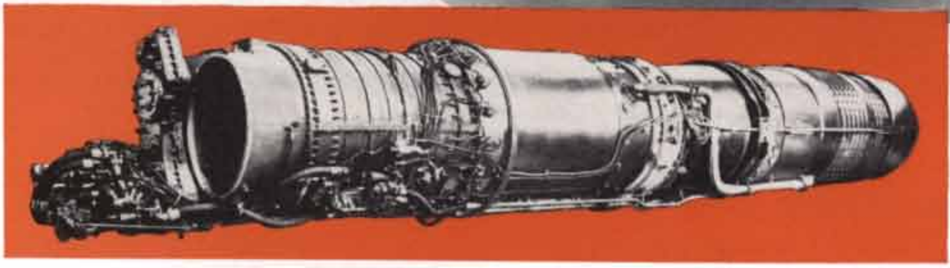

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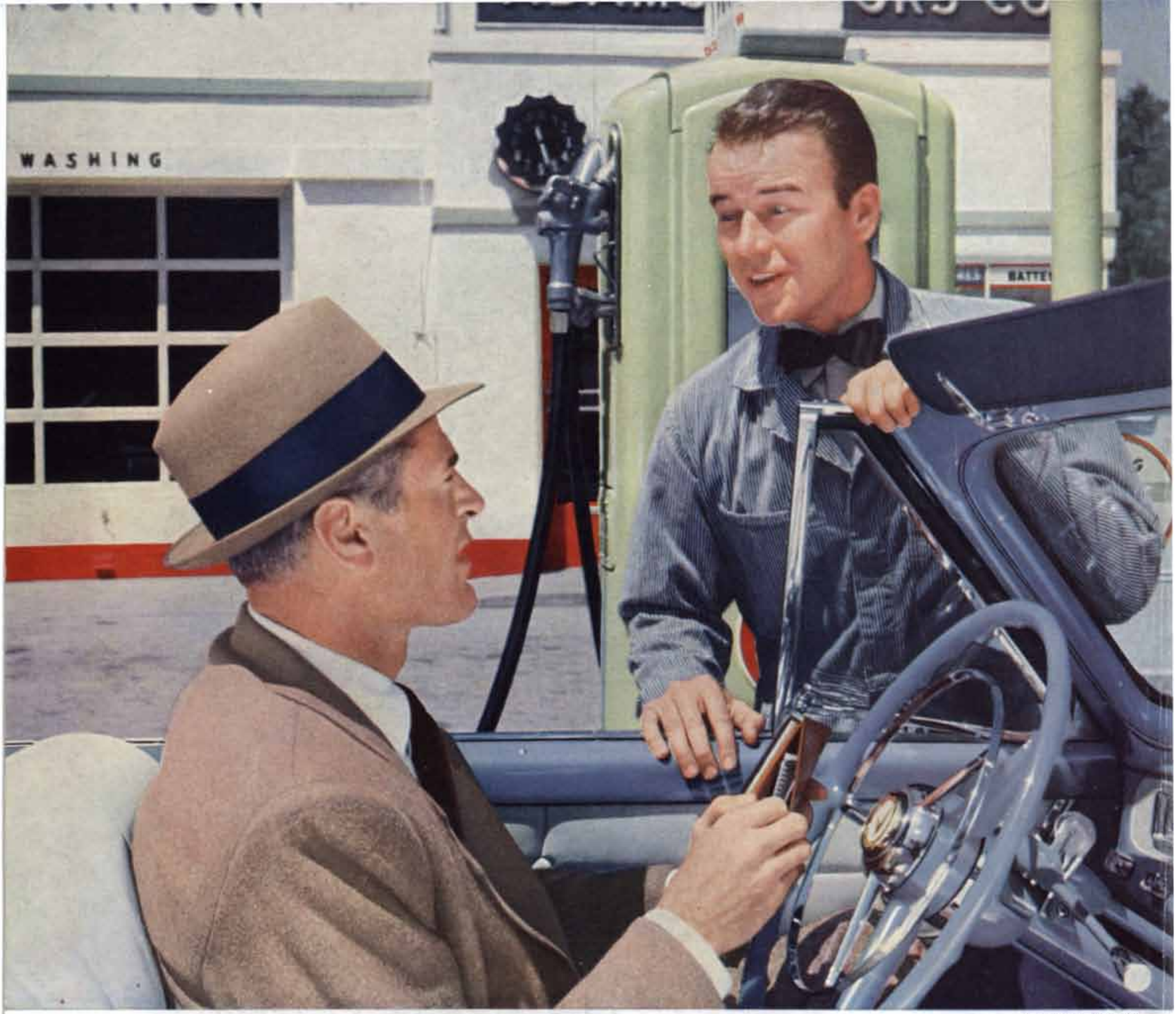

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