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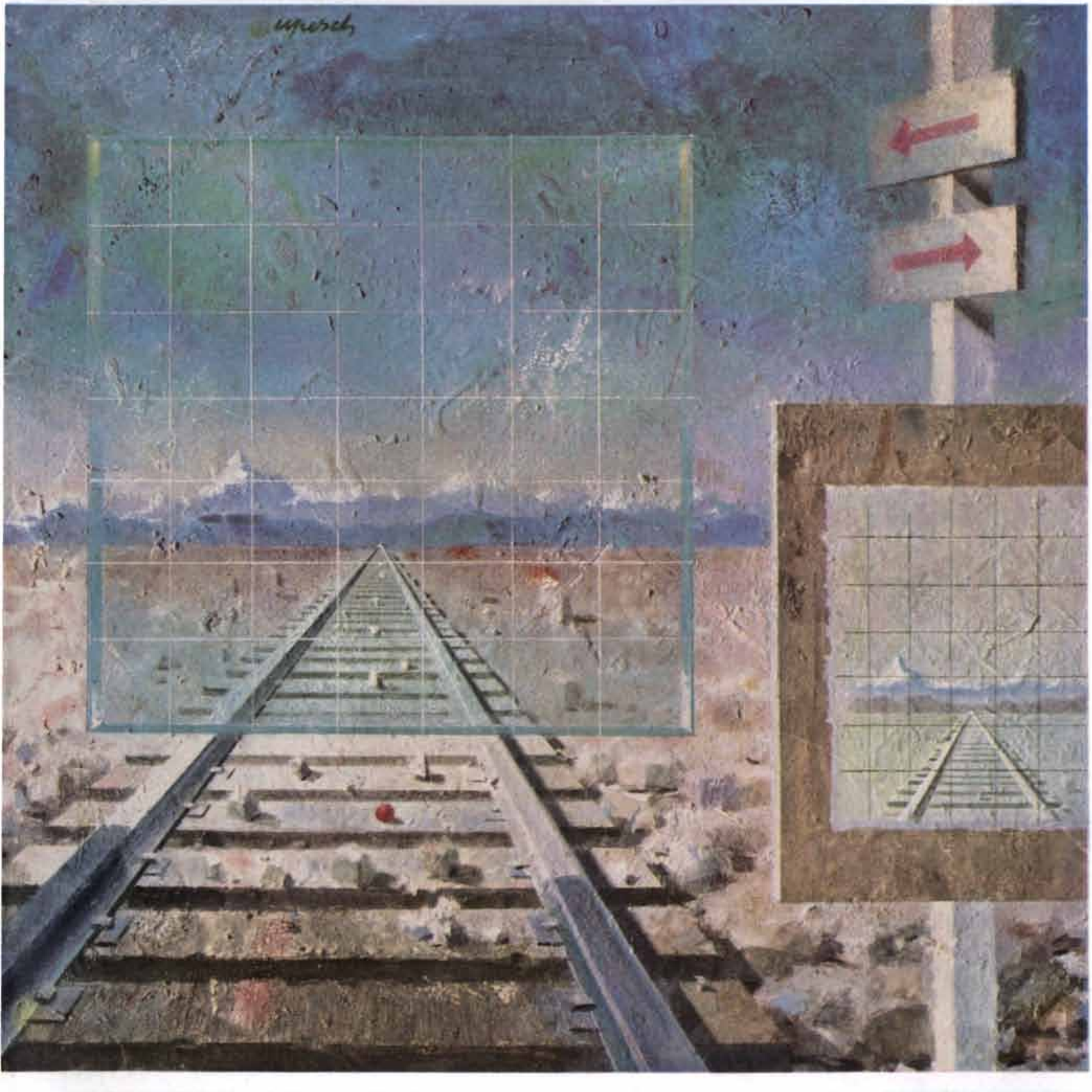

PROJECTIVE GEOMETRY

FIFTY CENTS

January 1955

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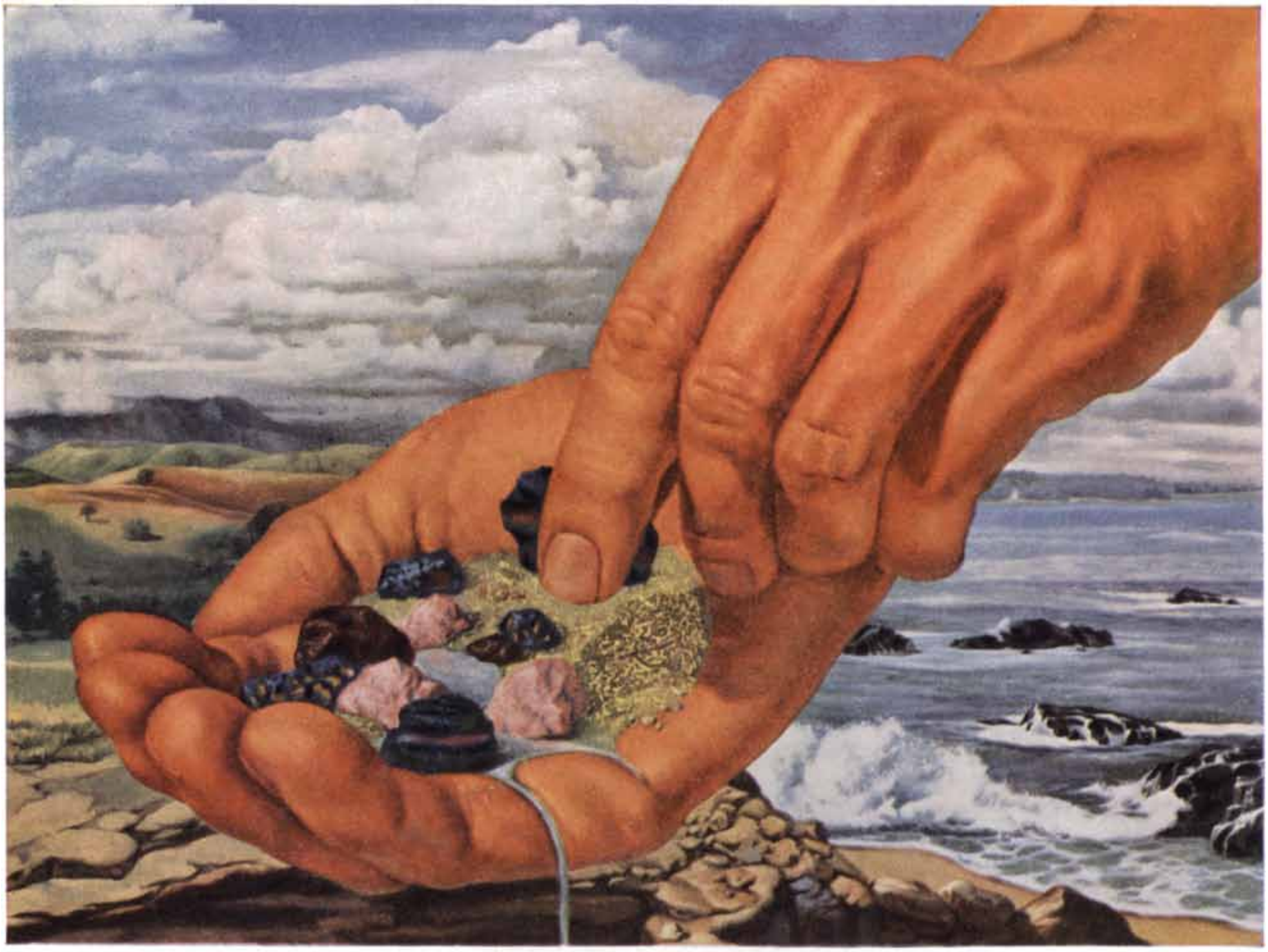

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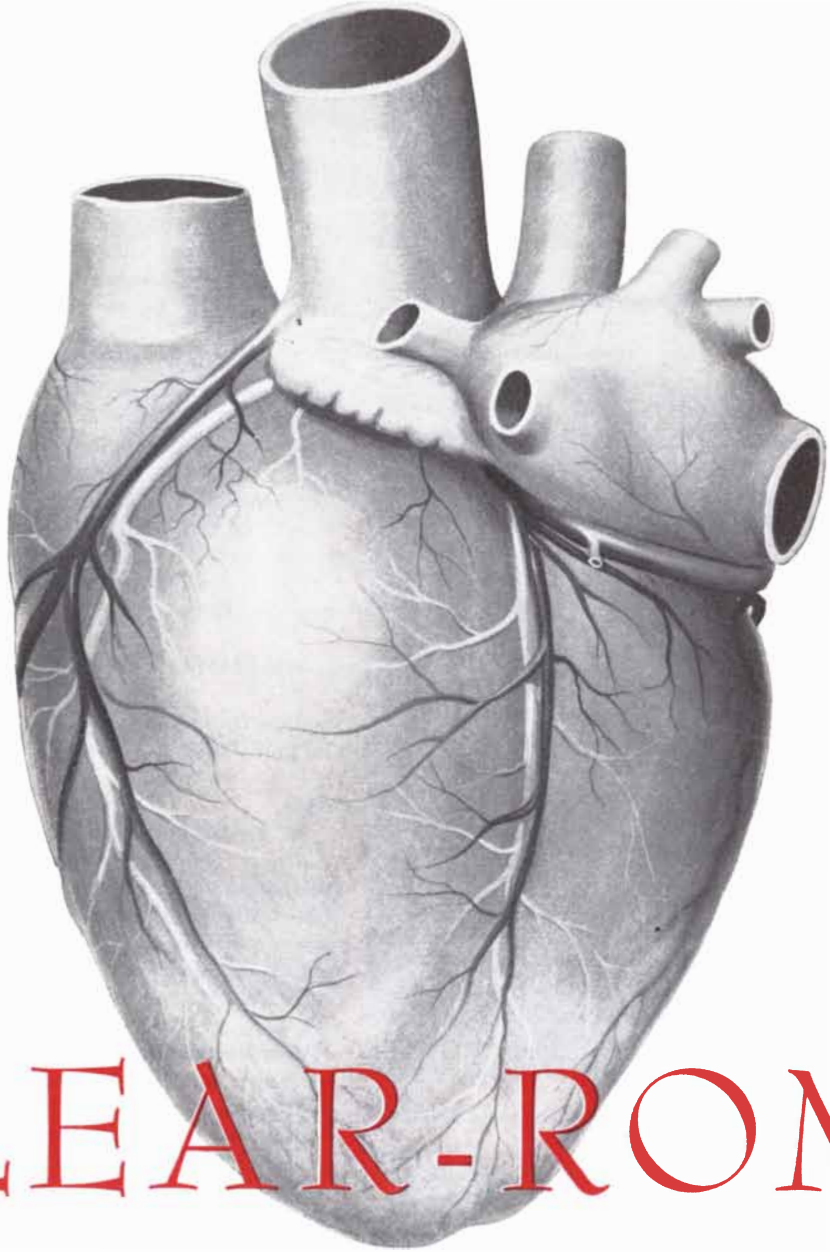

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LETTERS

Sirs:

As an oceanographer with considerable secondhand—and some firsthand—experience with tsunamis, I would like to suggest some slight modification of Joseph Bernstein's description of these waves [SCIENTIFIC AMERICAN, August].

To begin with, a tsunami is not, in general, a "terrifying phenomenon." They occur almost daily in some dimension, and the principal hazard from an occasional large one is their apparently innocuous behavior. They resemble nothing so much as the tide (hence the misnomer tidal wave), save that they are superimposed upon the local prevailing water level, and advance and retreat in a matter of half an hour instead of 12 hours. There is no "wall of water 10 to 100 feet high" crashing upon the shore. The average shore height of tsunamis is only 3 or 4 feet. The extreme heights reached by the water in specific locations is due to another phenomenon known to oceanographers as "seiching," which is similar to the sloshing of water in a bathtub. Semi-enclosed bodies of water having characteristic periods or frequencies of sloshing within the frequency spectrum of tsunamis (one cycle every 15 minutes to one hour) are fairly common along our coastlines. In such cases a sympathetic oscillation is set up analogous to repeated impulses to a pendulum, and very high amplitudes of water motion may result. Otherwise, depending on the stage of the astronomic tides, only a general inundation of low-lying areas occurs. If a high surf is running as well, it can, of course, add to the general catastrophe.

The tsunami warning system established in 1946 by the U. S. Coast and Geodetic Survey was a commendable step toward the ultimate goal of predicting several hours in advance the local height of an approaching tsunami. But this system is still woefully short of solving the problem because it is essentially only a warning indicator. Before wave heights can be predicted it is necessary to understand the propagation of long-period waves in *deep* water and the response of local bodies of water to such waves. A new instrument developed at Scripps Institution of Oceanography has been used to measure deep-water wave height and period and it is hoped to have a series of these instruments installed in selected areas in the Pacific Ocean within a year or two. . . .

WILLIAM G. VAN DORN, PH.D.

Scripps Institution of Oceanography
La Jolla, Calif.

Sirs:

In the November issue of *Scientific American* Dr. S. Fred Singer discusses the origin of meteorites, drawing his conclusions largely from the data on the age of iron meteorites as deduced from the helium method. It seems to me that these data are very doubtful because of the necessity for estimating the amount of cosmic ray helium-3 and helium-4 and making a very large correction on the helium ages on this basis. This doubtful correction constitutes nearly the entire effect. Some of us doubt these ages and believe that much more study of the subject must be made before any conclusions can be drawn at all. Also it seems to me that any theory for the origin of meteorites should try to account for the chondritic stone meteorites, which are the most numerous and most massive fraction of all meteorites.

Dr. Singer quotes me incorrectly. He says: "Uranium is relatively insoluble in iron, as Harold C. Urey has recently reported." I made no such statement and it is technically untrue, for uranium is soluble in iron. At the December, 1953, meeting of the American Association for the Advancement of Science I pointed out that uranium and thorium are very electropositive elements and that therefore they should have concentrated in the silicate phases of meteorites and that these elements, if actually present in the

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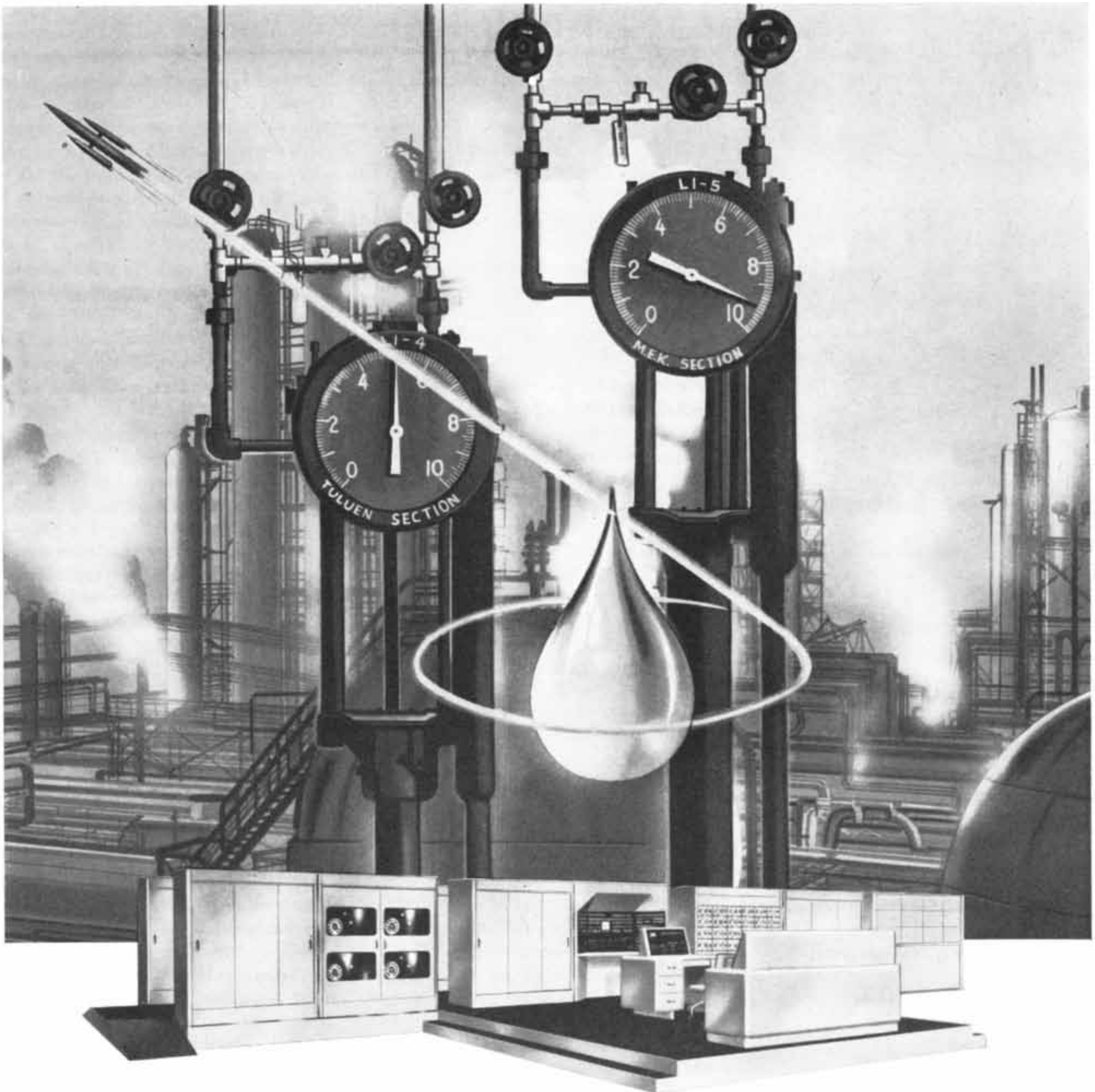

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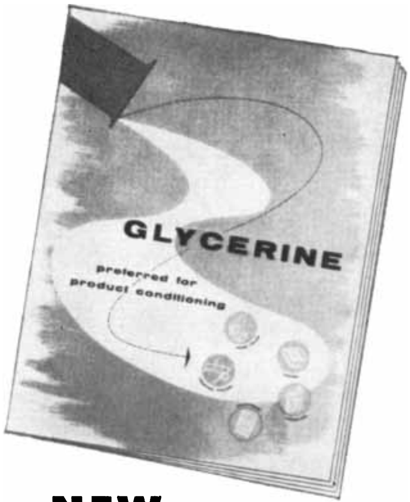

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iron meteorites, should be in the interstitial material between the iron crystals; hence any helium generated in such material should have escaped readily, and therefore ages determined by the helium method might well be in error. Professor Patrick Hurley expressed the view that this might well be the case.

HAROLD C. UREY

Institute for Nuclear Studies
University of Chicago
Chicago, Ill.

Sirs:

Professor Urey's letter, it seems to me, makes the following points:

1. We cannot rely on the iron meteorite ages deduced from the helium method.

2. Any theory of the origin of meteorites must account for the chondritic stone meteorites.

3. "Uranium is relatively insoluble in iron" is incorrectly quoted.

1. If Professor Urey means "geological age" (*i.e.*, time of most recent solidification) and "uranium-helium" method, as I assume he does, then I agree with him entirely, for this is the main point of my argument. The "age" which I obtained, however, is something quite different, namely the time of exposure to cosmic rays (and, therefore, probably the date of breakup of the parent planet). This "cosmic ray age" we get by dividing the *measured* helium-3 content by the calculated rate of production. Allowing, of course, for some uncertainties in the measurements and the theoretical calculations, I see no reason to doubt the validity of the procedure, and, therefore, of the results.

2. I would agree that a *complete* theory of the origin should explain the structure of chondrites, as well as a number of chemical anomalies, for example, the absence of certain elements. One of the most fascinating discoveries is the presence of organic material in some meteorites. In all of these studies Professor Urey and his collaborators have made distinguished and well-known contributions which form the groundwork of any description of the origin of stone meteorites. It is my feeling, however, that at the present time iron meteorites can give us more quantitative data mainly because of the metallurgical and nuclear physics evidence. At the time I wrote the article I was not aware that G. J. Wasserburg and R. J. Hayden in Professor Urey's laboratory had just succeeded in measuring the argon-potassium age of two stone meteorites.

3. I believe I am quoting Professor Urey essentially correctly. The statement applies to very high temperatures (*i.e.*, the long cooling period of the iron-nickel core). And the word "relatively" compares uranium to silicon dioxide. Professor Urey has calculated the free-energy changes at 1,500 degrees for the reduction of uranium and silicon dioxide by iron; he finds uranium to be more electropositive, hence less likely to be reduced and dissolved. He stated also that uranium oxides or sulfides should be less soluble in metallic iron than in the silicate or in the iron sulfide phase. Incidentally, this provides an explanation for the experimental results of Claire Patterson, Harrison Brown, George Tilton and Mark Inghram, who find that in the Canyon Diablo meteorite the uranium is entirely concentrated in the iron sulfide with none in the metal phase.

To speak of another matter entirely, I should like to correct a few errors in the illustrations that accompanied my article. These errors occurred because, when the article went to press, I was en route from Italy and therefore not in a position to check the illustrations and their captions.

In the illustration on page 36, as many intelligent readers have doubtless observed, the hyperbolic orbit passes to the wrong side of the sun.

In the caption for the illustration at the bottom of page 37 the statement is made: "These pits [in the Goose Lake Meteorite] appear due to collisions with other meteorites." It should be said that this statement is still in controversy.

In the caption for the second illustration from the top on page 39 the statement is made: "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*)." The words left and right should be transposed.

The illustration at the top of page 40 was originally intended as a comparison between the helium lost upon heating a stone meteorite (Pultusk) and that lost upon heating an iron meteorite (Mount Ayliff). The curve for the Mount Ayliff specimen, which shows that its helium content varies from 98 per cent (at 600 degrees) to 95 per cent (at 1,000 degrees), is missing. This comparison demonstrates why only iron meteorites are suitable for helium dating.

S. FRED SINGER

University of Maryland
College Park, Md.

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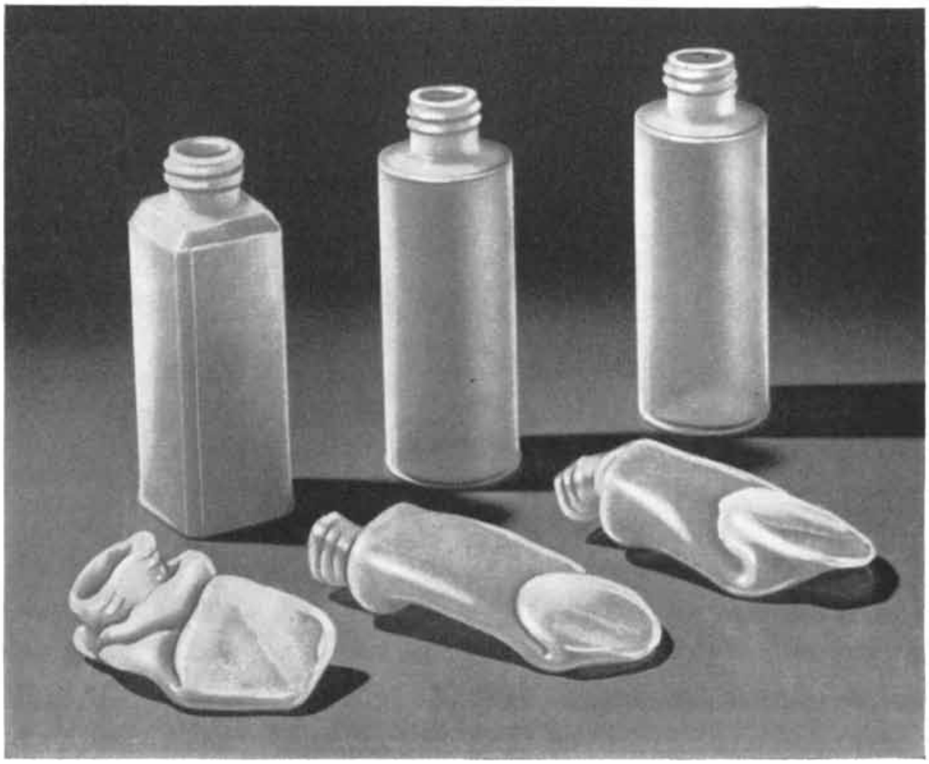
These 6 polyethylene bottles were kept at 250°F for 20 minutes

These 3 were first irradiated with a G-E electron beam generator

These 3 were not



The challenging potential of high-energy irradiation for chemical products and processes is indicated by the above photograph. The irradiated polyethylene bottles withstood temperatures that reduced their non-irradiated counterparts to shapeless masses. This improved form stability at elevated temperatures was accomplished without significant loss of flexibility.

Plastics are just one area of application for the G-E 1-mev electron beam generator. Research has also proved electron beams lethal to microorganisms. Investigation on such food products as meat, milk and bread is currently being conducted.

General Electric offers you an easy plan to carry on your own investigation. The G-E Laboratory will conduct preliminary tests with your cooperation. Should these show promise, equipment can be *rented* for use in your own plant under the G-E Maxiservice® rental plan.

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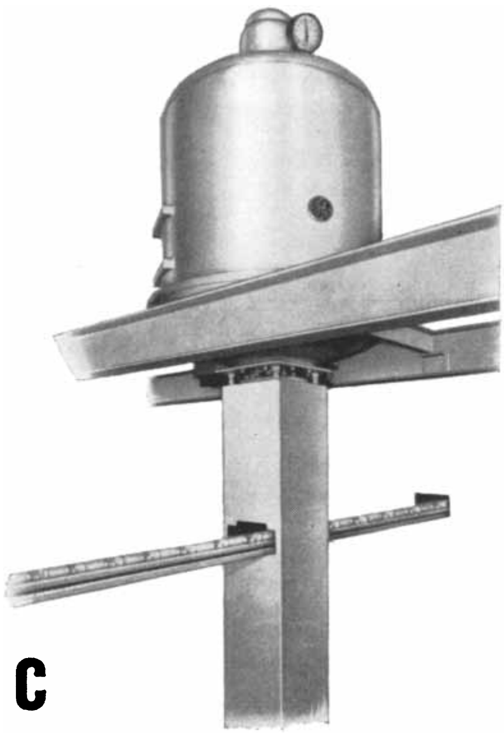

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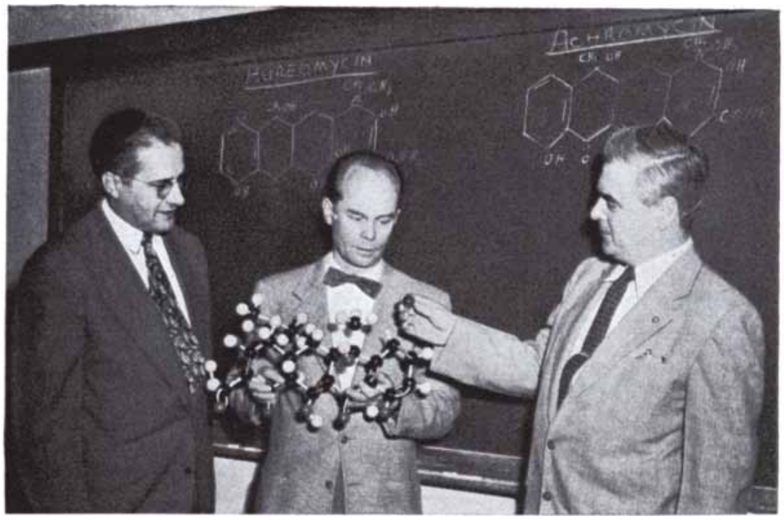
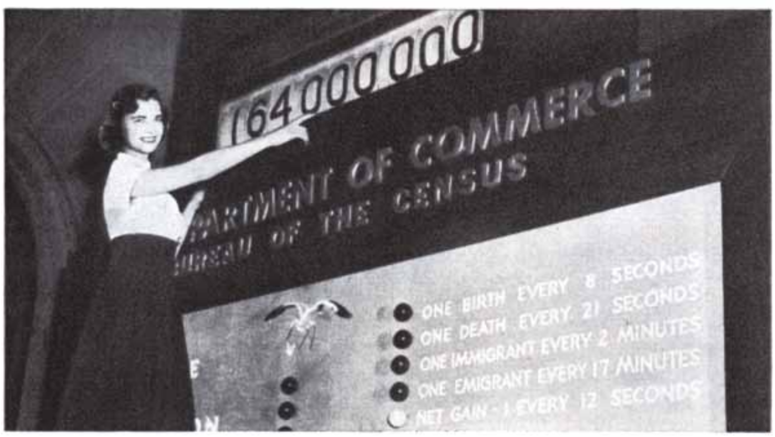
Life...on the Chemical



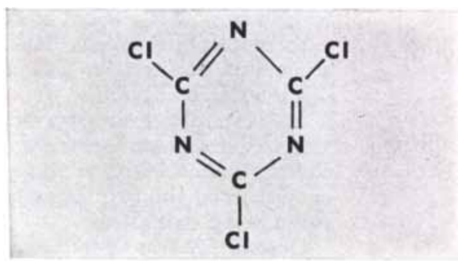
ACHROMYCIN FROM AUREOMYCIN—It looks simple here, but removing one chlorine atom from the Aureomycin* chlortetracycline molecule to produce Achromycin® tetracycline took years of research by many scientists at Lederle Laboratories. Dr. James Boothe, one of the chemists who worked on the problem, holds a three-dimensional atomic model of Aureomycin as Dr. J. H. Williams (right), Director of Chemical and Biological Research, removes the chlorine atom symbol. Dr. Nestor Bohonos, who heads Mycological Research, looks on. Achromycin is produced from Aureomycin by catalytic reduction at Cyanamid's Lederle Laboratories Division.

*Trade-mark

SLALOMING at 70 mph and over demands superb skill, super qualities in skis. Top ski performance over dips and bumps, with low friction and no tip and tail flutter, are obtained with new plastic skis molded of Cyanamid's LAMINAC® polyester resin and glass fiber. High strength and extreme durability are combined with light weight and molded-in color to produce skis that never warp or need refinishing. **(No. 2)**



U. S. POPULATION is expected to pass 164,000,000 this month. This Department of Commerce "clock" records population growth minute by minute. Every 12 seconds there is one more mouth to feed! But there is no Malthusian dilemma—food abounds, thanks to good farm practice, development of new strains of plants and animals, and chemical aids for farmers. Cyanamid, long a major supplier of chemical aids to farmers, now produces anhydrous ammonia for direct application to soil, thus providing essential nitrogen at lowest cost per unit. Anhydrous ammonia is used also in mixed fertilizers. **(No. 1)**



CYANURIC CHLORIDE with its stable triazine ring structure and highly reactive chlorine atom on each carbon, offers interesting opportunities for organic synthesis. For example, the chlorines may be replaced with allyl groups to make triallylcyanurate—the basis for new plastics which retain much of their strength at temperatures as high as 500° F. Other cyanuric chloride derivatives are used as therapeutics and as bactericides. Still others produce brilliant dyes, and brighteners for detergents and textiles. When converted to cyanuric triazide, a brisant explosive is formed. It offers many other possibilities for further synthesis. **(No. 3)**

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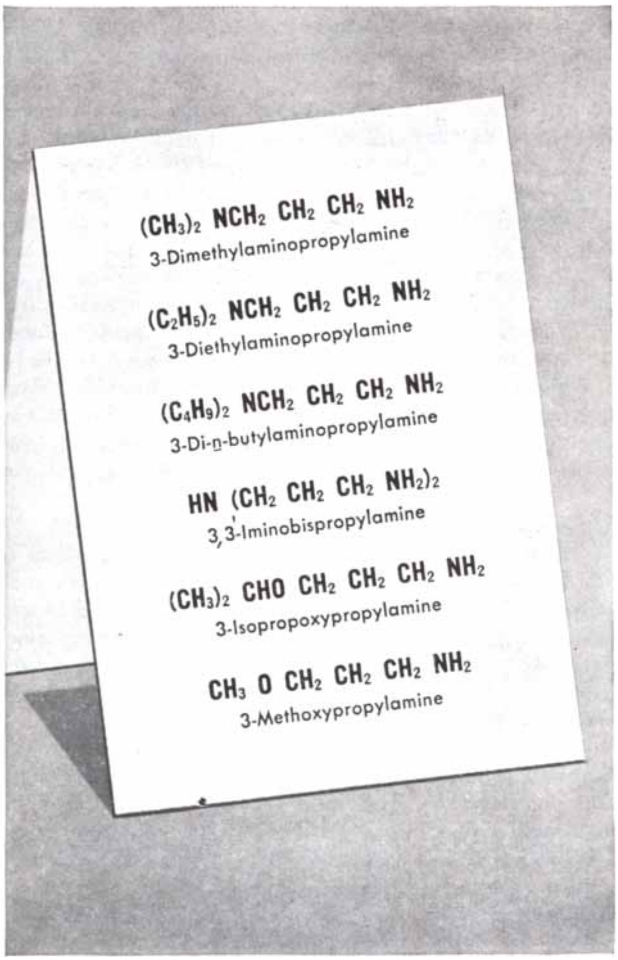
Newsfront

AMINES FOR NEW PRODUCT DEVELOPMENT listed below offer interesting possibilities. Stemming from Cyanamid's acrylonitrile, all are typical acrylo derivatives. Each has a propylamine group but varies in the other substituent, producing corresponding changes in physical properties. For example, as the substituent increases in size, vapor pressure decreases and solubility in non-polar solvents increases. Effect is seen in use as curing agents for epoxy resins where dimethylaminopropylamine provides rapid cure while diethyl and higher substituents offer greater pot life. These amines are useful in forming surface active agents. Cationics and nonionics are produced by reaction with fatty acids and have been employed as emulsifying agents for waxes and as flotation agents. The amines also are useful intermediates for products such as germicides, pharmaceuticals and dyestuffs. The New Product Development Department offers these amines in semi-commercial quantities. The only exception is the di-n-butyl derivative, which is available in trial-lot quantities. For data sheets, samples or price information on any of these amines, a coupon is attached for your convenience. (No. 4)



"Cogitations"

300,000 turkeys are estimated to have been lost last year by death from erysipelas. *Erysipelothrix rhusiopathie* is the culprit, which also produces the disease in swine and an erysipeloid infection in man. A new vaccine, DUOVAX® erysipelas bacterin *Lederle*, produced by Cyanamid's Lederle Laboratories Division, provides effective control of erysipelas in turkeys—with the added advantage that there is no danger of infecting vaccinator or the turkey houses as was possible with the former serum and culture type vaccine. (No. 5)

Anti-static agent CATIONIC SP is a boon to processors of materials such as textiles, plastics, paper, and glass since it is applied easily and eliminates troublesome static. Added to plastic compositions, it prevents accumulation of strongly adhering dust on the finished products. CATIONIC SP is one of a group of Cyanamid's surface active agents. These polar-nonpolar chemicals change the behavior of textiles, metals, oily materials, and fine powders by forming an extremely thin molecular layer on their surfaces. Usually, a very small percentage is all that is required. A Cyanamid surface active agent may be used to change the surface characteristics of a product easily, and improve its properties greatly. (No. 6)

The ultraviolet component of sunshine often causes discoloration and embrittlement in lacquers and plastics, checking and crazing in rubber, color changes in dyes and pigments, loss of strength in textiles, and blistering on tender skins. A small group of chemicals (substituted benzophenones) has been found to provide efficient protection against U. V. degradation. In particular, Cyanamid's U. V. ABSORBER 9, which is the 2-hydroxy-4-methoxy-benzophenone, is unusually effective. It absorbs harmful U. V. and converts it into harmless heat without fluorescence. New Product Bulletin #31, giving pertinent data regarding U. V. ABSORBER 9 and other related U. V. absorbers, is available on request. (No. 7)

More information on any of the products mentioned in these pages is available on request. Write to "Chemical Newsfront," American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y., or use the coupon below—simply checking the items on which you wish additional information.

SEND more information on the following items mentioned in the January, 1955 issue of LIFE on the Chemical Newsfront:

S. A.

No. 1, 2, 3, 4, 5, 6, 7.

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Is the development of *your design idea* hampered by the need for metals harder than steel . . . metals to resist deformation under high pressures, to maintain tolerances under abrasion?

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Rigidity and high temperature strength are other favorable characteristics of Kennametal. And, where corrosion or oxidation resistance is a factor, our titanium carbide, Kentanium,* may serve your purpose.

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SCIENTIFIC AMERICAN

JANUARY, 1905: "The French Admiralty has sanctioned the construction of the light type of submarine boats which are to be utilized strictly for defensive purposes."

"Prof. Charles Waldstein, of Cambridge University, England, lectured recently in New York on a plan of his to excavate the city of Herculaneum which, together with Pompeii, succumbed to Vesuvius. Herculaneum, historically considered, is a far more interesting city than Pompeii. Pompeii was but a provincial town inhabited by Romans of the lower class. Herculaneum, on the other hand, was a city of villas, and its inhabitants were the elite of the empire. More Greek than Roman in its artistic atmosphere, the city retained its distinctive character up to the time of its destruction and attracted many Greek artists and writers. The finds which were made a quarter of a century ago during the interrupted excavations gave promise of still more important discoveries. 'In one house alone,' said Prof. Waldstein, 'sixty-five copies of one work on Epicurean philosophy were discovered. . . . May we not find in Herculaneum the lost books of Livy, the great lost dramatist, and throw new light on the early history of Christianity?' It is Prof. Waldstein's plan to have the United States and the principal countries of Europe co-operate in unearthing the ancient town."

"An interesting paper was read at a recent meeting of the Institution of Naval Architects, which may lead to a very important improvement in the construction of passenger-carrying boats plying the high seas. The paper was read by Herr Otto Schlick, who called the attention of the body to his proposition to increase the period of oscillation of a vessel by means of the gyroscopic action of the flywheel and at the same time effectively lessen the craft's angle of heel. A large flywheel is set up on board the boat, and revolved at a great speed and, being held in a suitable framework which is somewhat flexible, the wheel and its frame is capable of some lateral movement, to enable it to counteract the motion of the boat. The paper was illustrated by means of models, the conduct of which was pronounced entirely satisfactory by those present, and the gathering included a number of the foremost engineers of England. As soon as any outside influence begins to heel the vessel over in a direction at right angles with its length, the flywheel frame will incline considerably, with the result that moments are produced which not only render the oscillations of the vessel considerably slower, but also very considerably reduce their extent. In the case of a medium-sized boat, say six thousand metric tons, it was calculated that a flywheel of 13 feet in diameter, weighing 10 tons, would very materially reduce the amount of oscillation."

"A telegram has been received at the Harvard College Observatory from Prof. W. W. Campbell at Lick Observatory stating that a sixth satellite of Jupiter, suspected by Perrine in December, was discovered by him January 4, 1905. The apparent motion is retrograde and the magnitude 14."

"About twelve years ago a French missionary interested in silk culture from spiders' webs started a systematic rearing of two kinds of spiders for the webs. This web factory is now in successful operation at Chalais-Meudon, near Paris, where ropes for balloons are made of spider web; and these ropes are said to be of the strongest character possible. Twelve spiders are placed above a reel, upon which the threads are wound, and each spider is supposed to furnish from thirty to forty yards of thread before it is released. Then the web is washed to clear it of the outer rubbish and sticky cover. Eight of these washed threads woven together make a strong yarn cord, that is found excellently adapted for use in balloon service."

"G. Bigourdan makes a proposal for the wireless distribution of time signals, which he has already subjected to some satisfactory tests. The directing clock, which breaks an electric contact every second, works a relay which, in its turn, sends a current into the primary circuit of an induction coil furnished with an oscillator. The secondary circuit of the coil thus provides an oscillating discharge of very short duration, which passes regularly every second. One of its poles is earthed, while the other is connected with an antenna several meters high. In view of the accuracy of modern

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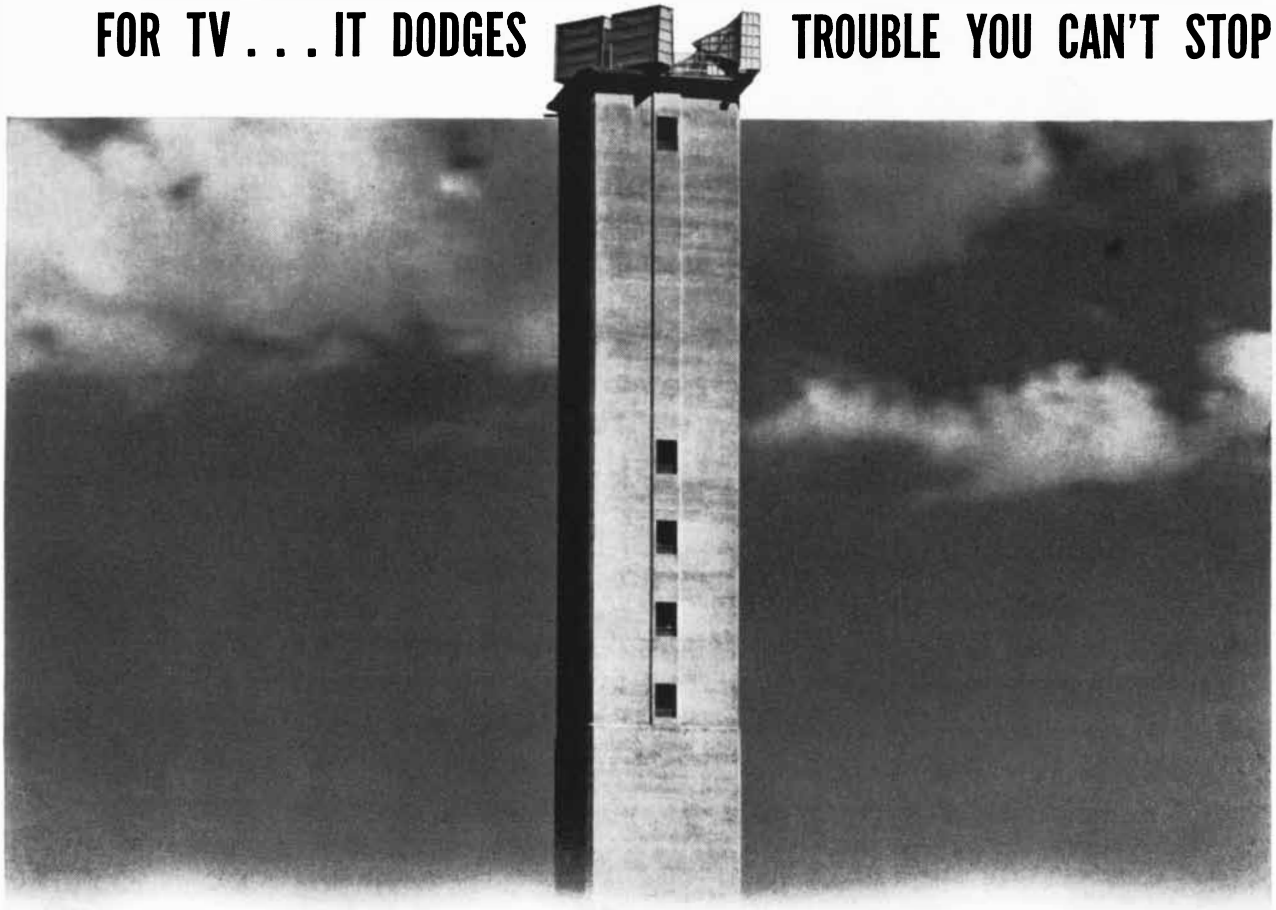

Radio Relay station on route between Chicago, Ill., and Des Moines, Iowa. Every fifth or sixth relaying tower is a control station, where high-speed switching equipment enables a TV picture to skip out of a troubled channel and into a stand-by protection channel faster than the eye can wink.

There's no way to stop atmospheric changes that threaten television with "fade." But, for TV that travels over Bell's Radio Relay System, Bell Laboratories engineers have devised a way to side-step Nature's interference.

When a fade threatens—usually before the viewer is aware—an electronic watchman sends a warning signal back by wire to a control station perhaps 200 miles away. An automatic switching mechanism promptly transfers the picture to a clear channel. The entire operation takes 1/500 of a second. When the fade ends, the picture is switched back to the original channel.

This is an important addition to the automatic alarm and maintenance system that guards Bell's Long Distance network for television and telephone calls. It marks a new advance in Bell Laboratories' microwave art, developed to make your Long Distance telephone service, and your TV pictures, better each year.

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

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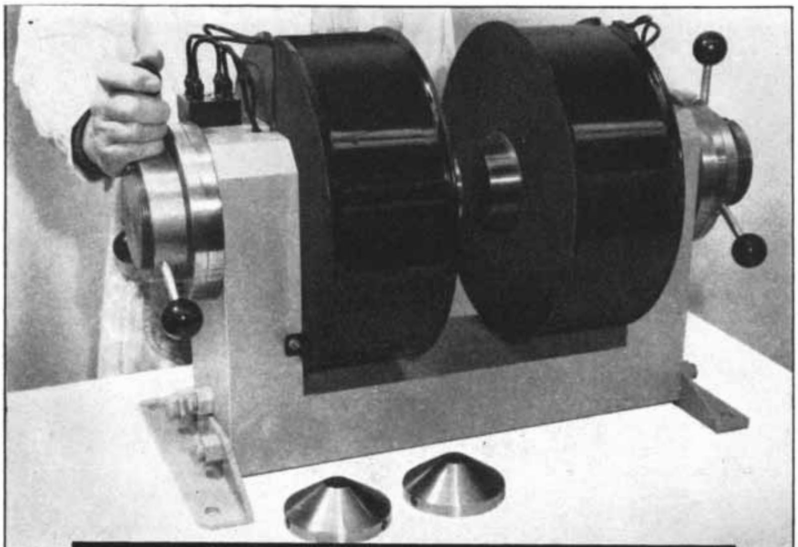

NEW Laboratory Electromagnet

lets you **vary gap geometry** with precision and ease

With **Varian's new V-4004,** you can achieve a wide selection of magnetic field strengths and configurations . . . by a simple adjustment of each pole piece or by changing pole caps. In this manner, air-gap width can be varied continuously from over 4" down to zero — and flux contours can be varied with flat, conical or other specially-shaped caps. Thus, you have convenient command of your magnetic fields . . . at flux densities up to 28,600 gauss. What's more, the V-4004's open design readily accommodates your experimental equipment. These features, unmatched by any other magnet, make the V-4004 the ideal tool for your general purpose needs.

TYPICAL PERFORMANCE AT MAXIMUM CONTINUOUS ENERGIZING CURRENT		
Gap Width (inches)	Dia. Pole Caps (inches)	Field Strength (gauss)
0.25	1	28,600
0.50	2	21,800
1.00	3	13,000
2.00	4	7,650
4.00	4	4,250

POLE ALIGNMENT ALWAYS MAINTAINED

There can be no misalignment of the field poles due to weight of coils . . . because each energizing coil is supported by a sleeve bearing which is permanently attached to the magnet yoke. This allows each pole to slide in and out with smoothness and precision. Both water-cooled coils are completely enclosed in a copper case for maximum protection.

A Complete Line of Quality Electromagnets

The V-4004 is the newest and most compact of Varian's famous laboratory electromagnets. A matching power supply and regulator will soon be available. Two larger magnet models — the V-4012 and V-4007 — are available for highly precise work requiring large field volumes and exceptional field homogeneities.

For Further Information on the incomparable new V-4004, as well as on all other Varian Laboratory magnet systems, write to:

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chronometers, the author does not consider it necessary to number the minutes, but he would make an interruption at every tenth second."

"G. Cartaud reports having found traces of a cellular structure in the soft metals lead, tin and zinc, which he has succeeded in polishing and etching. Lead, which is the most difficult to polish, also presents the most decisive evidence of cellular structure. When attacked by picric acid dissolved in acetone it shows a completely closed microscopic network of cells. There is, however, evidence to show that this network is shown up by a kind of development, and is but the relic of an actual structure in what might be called the embryonic stage."

SCIENTIFIC AMERICAN

JANUARY, 1855: "Mr. Perkins, the son of Jacob, the eminent American inventor, who invented and exhibited in London a steam gun, has through a contemporary, made the following offer. He says, 'I am prepared to undertake to supply the government with a steam gun capable of throwing a ball of a tun weight a distance of five miles. If such a gun were fixed in Brunel's large ship of 10,000 tuns, I venture to say that Sebastopol would be destroyed without losing a man."

"The American revolving pistols of Col. Colt are used in the Crimea by all the officers of the British Army, and they are spoken of in the most glowing terms."

"At a late meeting of the Institution of Mechanical Engineers, Mr. C. William Siemens, of London, exhibited a new instrument, the invention of Fessel, of Cologne, by which the stability of the axis of rotation in a revolving body was illustrated in an ingenious and striking manner. The instrument, named a gyroscope, consisted of a small flywheel revolving in a frame, attached by gimbal joints at the end of a supporting rod, which was left free to move in any direction, by passing through a ball-and-socket joint fixed upon a center pillar. The instrument was shown in action by Mr. Siemens, and he explained that its original invention had arisen from an investigation into the laws of the stability in the axis of the earth's rotation."

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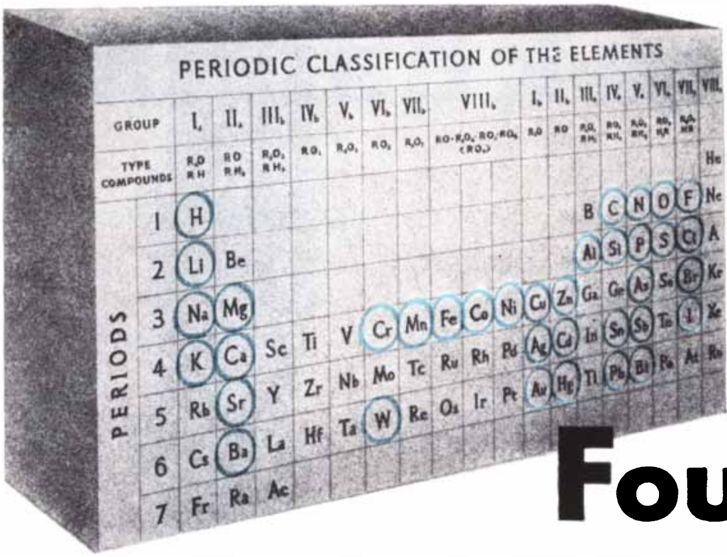
K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn			As		Br
	Sr						Ag	Cd		Sn	Sb		I
	Ba	W					Au	Hg		Pb	Bi		



the Foundation

Many factors
are involved in the final quality of a product
in the process industries. The inside story of many difficulties, however,
is often imperfect starting materials – chemicals, for example.
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Let something go wrong at the beginning and there is often no cure,
no way to avoid trouble, expense and rejections. That's why so many concerns
start with Mallinckrodt chemicals. They're exactly right, always dependable,
and most chemicals you might need are immediately available.
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to meet specific problems – Mallinckrodt will help you in a hurry
with the right chemical in the right physical form.
An important advantage of a chemical plant like Mallinckrodt's is flexibility
of research and production facilities.

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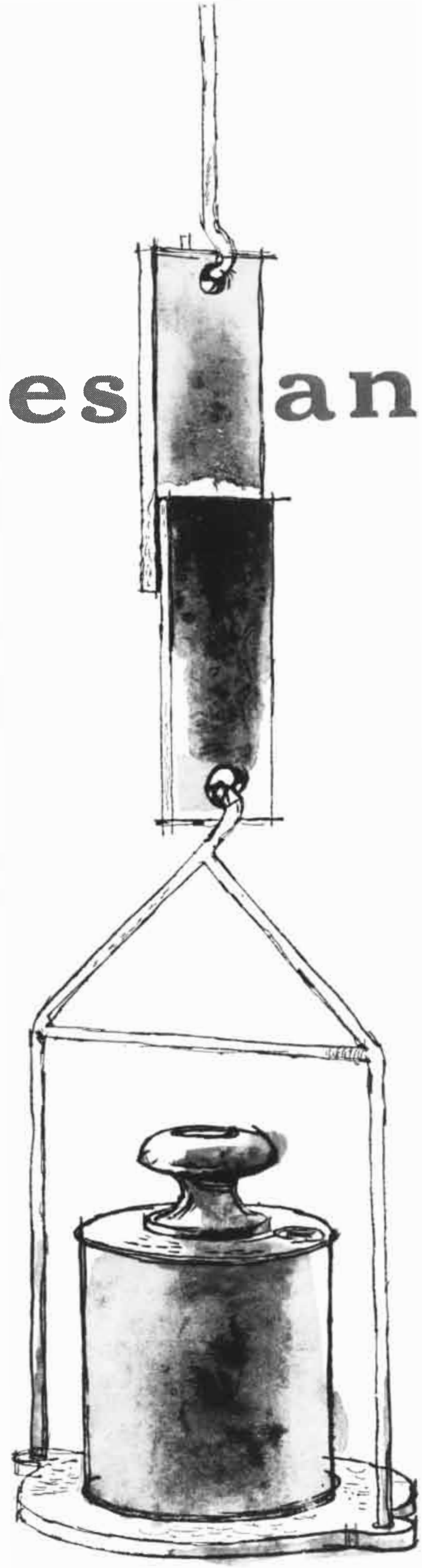
What makes an

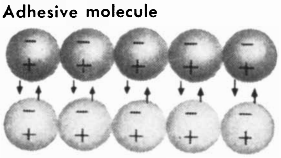


3 theories of adhesion

These theories describe what most research chemists agree are the important factors in bonding. As yet there is no agreement on a general theory of adhesion that would explain why all adhesives work.

Molecular attraction

Adhesive molecule

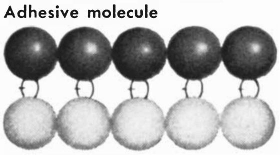


Surface molecule

All matter contains electrical forces in excess of those needed to hold the atoms within a molecule together. These tiny electrical forces are capable of providing a very strong attraction between the adhesive film and the surfaces to be bonded.

Chemical reaction

Adhesive molecule

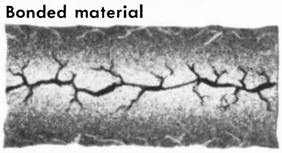


Surface molecule

In some instances, the adhesive reacts chemically with the surfaces of the materials to be bonded. A chemical bridge is formed which knits the two materials together.

Mechanical tie

Bonded material



Bonded material

With porous materials, the adhesive (dark line) fills the pores of the materials being bonded. When the adhesive hardens, it interlocks or "hooks" the two materials together as pictured above.

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adhesive stick?

Researchers don't agree on the answer . . .
but they keep on turning out amazing new adhesives

Wherever you look on the industrial horizon, adhesives are replacing nuts and bolts, rivets, and other mechanical fastenings. Materials like metals, glass, plastics, and ceramics are being bonded together with a speed and effectiveness that would have been impossible a few years ago.

When you consider this amazing progress, it's a little surprising to find that research chemists don't agree upon a basic theory that explains why adhesives stick. It seems that in some bonds, chemical reaction does the trick. In others, it may be molecular attraction, a mechanical tie, or possibly some combination of these and other still unknown factors.

None of these theories, however, seems to explain fully why adhesives like asphalt emulsion or putty will stick only as long as they remain "liquid." By contrast, most adhesives must pass through a liquid stage, then harden or change to a solid to form a bond.

It's easy to understand why a comprehensive theory has not been evolved. Research chemists have been tied to their benches by the pyramiding demand for new and better industrial adhesives. They have had to keep pace both by improving established adhesives and by exploiting the advantages of promising new basic materials.

This practical work, of course, has tended to confirm some theories and disprove others. Up to now, however, no complete proof of a fundamental theory of adhesion has been established. Even so, it seems reasonable to expect that before too long the final mystery of why adhesives stick will be solved.

For practical solutions to bonding problems, many manufacturers today turn first to the Armstrong Cork Company. Because of our 35 years of experience in making and using adhesives, we've been able to help a lot of fabricators find better ways to join things. For instance, Armstrong's new and stronger air-drying adhesives are bringing the speed and economy of assembly-line production to operations where overnight drying has been necessary.

If you're using adhesives, or would like to, get in touch with us. We'll be glad to study your problem and suggest a practical, economical solution.

For helpful information on using adhesives, send for our new 36-page illustrated manual, "Adhesives, Coatings, and Sealers." It's free to industrial users. Write on your letterhead to Armstrong Cork Company, Industrial Division, 8201 Inland Road, Lancaster, Penna.

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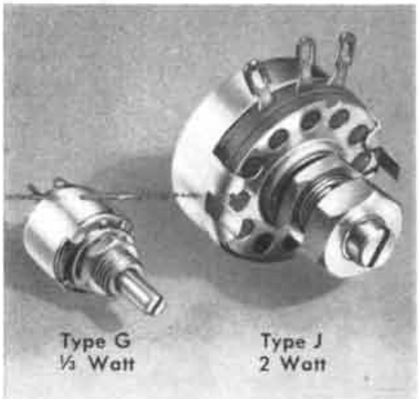

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THE AUTHORS

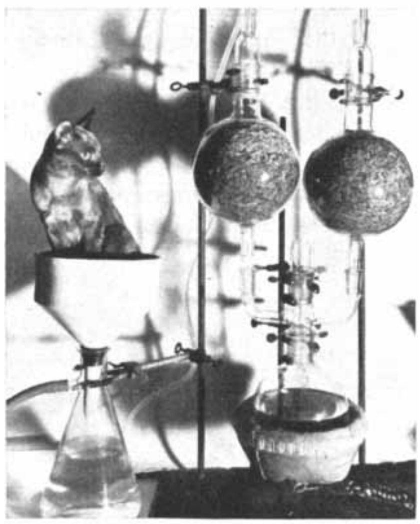
LEWIS M. TERMAN ("Are Scientists Different?") was for many years executive head of the department of psychology at Stanford University; he is now professor emeritus. He has spent his entire career in the study of intellectual differences. He writes: "My introduction to the scientific aspects of the subject occurred when I was a senior in psychology at Indiana University and was asked to prepare two seminar reports, one on mental deficiency and one on genius. The reading for those reports opened up a new world to me—the world of Galton, Binet and their contemporaries. Later in my last graduate year at Clark University I decided to find out for myself how mentally advanced children differ from the mentally retarded by doing a doctoral dissertation on the intellectual processes of seven bright and seven dull boys from a large city school. The experiment contributed little to science but it helped set the pattern for my lifelong interest in mental tests and gifted children." A Commonwealth Fund grant in 1921 enabled Terman to launch his famous study of more than 1,000 boys and girls with I.Q.'s of 140 or higher. He is at work on the fifth volume of his *Genetic Studies of Genius.* His son, Frederick E. Terman, is dean of the School of Engineering at Stanford.

HENRY STOMMEL ("The Anatomy of the Atlantic") is with the Woods Hole Oceanographic Institution. He grew up in Freeport, on Long Island, where he spent much of his time around small boats. After graduation from Yale University in 1942 he stayed on as an assistant in physics and as an instructor in navigation and nautical astronomy until 1945, when a grant from the National Research Council enabled him to begin research in oceanography. He has since explored a wide variety of subjects, from the development of cumulus clouds to the exchange of fresh and salt water in estuaries.

LAWRENCE P. LESSING ("Helicopters") a former member of the editorial board of *Fortune* and later of SCIENTIFIC AMERICAN, is a frequent contributor of articles to this magazine.

LOUIS F. FIESER ("Steroids") is Sheldon Emery Professor of Organic Chemistry at Harvard University. He was born in Columbus, Ohio, did his undergraduate work at Williams College and his graduate work at Harvard and in Europe in the 1920s. The author of a notable output of research (284 research papers and four books), he has honorary degrees from Williams College and the University of Paris and in 1941 received the Katherine Berkhan Judd Prize for Cancer Research. He lives in Belmont, Mass., with his wife and collaborator, Mary Fieser, and a bevy of Siamese cats. The cats, in fact, are also collaborators of a sort; a portrait of one of them, J. G. Pooh (named after the jellied gasoline bombs Fieser conceived) graces the third edition of the well-known Fieser book on *Phenanthrene*. An unauthorized translation of the book is now circulating among Russian chemists; the cat was not appreciated by the Soviet publishers and was omitted. Fieser writes: "The other day we submitted the final chapter of the 3rd edition of *Experiments in Organic Chemistry*. That night in celebration we went to the cat show and put down $75 for a beautiful little Burmese kitten. He looks pretty good; maybe he will have a book."

RAYMOND M. GILMORE ("The Return of the Gray Whale") is a research biologist with the U. S. Fish and Wildlife Service. After early studies in zoology at the University of California and Harvard University he joined the International Health Division of the Rockefeller Foundation as a field zoologist in 1935, and spent the following six years in South America. He returned to the U. S. in 1941 and took a Ph.D. in zoology at Cornell University. A former associate curator of mammals at the Smithsonian Institution, he has been with the Fish and Wildlife Service since 1946. Gilmore's hobby is exploring the almost un-



Fieser's Burmese cat "Ursolic Acid"

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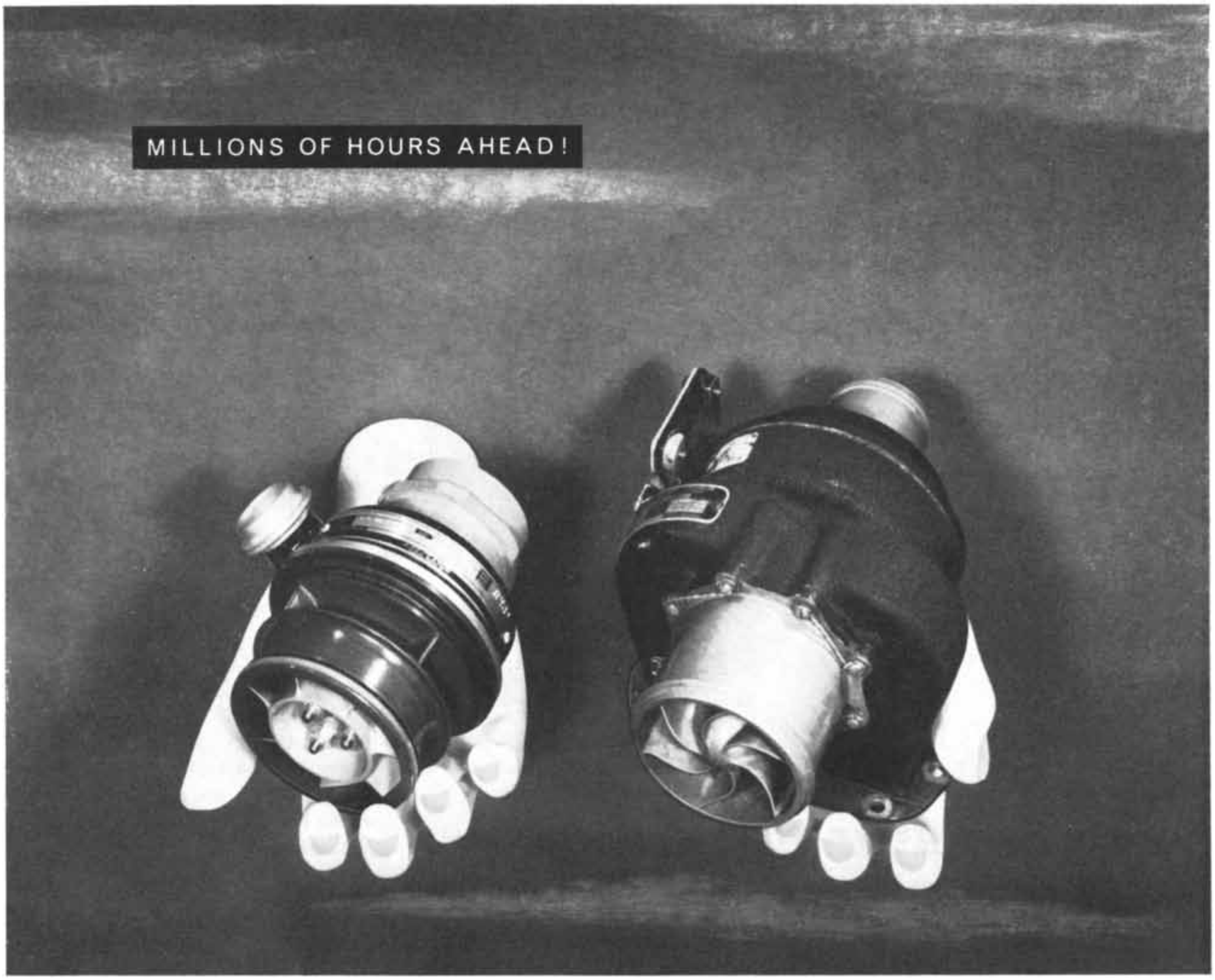

New hand-size cooling turbine weighs less than 2 pounds!

You've read about the new deadly miniature combat jets like the Douglas A4D. Here, even the rivets had to be scaled down in size to meet the critical weight problem.

Existing cooling components could not meet the exacting specifications. AiResearch engineers, designers of the first midget cooling turbine (right) for America's early jets, solved the problem by designing the refrigeration turbine shown on the left.

This new turbine weighs less than 2 lbs. It produces 15½ h.p. and has the cooling capacity of 2300 lbs. of ice per hour. *Its weight is half the original unit, yet it has twice the cooling capacity.* Operating on the A4D and the Grumman F9F9, this cooling turbine has already demonstrated its high efficiency and extremely low oil consumption.

In the field of air turbine refrigeration, AiResearch has devoted over 900,000 research and development hours. Nearly 50,000 units have been produced. Still the search goes on relentlessly for ways to achieve ever more efficient performance from smaller units of less weight.

Qualified scientists, engineers and craftsmen are needed now. Write for information.

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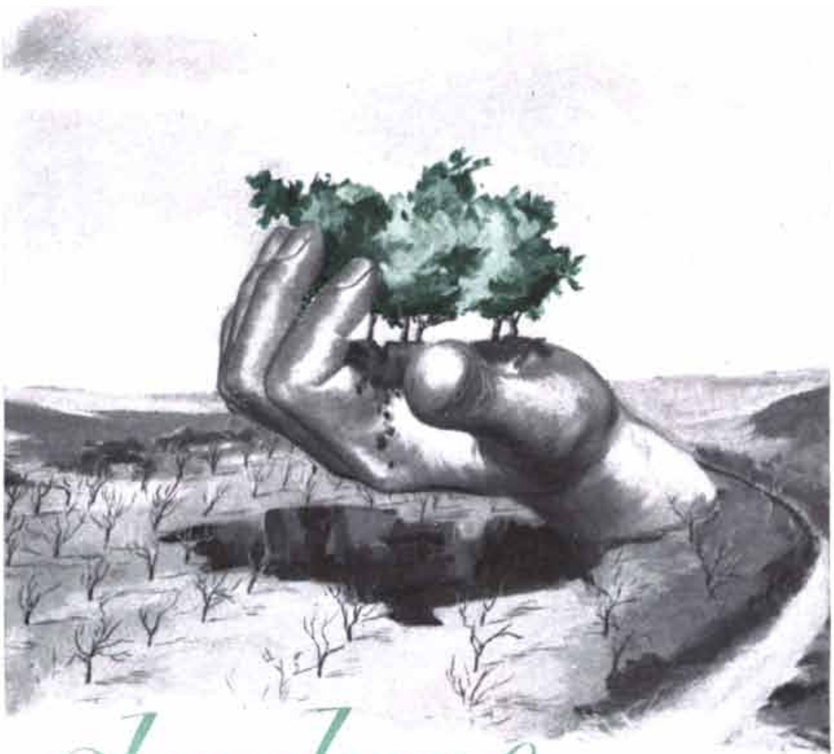

abundance

IS A PRODUCTIVE WORD

TIDE OF HUNGER

A great tide of world-wide hunger is rising over the earth. Stark figures show with chilling clarity that more than a billion people are already near starvation. With 70,000 new mouths to feed each day on 40,000 fewer acres of cultivated soil, it's easy to see why man is fast outrunning his own food supply. *Abundance* is now an urgent, desperate need.

SECRET OF THE SOIL

The secret of abundance lies hidden in the soil waiting to be discovered by small steady advances in agriculture. Sometimes science gives a large assist with a new concept in thinking. One of these is believed to be the new chemistry of chelation and the powerful Versene® chelating agents. Exciting experimental evidence backed by practical commercial use now proves that these chelated chemicals for agriculture can *return lost fertility* to the soil and give it new *growing power.*

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inhabited coast and islands of northwestern Mexico.

RICHARD M. BOZORTH ("Magnetic Materials") is a physicist who has been with the Bell Telephone Laboratories since 1923. Born in Salem, Ore., he went to Reed College and took a Ph.D. in chemistry at the California Institute of Technology. At the Bell laboratories he has applied himself to research on crystal structure and on the physical phenomena of ferromagnetism.

MARIANNA R. BOVARNICK ("Rickettsiae") is a biochemist who specializes in cell parasites. She lectures at the College of Medicine of the State University of New York and conducts her research at the Veterans Administration Hospital in Brooklyn. She took her B.A. at Vassar College and a Ph.D. in biochemistry at Columbia: She writes: "I had no particular intention of going into science before entering college. However, during my first year there I enjoyed chemistry so much that I decided to major in it and thereafter never wanted to stop." During World War II she worked on a project dealing with the metabolism of malarial parasites; later, at the Harvard School of Public Health, she worked with J. C. Snyder on the metabolism of rickettsiae.

MORRIS KLINE ("Projective Geometry") is professor of mathematics and director of electromagnetic research at the Institute of Mathematical Sciences at New York University. After several years in business in New York City, he went back to school at N.Y.U. and obtained a Ph.D. in mathematics in 1936. For the next two years he was research assistant on the staff of the Institute for Advanced Study at Princeton, N. J. During World War II he served as a radio engineer with the Signal Corps Engineering Laboratories. He holds several patents, one of which covers the basic features of the radio meteorological system used by the military services. Kline's recent book, *Mathematics in Western Culture*, was reviewed in the February, 1954, issue of SCIENTIFIC AMERICAN.

REUEL DENNEY, writer of the chief book review on *Communication and Persuasion* in this issue, teaches at the University of Chicago and is associated with the University's Graduate Committee on Communications. He is a graduate of Dartmouth College (1932) and a former member of the staff of the weekly *Time*. He has worked at Chicago with David Riesman and Mark Benney.

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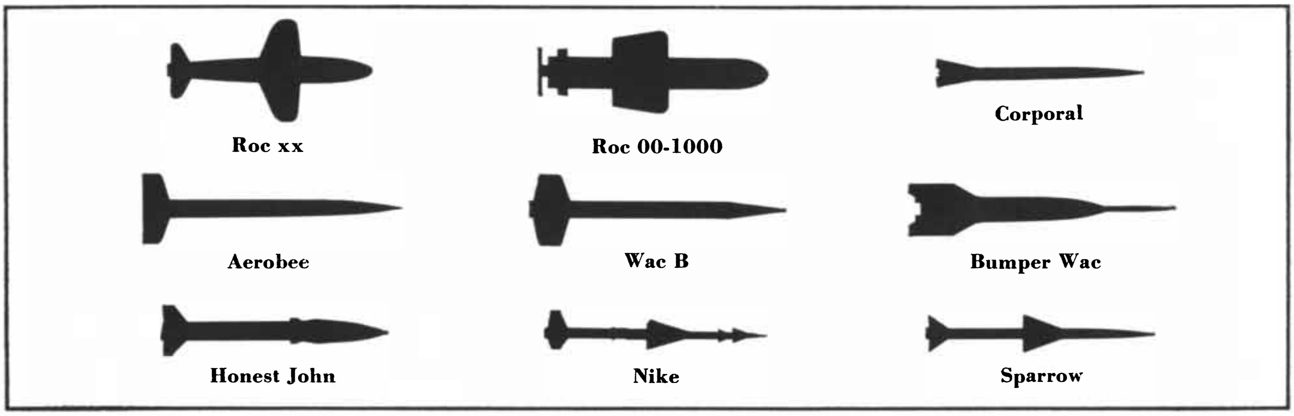

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A box score of 15 years continuous participation in designing and building guided missiles for the Air Force, Army and Navy

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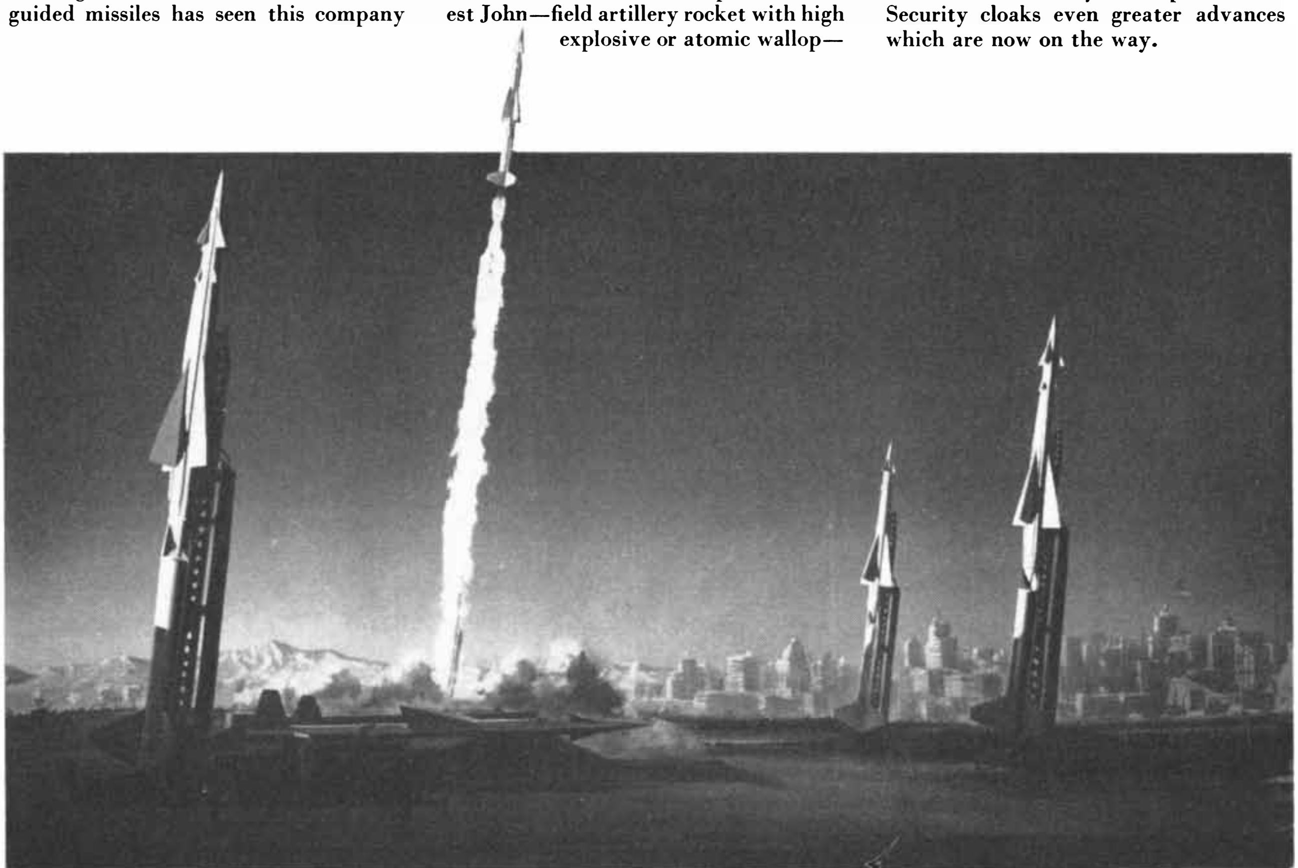
Douglas association with rockets and guided missiles has seen this company at work with other industrial leaders and our Armed Forces—to move missile development from a dream of push-button warfare to a solid reality. You saw it in the Bumper Wac research rocket, world altitude champion, in Honest John—field artillery rocket with high explosive or atomic wallop—in missiles of every type . . . air to air . . . air to ground . . . ground to ground . . . ground to air.

Douglas leadership in rocket airframe design has helped give us *operational* missiles in a relatively short span of time. Security cloaks even greater advances which are now on the way.



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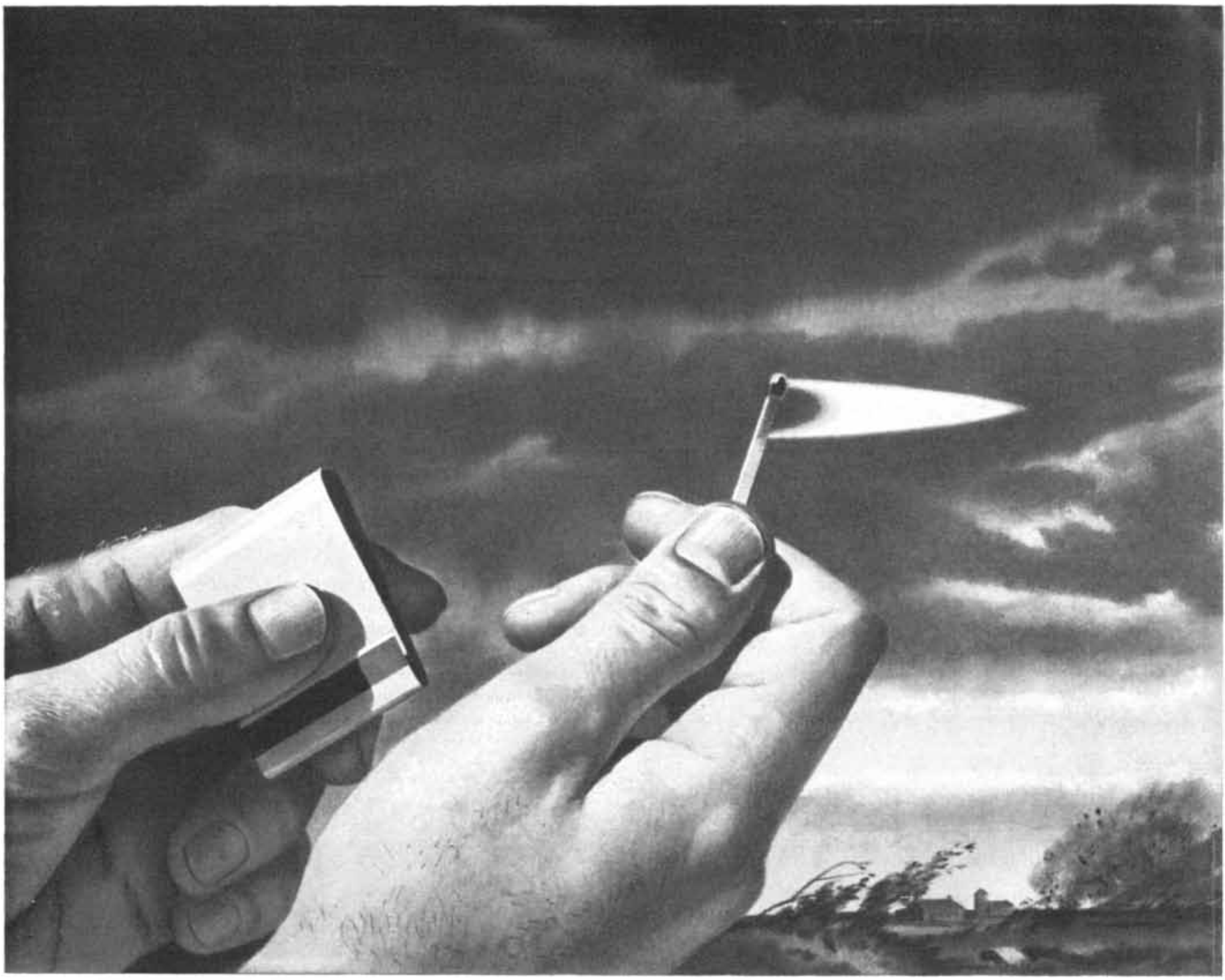

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Nation's Foremost Source

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Continual research and years of practical field operation have fitted us to anticipate and solve ignition problems; and that's why engine manufacturers, seeking advice, talk to Bendix-Scintilla people.

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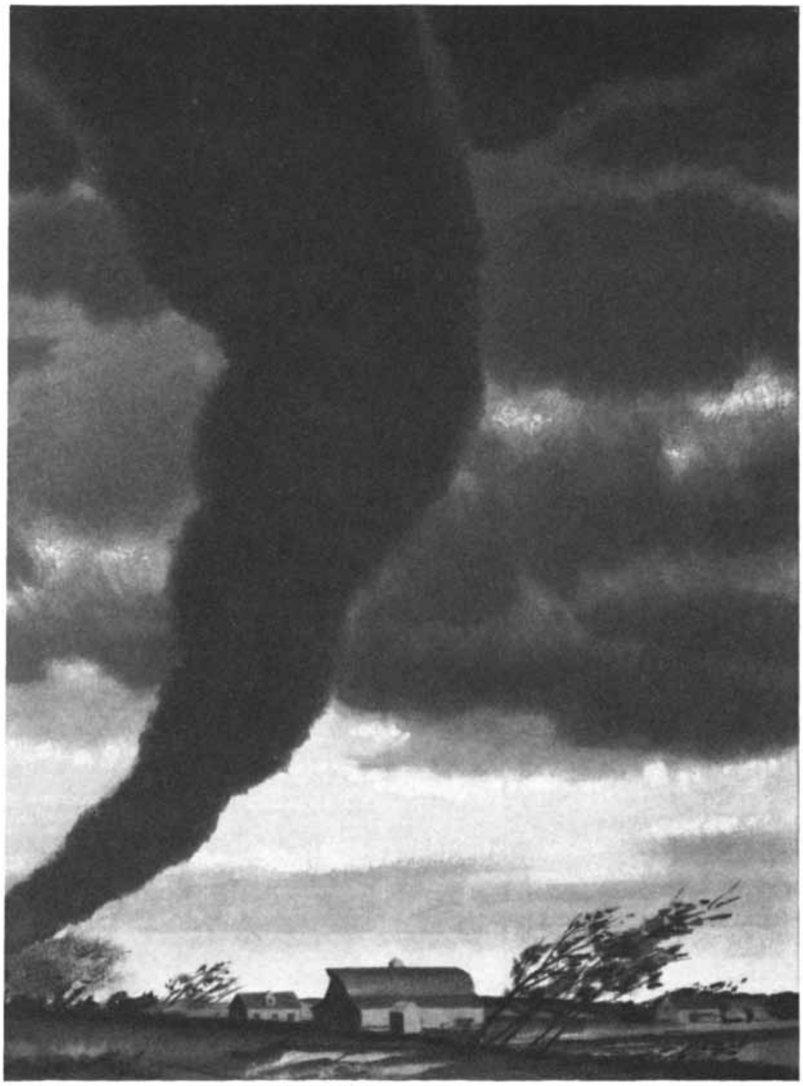

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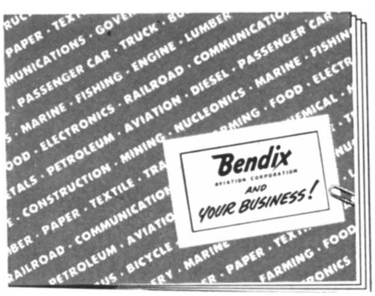

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THE COVER

The painting on the cover is a fanciful representation of the principles of projective geometry (*page 80*).

THE ILLUSTRATIONS

Cover painting by Walter Murch

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14	Paul Weller
25	Bernarda Bryson
26-28	Sara Love
29	Bernarda Bryson
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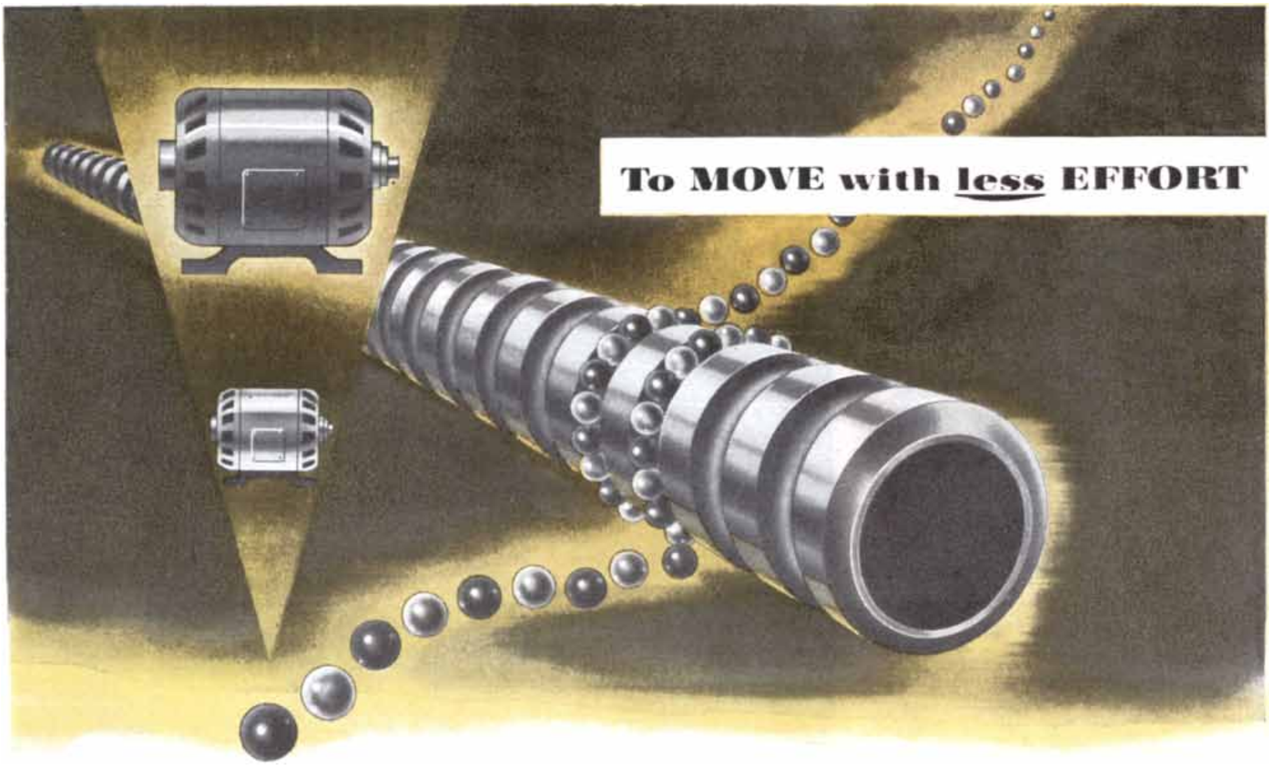

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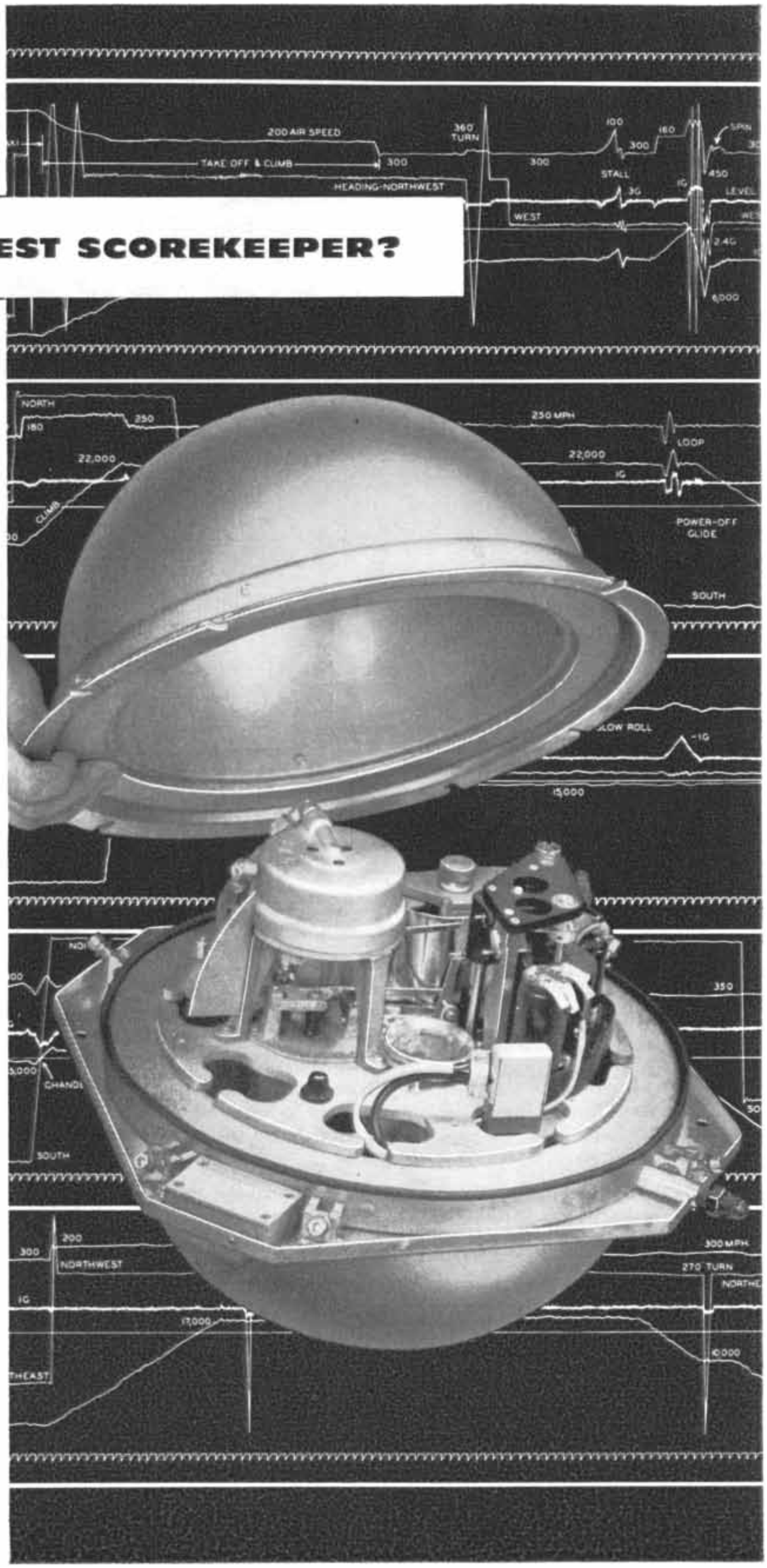

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ARTICLES

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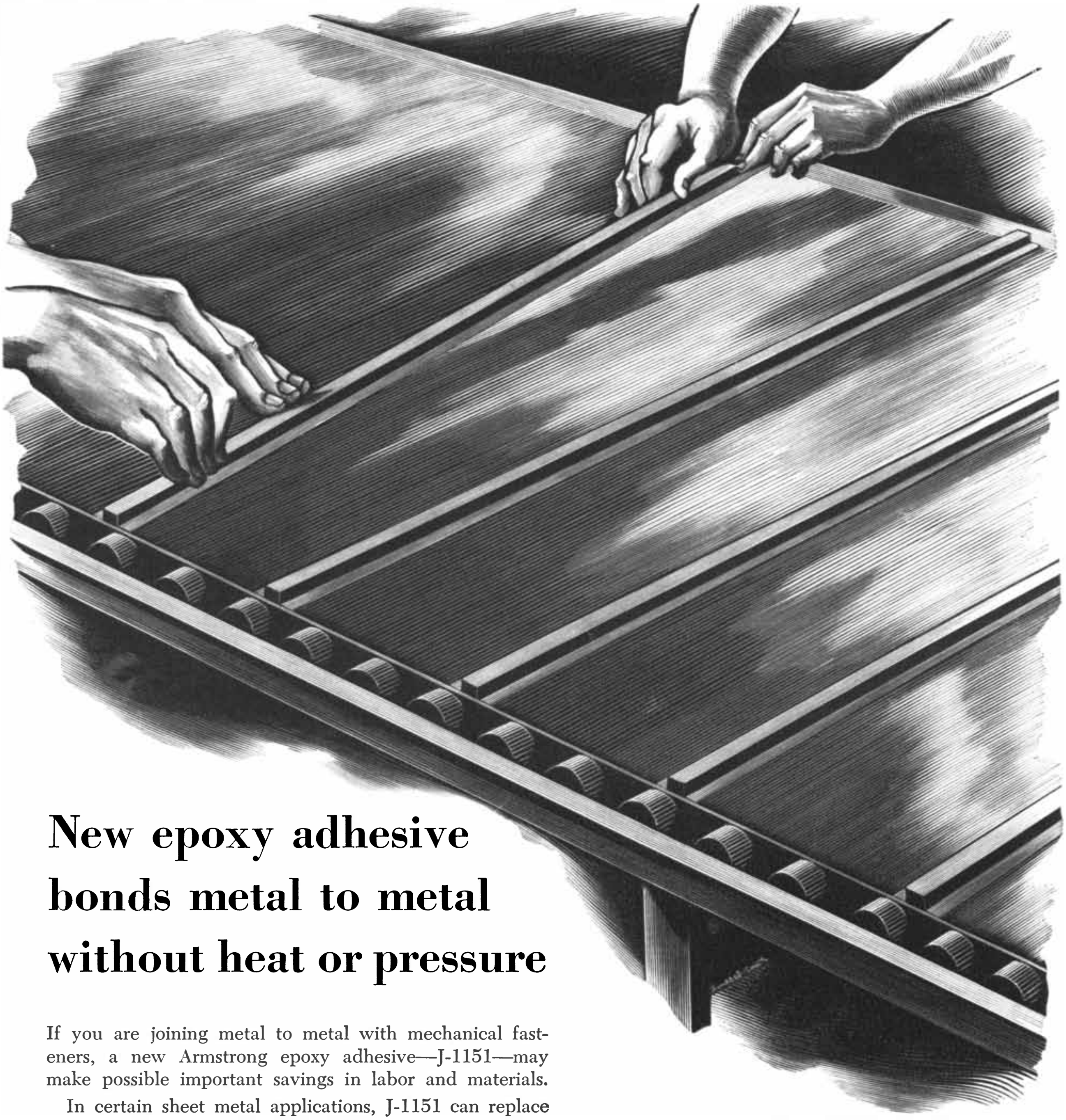

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Are Scientists Different?

The question is raised by the current friction between scientists and government officials. The answer is sought in the differences between scientists and nonscientists in a group studied since 1921

by Lewis M. Terman

Of the many reasons why we need to know more about scientists than we do, two are particularly important at this time. One is the current shortage of scientists, especially in the physical sciences and engineering. This shortage exists despite the rapid rise in the numbers trained in recent decades, and the ratio of supply to demand promises to become less rather than more favorable. To develop more fully the scientific resources of our population will require the identification of potential scientists at a reasonably early age, and this in turn calls for more specific information than we have about the "earmarks" of scientific talents.

The second reason we need more information about scientists is the tension that is building up between them and important segments of the general public. The scientist is looked upon by many as an object of suspicion, and he in turn is irked by the distrust he senses and by the restrictions government work imposes upon him.

Suspicion of scientists has a long history. In the Middle Ages their works were easily confused with black magic and sorcery. Later they came to be looked upon as enemies of the Church; some were tried and condemned for heresy. Even as recently as 75 years ago a scientist (especially a biologist) who proclaimed a new theory was likely to be met with angry vituperation. By 1900 scientists had won the freedom to explore and to publish in all but the most backward areas of the western world. They were free to work at problems of their own choosing and to discuss them freely with one another. Their research was inadequately supported, but they were beholden to no government.

The fission of the atom changed all that. Scientists suddenly found themselves strait-jacketed by security regulations which limited severely their contacts with fellow scientists, their freedom to publish, their right to work on specific problems, even their right to travel abroad. Although these limitations were often carried to unnecessary lengths, during the war the great majority of scientists patriotically acquiesced in them. It is hardly surprising that now, in the current climate of suspicion and fear, more and more of them are reluctant to work for a government which does not protect them from harassment and unjust accusations.

The scientist

It is not our purpose to apportion blame for the misunderstandings but rather to try to identify some of the human factors that contribute to them. If scientists are frequently misunderstood by nonscientists, the converse also is true, and information capable of throwing any light on the differing attitudes of the two groups ought to be welcomed.

For the double purpose, then, of trying to learn how to detect specific scientific talents and of understanding the differences between scientists and nonscientists, we undertook, with financing from the Office of Naval Research, a comparative study of the men in the well-known group of gifted persons whose careers we have followed for more than 30 years.

Our entire group consists of 800 males and 600 females who were selected in 1921 when they were students in the

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top 1 per cent of the school population in general intelligence, as measured by mental tests. The careers and development of all these persons have been followed almost continuously, through questionnaires mailed to them from time to time and by four detailed field studies (in 1921, 1927, 1939 and 1950). The group is the only one of its kind that has been studied so intensively over so long a period.

For the comparative study of scientists and nonscientists we confined ourselves to the 800 men, because only a few of the women have pursued scientific careers. We classified the men into seven groups:

Physical Science Research—workers in basic physical science or engineering research. This group of 51 includes 18 engineers, 17 chemists, 9 physicists and 7 in four other fields.

Engineers—practicing engineers and those who have done some applied research. The group totals 104.

Medical-Biological—workers in biological research or in medicine. Of the 61 members of this group, 26 are researchers and 35 practicing physicians.

Physical or Biological Science, Nonresearch—men who majored in a science as undergraduates but have mainly gone into other fields of work. Of the 68 in the group, 11 are science teachers.

Social Science—men who majored in a social science. Most of these persons are in business occupations. Those who became research social scientists, mostly psychologists, were omitted from our comparisons because they seemed not to belong with the business group and were too few in number (19) for statistical treatment as a separate group. The SS group totals 149.

Lawyers—a group totaling 83.

Humanities—men who majored in a field of the humanities in college. They have gone into a great variety of occupations, with teaching and business predominating. The group totals 95.

To uncover differences among these groups, information about the individuals under several hundred headings was analyzed by means of IBM cards and a sorting machine. The method used in assessing the differences for a given variable was the chi square technique. Of the many variables on which these groups were compared, 108 yielded significant differences. We shall consider here only those in three categories: (1) scientific interests evidenced, (2) interests in business occupations, (3) social traits and social adjustment.

Let us see first how the groups compare in scientific interests. For rough purposes of comparison we can class as scientists the workers in physical sciences, the engineers, the workers in biology and medicine and the men who majored in science in college; the nonscientists include the lawyers, the majors in the humanities and the majors in social science. The reader should bear in

	Variable tested	Physical Sciences (Research)		Engineering		Medical-Biological Sciences		Physical-Biological Sciences (Non-Research)		Social Sciences		Law		Humanities		Total	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
1922	A science named as suitable occupation for the child by the parent	27	59	49	59	25	40	24	58	50	14	40	10	46	20	261	34
1922	A science named as suitable occupation for the child by the teacher	12	67	39	49	16	56	21	43	43	23	36	14	32	25	199	34
1922	Child named a science as his occupational preference	34	74	76	62	45	58	46	52	109	31	67	21	64	28	441	43
1922	Child named engineering as his occupational preference	34	38	76	58	45	20	46	33	109	13	67	9	64	14	441	25
1922	High on mechanical ingenuity: composite of parent and teacher ratings	45	47	94	63	50	34	64	52	137	28	77	31	82	33	549	40
1940	Interest in science above average on self-rating	45	98	89	88	53	96	58	86	130	36	73	32	83	49	531	63
1940	Interest in mechanics above average on self-rating	45	64	89	82	53	34	58	60	130	24	73	21	83	30	531	43
1940	Score of B+ or better for chemist on vocational interest test	44	98	82	83	44	73	55	64	116	25	61	28	78	41	480	53
1940	Score of B or better for engineering on vocational interest test	44	95	82	87	44	64	55	75	116	32	61	31	78	33	480	55
1940	Score of B or better for math-science teacher on vocational interest test	44	77	82	78	44	66	55	64	116	40	61	41	78	46	480	56
1940	Score of B or better for physician on vocational interest test	44	75	82	49	44	86	55	62	116	24	61	38	78	62	480	51

SCIENTIFIC INTERESTS of men in the group studied by Terman are correlated with their present occupations (*upper right*). Engineering is combined with the other sciences in the first three items of the table and is also treated separately as the fourth item.

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mind that the three categories based on majors in college (in science, social science or humanities) are heterogeneous groups embracing a wide variety of occupations in each case.

Eleven items of information relating to scientific interests or ability yielded highly reliable differences between scientists and nonscientists. The first five of these items represent the early interests and talents of the subjects as youngsters; the information was obtained in 1922, when the average age of the subjects was close to 11 years. The remaining six items report their interests 18 years later in 1940, when they were grown men and launched on their careers. The ratings of the groups on these 11 items, in terms of the percentage of persons who exhibited interest or talent on each variable, are summarized in the table on the opposite page.

Even as children those who later fell in the four science groups showed a far higher tendency to aptitude in science than those in the three nonscience groups. This is in accord with studies of the early mental development of eminent scientists, which have shown that often their bent is foreshadowed by their interests and preoccupations in childhood. Apparently the same is true of scientists whose achievement to mid-life is much less distinguished. It is especially significant that aptitude for science is so often detected by parents and teachers with little or no professional training in psychology, and even more often by the children themselves.

It might be supposed that the interests of our subjects in 1940, when their average age was about 30, would not reflect natural bents so much as the effects of educational concentration and vocational experience. That such experience is far from being the sole factor in shaping interest patterns is indicated by the fact that the intergroup differences in 1940 were in most cases very similar to those in 1922. Indeed, scores on the Strong vocational interest test are surprisingly constant. Of 250 men who took the Strong test as college freshmen and again 20 years later, few showed appreciable changes in their scores, and such changes as occurred bore little relation to the kind or amount of educational or vocational experience in the interim.

It can be seen in the table that the groups with the most consistently low percentages on scientific interests are the social science majors (mainly businessmen) and the lawyers. The humanities group is fairly high on one item but is relatively low on all the others. At the opposite extreme are the physical scientists, engineers and science majors, who are high to very high on at least 10 of the 11 items. The contrast between the four groups of scientists and the three groups of nonscientists in this gifted population is much the same for the childhood data as for the data obtained nearly 18 years later.

When we come to interest in business

VARIABLE TESTED	PHYSICAL SCIENCES (RESEARCH)		ENGINEERING		MEDICAL-BIOLOGICAL SCIENCES		PHYSICAL-BIOLOGICAL SCIENCES (NON-RESEARCH)		SOCIAL SCIENCES		LAW		HUMANITIES		TOTAL	
	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT
SCORE OF C+ OR BETTER FOR BANKER	44	25	82	29	44	23	55	42	116	67	61	59	78	35	480	44
SCORE OF B− OR BETTER FOR PURCHASING AGENT	44	36	82	57	44	20	55	44	116	67	61	44	78	24	480	46
SCORE OF B− OR BETTER FOR CERTIFIED PUBLIC ACCOUNTANT	44	70	82	44	44	48	55	47	116	71	61	80	78	50	480	59
SCORE OF B− OR BETTER FOR ACCOUNTANT	44	43	82	54	44	25	55	47	116	61	61	46	78	27	480	46
SCORE OF B− OR BETTER FOR OFFICE WORKER	44	30	82	49	44	39	55	49	116	74	61	46	78	37	480	50
SCORE OF B OR BETTER FOR PRODUCTION MANAGER	44	68	82	91	44	55	55	71	116	51	61	30	78	26	480	55
SCORE OF C+ OR BETTER FOR SALES MANAGER	44	27	82	48	44	32	55	51	116	84	61	70	78	53	480	57
SCORE OF C+ OR BETTER FOR LIFE INSURANCE SALESMAN	44	16	82	22	44	36	55	35	116	75	61	62	78	54	480	47
SCORE OF B OR BETTER FOR LAWYER	44	36	82	18	44	48	55	40	116	65	61	89	78	72	480	54

OCCUPATIONAL INTERESTS in business of men in the same group were graded in 1940 by the Strong vocational interest test. This further indicates that the differences between the groups of scientists and nonscientists changed very little from 1922 to 1940.

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occupations, the picture is reversed, as we might expect [*see table on preceding page*]. The nonscientist groups score highest on interest in the nine business occupations listed (the law is included among them because so much legal work is concerned with or similar to business). In contrast, the three groups of workers in science score low to very low on interest in business, and the science majors hold an intermediate position; it will be recalled that most of the latter went into fields other than science. In the exceptional cases where a science group showed high interest in a business occupation, the reason is fairly obvious. For example, the occupation of certified public accountant would be expected to have some appeal to a physical scientist, who has an interest in numbers. Similarly the interest of engineers in the jobs of purchasing agent and production manager reflects their preoccupation with "things," while their low score on interest in the occupation of life insurance salesman probably reflects ineffectiveness in person-to-person relationships.

The marked contrast between the groups of scientific workers on the one hand and the lawyer and social science majors on the other is most significant. For it is physical scientists, engineers and biologists who do most of the Federal Government's secret research, and do it under rules that are laid down by a Congress composed mainly of lawyers and businessmen. It would be an oversimplification, however, to assume that the difficulties of these contrasting groups in trying to understand each other are fully explained by their differing interests *per se*. Rather the differences in interest are symptomatic of underlying differences in personality.

This brings us to the group differences in social traits. They were expressed in terms of 15 items relating to sociabil-

VARIABLE TESTED	PHYSICAL SCIENCES (RESEARCH)		ENGINEERING		MEDICAL-BIOLOGICAL SCIENCES		PHYSICAL-BIOLOGICAL SCIENCES (NON-RESEARCH)		SOCIAL SCIENCES		LAW		HUMANITIES		TOTAL	
	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT
HIGH COMPOSITE RATING BY PARENT AND TEACHER ON FIVE SOCIAL TRAITS—1922	45	46	96	44	50	62	64	44	138	59	78	67	83	49	554	53
HIGH SOCIABILITY SCORE ON PLAYS AND GAMES TEST—1922	17	53	43	56	25	76	26	81	78	74	45	84	41	71	275	72
IN HIGH SCHOOL ENGAGED IN SEVERAL TO MANY ACTIVITIES	43	47	91	43	58	53	61	52	134	60	80	67	83	69	550	57
MORE THAN AVERAGE INTEREST IN SOCIAL LIFE—1940	45	24	89	12	53	40	58	31	130	38	73	33	83	23	531	29
MORE THAN AVERAGE INTEREST IN POLITICS—1940	45	42	89	39	53	43	58	47	130	57	73	66	83	43	531	49
ALWAYS VOTED IN LOCAL ELECTIONS—1950	45	24	95	52	56	46	60	44	132	52	74	59	82	54	544	50
SCORE OF C+ OR BETTER FOR SCHOOL SUPERINTENDENT ON VOCATIONAL INTEREST TEST—1940	44	52	82	27	44	43	55	44	116	53	61	74	78	68	480	52
SCORE OF B− OR BETTER FOR SOCIAL SCIENCE TEACHER ON VOCATIONAL INTEREST TEST—1940	44	30	82	23	44	45	55	33	116	65	61	61	78	54	480	47
BELONGS TO TWO OR MORE CLUBS OR ORGANIZATIONS—1950	44	77	93	59	56	89	59	68	126	62	74	88	77	66	529	71
ENGAGES IN ONE OR MORE SERVICE ACTIVITIES—1950	44	23	93	41	56	46	59	49	126	48	74	58	77	42	529	45
MORE THAN MODERATE INTEREST IN COMPETITIVE SPORTS, AGES 12-20—1951	37	27	79	44	46	30	45	42	111	60	64	55	65	38	447	46
ABOVE AVERAGE IN CONFORMITY TO AUTHORITY AND CONVENTIONS—1951	36	47	75	41	45	47	42	55	109	49	62	74	63	52	432	52
MORE THAN MODERATE INTEREST IN SOCIAL SUCCESS, AGE 12-20—1951	37	14	78	28	46	37	45	27	109	52	64	33	65	37	544	36
IN CHILDHOOD AND YOUTH FELT DIFFERENT FROM OTHERS—1951	37	68	82	52	49	67	50	56	116	46	66	52	69	77	467	57
GOOD SOCIAL ADJUSTMENT HAS FURTHERED LIFE ACCOMPLISHMENT—1951	37	27	78	47	46	46	44	45	108	58	62	47	62	56	437	49

SOCIAL TRAITS of the various groups are reflected by items of information gathered by the studies of 1921-22, 1939-40 and 1950-51. The subjects were 800 men who were selected in 1921 from the top 1 per cent of the school population in general intelligence.

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The nonscientist?

ity, social adjustment, interest in people and social insight [*see table on opposite page*]. The sociability score was derived from the subjects' preferences, as children, between social play and less social or solitary activities. Some items in the table are based on self-ratings; interest in people was measured by the subjects' reactions to two occupations calling for such interest. On the next to last item of the table a high score signifies a tendency to poorer social adjustment.

The analysis leaves no doubt that nonscientists tend to score higher than scientists in social relations. The lawyers and social science majors usually rated highest; the physical science researchers, engineers and science majors generally rated lowest; and the medical-biological group and humanities majors were in between. The groups showed a consistency of scores which is remarkable when one considers the wide range of attributes, indexes and times represented by the 15 items.

Nevertheless one must guard against overgeneralization. Actually all degrees of social adjustment and social understanding are found within each of the seven groups. Everyone knows that some scientists are extremely adept in social perception and in social relations—sufficiently adept to become deans, college presidents or other administrative officials. Yet it is true that the bulk of scientific research is carried on by devotees of science for whom research is their life and social relations are comparatively unimportant.

The life histories of the physical scientists and engineers among our gifted subjects bear interesting similarities to those of the 22 eminent physicists examined by Anne Roe [see "A Psychologist Examines 64 Eminent Scientists," by Anne Roe; SCIENTIFIC AMERICAN, November, 1952]. Her physicists and our two groups exhibited the same early interest in mechanics, mathematics and science. The resemblance also holds for social traits: as a group her physicists tended to be shy, lonely, slow in social development, indifferent to close personal relationships, group activities or politics. There are also some resemblances between Roe's 20 eminent biologists and our medical-biological group: most of these individuals showed little interest in mechanics or mathematics, either in childhood or later. However, our physicians and biologists displayed more social interests than our physicists, chemists and engineers, whereas Roe described her biologists as socially very similar to her physicists. Her 22 professional social scientists are not comparable with the businessmen of our SS (social science major) group.

Are the social traits that characterize so many scientists to be regarded as defects of personality bordering on the abnormal? The answer is no. Mental or emotional breakdowns were no more common among scientists than among nonscientists in our gifted sample of the population. It appears that departures from the average personality pattern, upward or downward, may be decidedly favorable to the making of a scientist; for example, a below-average interest in social relations and a heavy concentration of interest on the objective world.

At any rate, in our gifted group the physical scientists and engineers are at the opposite pole from the businessmen and lawyers in abilities, in occupational interests and in social behavior. These basic personality differences may well account for much of the current friction between scientists and the government officials who are responsible for their security clearances and for the restrictions imposed upon them.

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THE ANATOMY OF THE ATLANTIC

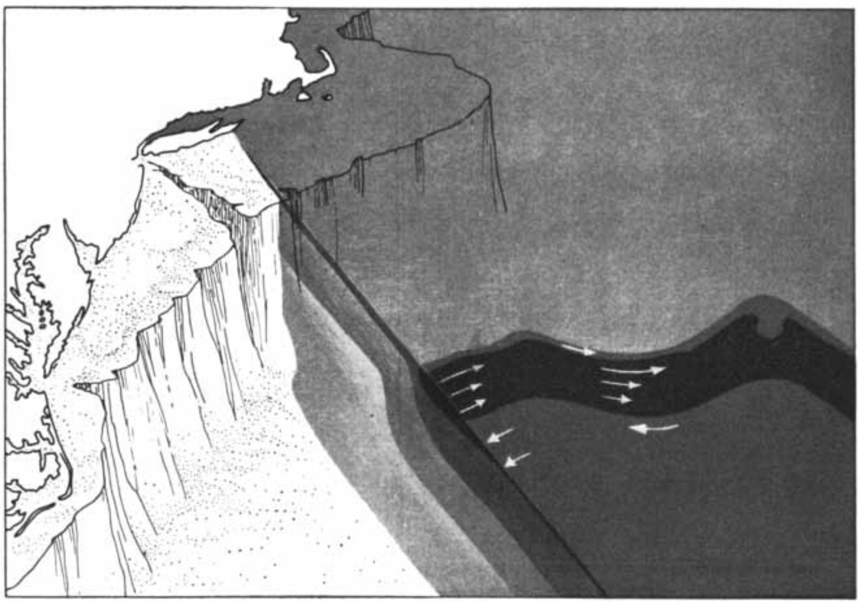
This vast body of water has an architecture not only of currents but also of temperature, saltiness and oxygen content. The details have emerged from the oceanographic voyages of the past 30 years

by Henry Stommel

Although the steamship has reduced the ocean currents to minor significance in navigation, they are still a matter of great interest to oceanographers. We want to know what forces and physical processes are responsible for the currents and where they run. Besides satisfying our curiosity, this information may some day become highly useful again, especially if the atomic power industry of the future dumps its radioactive wastes in the seas.

The best place to study the currents is in the Atlantic Ocean, because in the 1920s and 1930s its currents were extensively surveyed by the German research vessel *Meteor,* the British *Discovery,* the Norwegian *Armauer Hansen* and the U. S. *Atlantis.* In examining the dynamics of ocean currents we start from the fact that they are governed mainly by the Coriolis force set up by the rotation of the earth ["The Coriolis Effect," by James E. McDonald; SCIENTIFIC AMERICAN, May, 1952]. In a river or similarly shallow body of water the slope of the bed and friction over the bottom dominate the dynamics of flow. In the deep sea, however, the driving forces and frictional forces are so small that the Coriolis force becomes dominant. Here the situation is like that in the atmosphere, where winds blow in a circular fashion rather than directly from regions of high pressure to regions of low pressure. In the ocean horizontal pressure gradients associated with slopes of the water keep the currents in straighter paths.

Because of the Coriolis force, the oceans are far from level. In the Northern Hemisphere, where the Coriolis force acts to the right of the direction of the current, the surface of the ocean also slopes upward to the right; the average sea level is about four feet higher in the middle of the Atlantic than along the U. S. coast [*see chart on opposite page*]. The Gulf Stream on its eastward side slopes up steeply toward Bermuda. In the Southern Hemisphere, where the Coriolis action is toward the left, the great Antarctic circumpolar current of the South Atlantic slopes upward toward the west. Near the Equator, where the Coriolis force is small, the sea slopes only gently. Here the two trade-wind systems maintain two westward flowing equatorial currents, separated by a curious equatorial countercurrent flowing in the opposite direction along the northern boundary of the doldrums.



THE GULF STREAM flows in a wavy path, the waves proceeding downstream at five to 10 miles per day. The temperatures in late autumn are indicated by tones from dark to light gray, corresponding to the range from 84 to 50 degrees Fahrenheit at the extremes.

One of the most striking features of the ocean is the great fall in temperature from the top to the bottom [*see charts on page 33*]. Except in the polar regions, where the water is cold all the way up to the top, the oceans are stratified by zones of sharply contrasting temperatures. In the middle North Atlantic, for example, the top 1,500 feet averages at least 65 degrees Fahrenheit, winter or summer. From 1,500 feet down to about 4,000 feet the temperature declines rapidly to a frigidity in which one would not care to swim.

This "thermocline" is one of the mysteries of the sea. Why should there be so abrupt a change of temperature with depth? Why isn't it gradual? The really deep water, between 4,000 feet and the bottom at 18,000 feet, is close to freezing, even in the tropics. This must mean that most of the water in the oceans flows down from regions near the poles. How-

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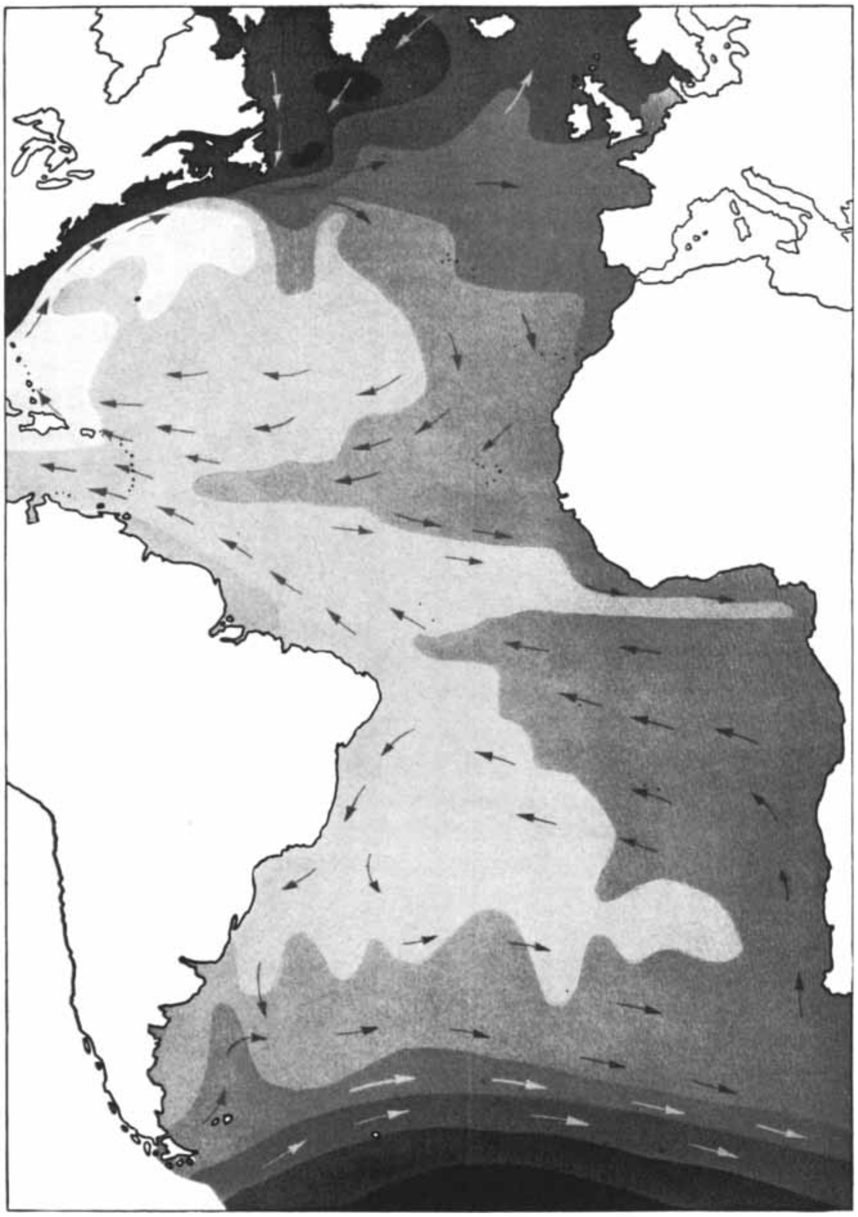
ever, there are no strong currents in the deeper regions of the ocean. The great wind-driven currents are confined to the upper quarter of its depth.

One of the striking features of these surface circulations is that the center of circulation is not in the ocean's middle but toward the western side, with the result that the current is stronger on the western side. The explanation of this asymmetry has emerged in recent years. In the Northern Hemisphere the pattern of prevailing winds gives a clockwise twist to the Atlantic surface circulation. For many years it was supposed that the balancing force that kept this rotation in equilibrium was simply the resistance of internal friction in the water. But in 1947 the Norwegian oceanographer Harald Sverdrup showed that the balance is actually supplied by a slow drift of surface water toward the Equator which applies a counterclockwise force (in the Northern Hemisphere) opposing the wind torque. The question arose: What happens to the water piling up on the Equator from both hemispheres? The writer and Walter Munk of the Scripps Institution of Oceanography pointed out that swift, narrow currents along the western boundaries of the oceans would carry the water back toward the poles at a rate which matched the equatorward flow. These strong western currents are of course the Gulf Stream in the North Atlantic and the Brazil Current in the South Atlantic They flow at velocities of up to five miles per hour. The Gulf Stream, about 50 miles wide and 1,500 feet deep, carries away about 70 million tons of water per second—about 1,000 times as much as the maximum discharge of the Mississippi River. Other currents are much slower than the Gulf Stream and Brazil Current; for example, the equatorial currents rarely move faster than a third of a mile per hour. A particle of water may move 100 miles per day while it is in the swift portions of the Gulf Stream, but it could easily take a year to make a complete circuit of the North Atlantic.

The condition of the Gulf Stream in late autumn is diagrammed on the opposite page. A narrow strip of warm water (77 to 84 degrees F.) about 50 miles wide and 300 feet deep runs through the heart of the Stream, with the fastest current along the left-hand side of this strip. Beneath it are two layers of cooler water—68 to 77 degrees and 50 to 68 degrees respectively. The water in the colder layers below 3,000 feet is practically at rest, taking little or no part in the general flow of the Gulf Stream.



UNEVEN SURFACE OF THE SEA is represented by this diagram. The tones from dark to light gray indicate the elevation of the water above the theoretical sea level (assuming the sea was homogeneous and stagnant). Each tone corresponds to a difference of 10 inches.

The surface water on the inshore side of the Gulf Stream is, on the average, much denser than that on the offshore side. The Gulf Stream is not so much a stream of warm water as it is a current along the edge of the warm body of water making up the surface of the Central Atlantic. The Coriolis force driving the Gulf Stream to the right keeps the warm water away from the North American coast.

As the diagram shows, the Gulf Stream flows in a meander-like path. The shape of these meanders changes from time to time, the wavelike patterns generally progressing downstream at a rate of about 5 to 10 miles a day.

Surface currents can be measured by the drift of a ship, by a propeller-type current meter on a stationary ship or by electrical voltages induced in the water by its motion through the earth's magnetic field. But water movements in the ocean depths cannot be measured so easily. We can only estimate them indirectly from pressure fields in the water and from temperature and salinity.

The German oceanographers Albert Defant and Georg Wuest have analyzed

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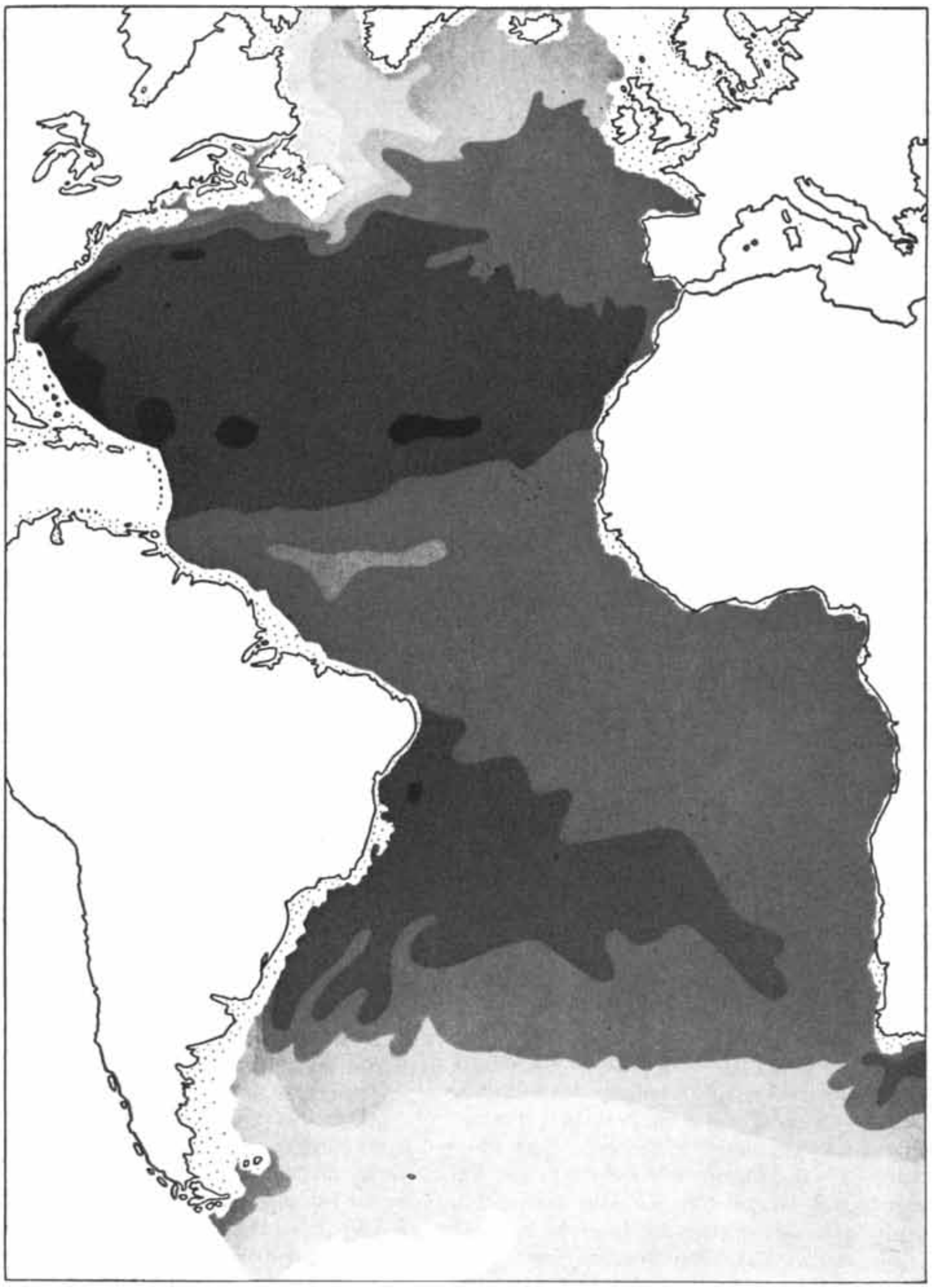
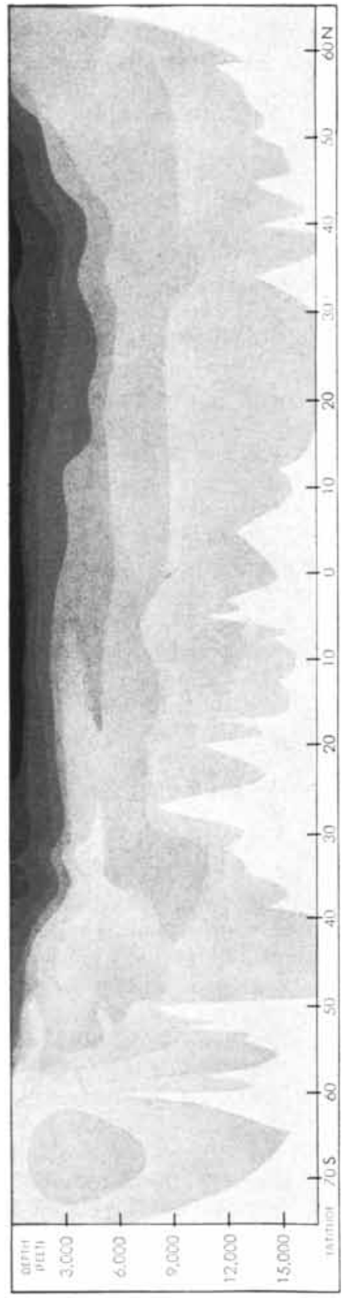
deep-water movements in this way. In the Atlantic Ocean the saltiest water, of course, is at the surface, where fresh water is evaporated away. The deep water is about .5 to 1 per cent fresher [*see chart below*]. The very freshest water in the Atlantic originates at the surface in the Antarctic between Cape Horn and the Cape of Good Hope. From there it flows northward beneath the surface currents, sinking to depths between 1,500 and 3,000 feet. It moves as a subsurface stream along the western border of the South Atlantic, crosses the Equator and dissipates in the North Atlantic at about 20 degrees north latitude. Wuest has computed that in its strongest stretch, off the coast of Brazil, this subsurface stream moves at rates up to five miles per day.

Below this level is a mass of very salty water, called the Upper Deep Water [*chart at right below*]. Its source appears to be the Mediterranean, where the surface water is made extremely saline by a high rate of evaporation. The salty water flows out of the Straits of Gibraltar, sinks quickly to a depth of 6,000 feet and then spreads out over the Atlantic. Inasmuch as the amount of saline water flowing out of the Straits of Gibraltar can be measured easily, this phenomenon is a useful indicator of the speed of deep-water circulation.

Movements of deeper Atlantic water at the levels between 9,000 and 13,000



SALINITY AT 600 FEET is indicated by this diagram. The tones from dark to light gray correspond to the variation from approximately 3.70 per cent to 3.40 per cent of salt. The freshest surface water (between 3.45 to 3.40 per cent) circulates north from the region between Cape Horn and the Cape of Good Hope. It sinks to depths of 3,000 feet.



SALINITY IN DEPTH through the Western Atlantic varies as subsurface streams. Each tone indicates .05 per cent above 3.45.

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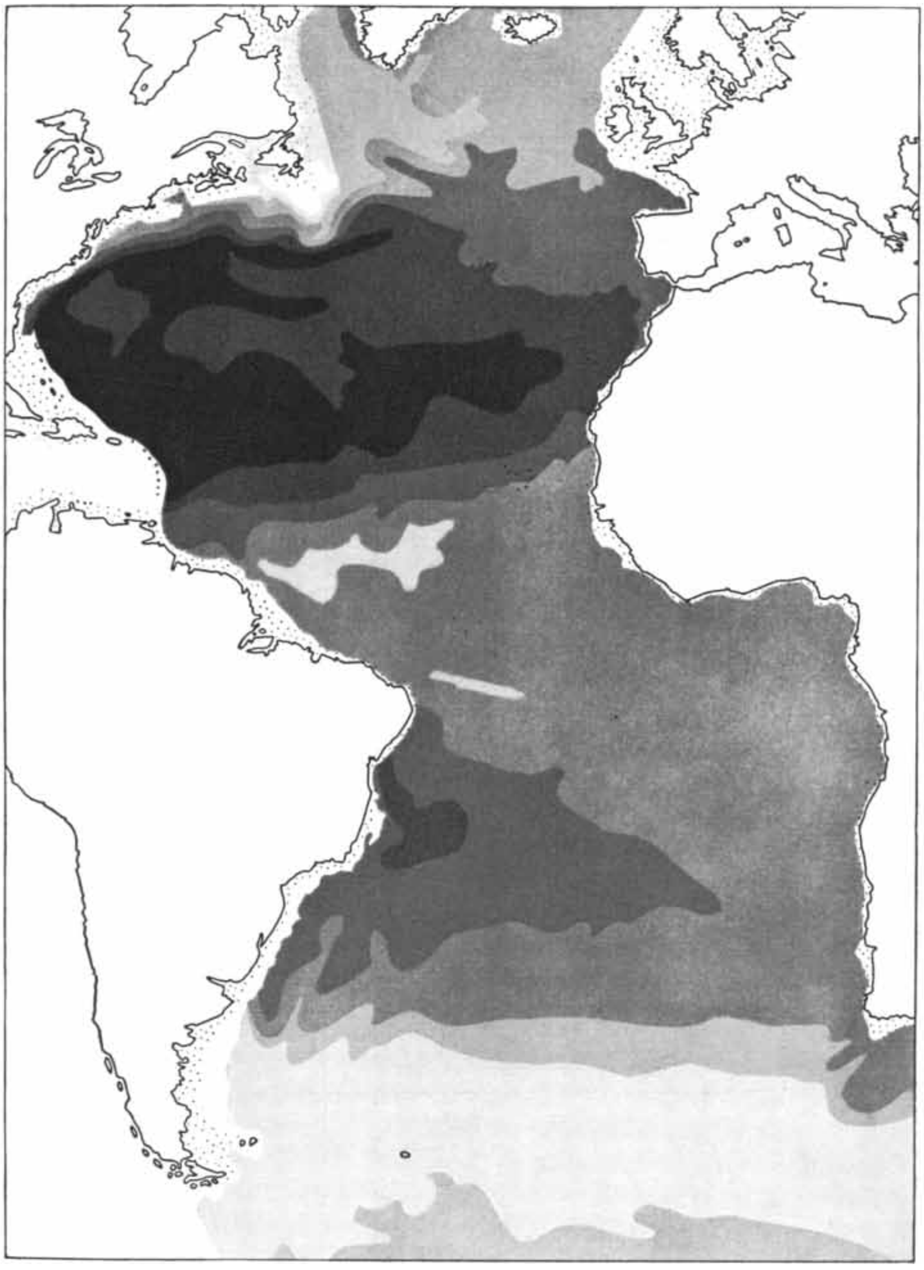
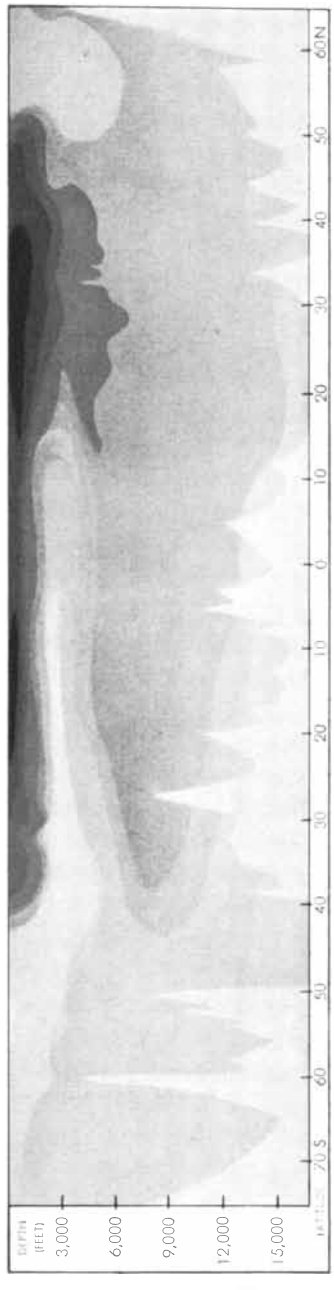
feet can be traced by the fact that it is particularly deficient in dissolved oxygen. This water originates in the late fall and winter east and southeast of Greenland [*chart on next page*]. It sinks halfway down in the ocean and spreads out to the south. Its strongest currents are in the western Atlantic. As the water flows toward the south, it gradually gives up some of its dissolved oxygen to oxidation of dead plankton and other material raining from above. Samples of water taken from its depth therefore show the location of the water mass and its direction of motion.

From the Antarctic comes the deepest water mass of all. It forms on the shelf of the Antarctic continent and slides northward over the ocean bottom [*chart on page 35*]. Its movement of course is channeled by the great mountain ranges in the Atlantic (whose peaks form the Azores, Ascension, Tristan da Cunha and other islands). Thus the Antarctic bottom water cannot flow up along the coast of Africa but is confined to the western half of the South Atlantic until it passes the Equator. Then it crosses to the African coast through a narrow pass. In the North Atlantic it mixes with water in the layer above it and disappears as a current.

All of these currents are too weak to measure by any kind of current meter; they are masked anyway by fair-



TEMPERATURE AT 600 FEET is represented here. If the ocean were lowered by this amount, the continental shelves off many shores would be high and dry. The darkest gray tone represents water warmer than 68 degrees F. The lightest tone represents water colder than 32 degrees. Each intermediate tone corresponds to a difference of nine degrees.



TEMPERATURE IN DEPTH varies in stratified zones, except in polar regions. This profile was taken along the Western Atlantic.

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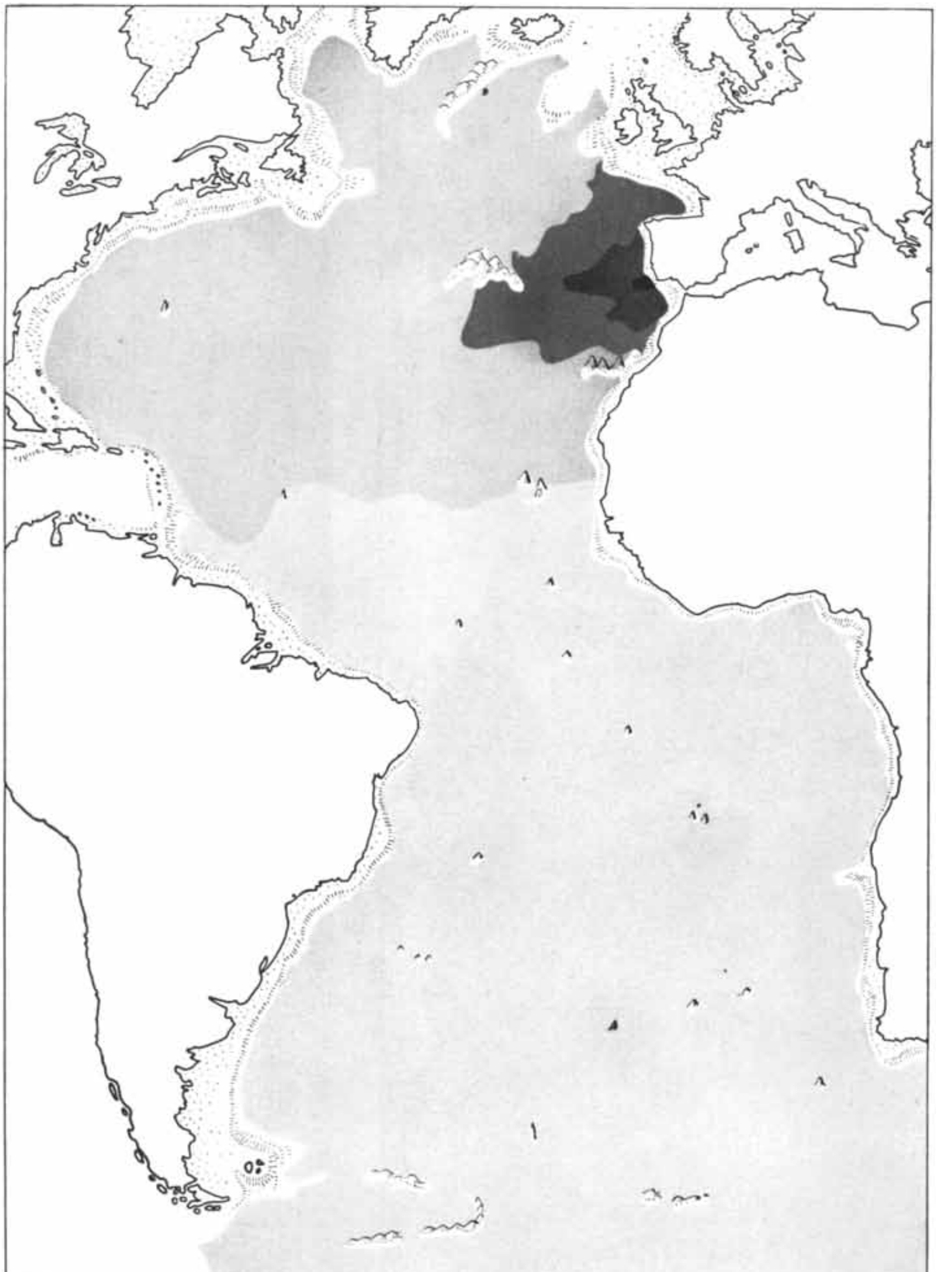
ly strong oscillatory tidal movements. Perhaps some day the currents may be followed by means of a ballasted float which will be set at a deep level and tracked by sonar.

Another way of studying the circulation of deep ocean water is to determine by the carbon-14 dating method how long it has been out of contact with the atmosphere. The few such measurements made so far indicate that the bottom water is about 1,500 years old, but Wuest has calculated by other methods that it is no older than about 300 years.

Wuest's estimates of the velocity of deep-water circulations are based upon the assumption that the layers of water are being formed continuously at the postulated places of origin near the surface and flow steadily along the suggested routes. However, L. V. Worthington of the Woods Hole Oceanographic Institution has recently turned up some evidence that this may not be the case. He found that the amount of dissolved oxygen in deep North Atlantic water seems to have decreased appreciably in the past 30 years. This may mean that the water has lain more or less dormant there. Worthington estimates from the rate of oxygen loss that this water was near the surface about 140 years ago—a time of cold winters and summers (as Napoleon's ill-fated winter in Russia testifies). Thus it is possible to suppose that masses of water tending to sink to



SALINITY AT 6,000 FEET in the mass called the Upper Deep Water is indicated in a chart showing the water above this level stripped away. The darkest tone, corresponding to 3.6 per cent salt, shows the outflow from the extremely salty water of the Mediterranean which sinks quickly to this depth and diminishes to a salinity of 3.47 per cent, as shown by the lightest tone.

OXYGEN AT 9,000 FEET in the mass called the Deep Water is represented in this chart. Oxygen content at this level, from the maximum

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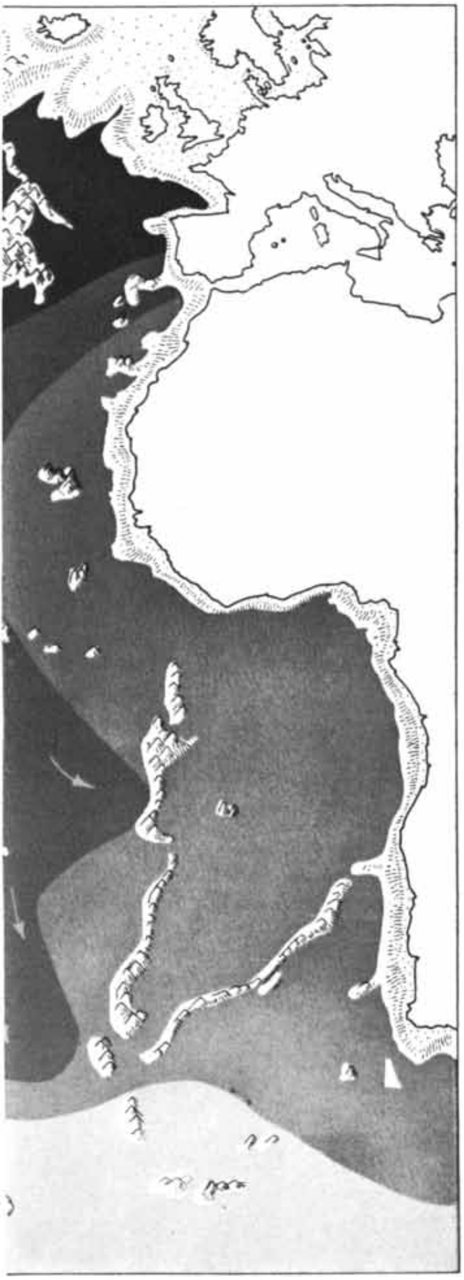
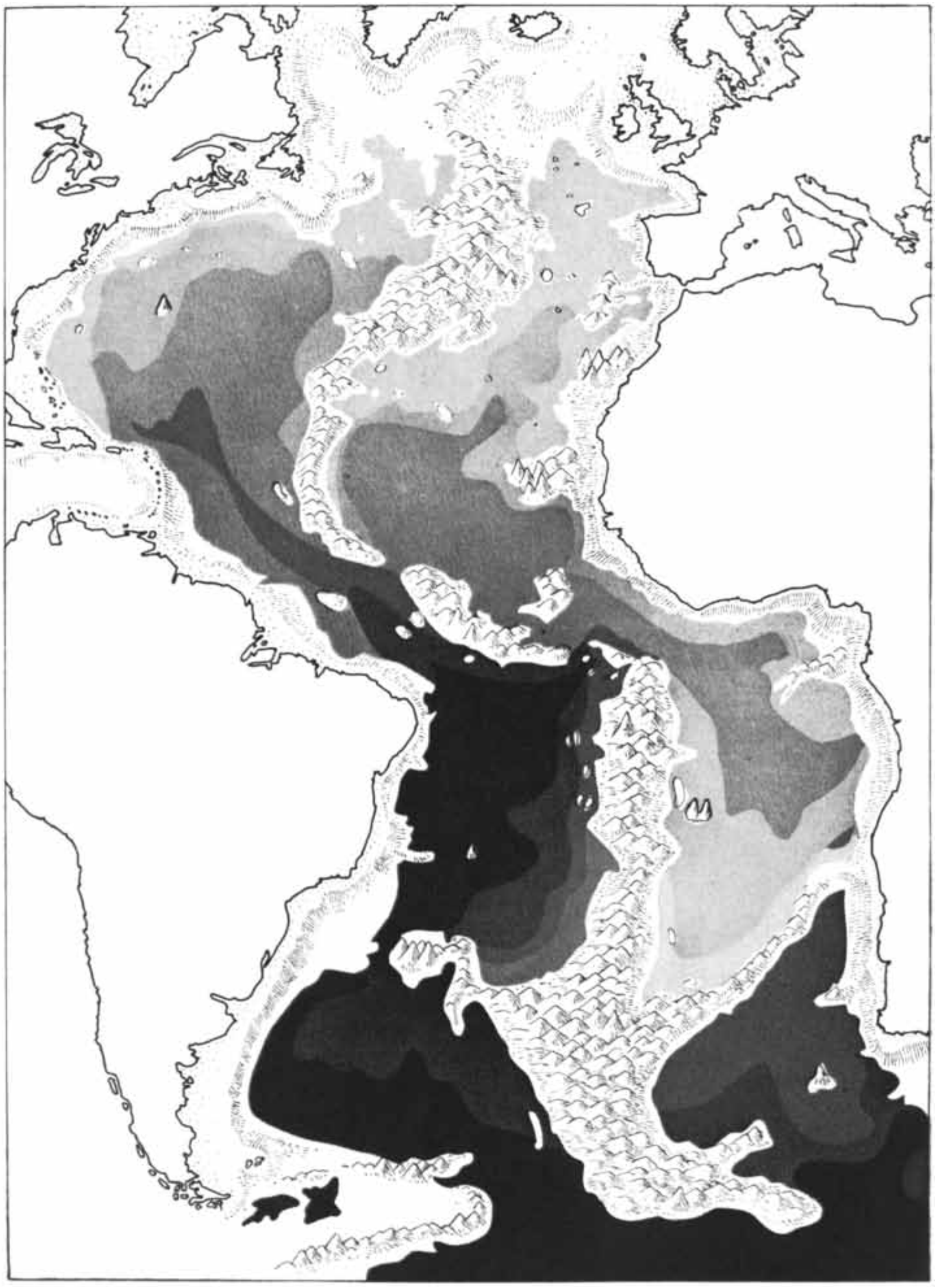
the depths are formed only spasmodically, under unusual climatic conditions, instead of continuously.

At the surface the large-scale currents are remarkably constant from season to season and year to year. To be sure, the vagaries of the winds stir them up; a local storm may produce temporary rotary currents which last from 12 to 48 hours after the storm has passed. In regions such as the Sargasso Sea, where there is little in the way of permanent current, transitory currents are the most noticeable feature of the surface movement. But the effect of storms on a large-scale current such as the Gulf Stream is too trivial to be observed.

While the general surface circulation of the North Atlantic Ocean does respond slightly to seasonal changes in the wind pattern, short-period interruptions of the normal wind distribution have no discernible effect on currents below the upper few hundred feet. The reason is that the large-scale circulation of the ocean has available a considerable store of energy from the lens-shaped masses of warm water in certain regions of the ocean. It is estimated that even if all the winds were to stop and the atmosphere to fall into a dead calm, the great surface circulations could draw enough energy from the potential stored in the warm lenses to go on flowing for about three years.



east southeast of Greenland of 6.5 milliters per liter to the minimum of 4.7 in the south, enables the charting of this water's circulation.



CIRCULATION AT 12,000 FEET of the deepest water mass, called the Antarctic Bottom Water, is shown by this chart. Lowering the sea to this level exposes the mountain ranges which channel the flow of the Bottom Water up the western side of the barrier until it reaches a pass above the Equator. The darkest tone indicates the pure Bottom Water before its gradual dilution.

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BELL 47D HELICOPTER takes off from a mountain camp of the $500-million hydroelectric power project of the Aluminum Company of Canada near Vancouver. This machine carries two passengers. Beneath it is a carpet which serves as a landing field.

PIASECKI YH-16 HELICOPTER flies above Philadelphia. The largest machine in the air, it carries 40 passengers. It has two large rotors, each driven by a 1,650-horsepower piston engine. A variation of the model will use the shaft power of gas turbines.

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Helicopters

The odd appeal of hovering flight may have led people to expect too much of the machines too soon. However, their technological evolution now promises some real progress in their general use

by Lawrence P. Lessing

Leonardo da Vinci's notebooks contain a sketch, dated 1483, of a rudimentary helicopter (which he called a helixpteron). The idea of the helicopter was repeatedly revived by later inventors, and models were actually built in the 19th century. In 1944 a cautious enthusiast wrote a book entitled *The Helicopters Are Coming*. They are still coming. The era of the helicopter has been hailed prematurely so often that another prediction of its arrival is likely to be greeted with skepticism. Yet the machine has come along so rapidly in the past three or four years that it has in fact begun to make a definite place for itself. Helicopters are now in regular passenger service in Europe. The U. S. armed forces have established their value for many military uses. And some of the technical problems that have held the machines back are at last being solved.

The helicopter is a bundle of paradoxes. Its charm as a means of travel lies in the fact that it makes haste slowly. Although so far it has been of greatest interest to the military, it is not essentially an engine of destruction; even for military purposes it is simply a means of transport and rescue. On the technological side, the helicopter seems the simplest of flying machines, but it is actually the most complex. Although it was one of man's earliest conceptions for mechanical flight, it was about the latest to get into the air in a practical form.

The helicopter's basic principle of course goes back to the windmill and similar devices; in fact, its lineage can be traced to the ancient Chinese toy known as the flying top. In its modern, still fascinating version the flying top consists of a bright tin propeller, slightly twisted and slotted in the center, which rotates freely up and down a spiral wire. When a sliding ring below the propeller is pushed up rapidly, the propeller whirls up the spiral and off the end of the wire for a soaring flight of many feet. The helicopter, like the flying top, climbs a tight spiral staircase, but the staircase is made only of the air pressures induced by the motion of its whirling rotor. The fish-shaped blades of the rotor attack the air edge-on at a slightly elevated angle or pitch, building up pressure on the underside of the blades while reducing the pressure above them to give the craft lift. The aerodynamic principle is exactly the same as is used to give lift to the fixed-wing airplane, but it is applied in a manner which enables the machine to fly straight up or down, forward, backward or sideways, or hover motionless in mid-air.

Men were early attracted to the helicopter flight scheme because it seemed to come reasonably close to the method by which birds fly—by the movement of wings. As it turned out, the easiest solution to the problem of human flight proved to be the application of brute power by means of a propeller pushing a fast stream of air under fixed wings. Helicopter flight involved subtle aerodynamical and mechanical problems which took more sophistication to solve.

In 1843 the English philosopher George Cayley conceived a craft with four rotors driven by a steam engine, and in 1878 an Italian, Enrico Forlanini, built a miniature steam-driven model that hovered 40 feet above ground for a few seconds. As gasoline engines became available, helicopters were built with rotors like whirling box kites, rotors like giant pinwheels, rotors like great paddles flailing the air. In 1907 a weird biplane helicopter carried the French aeronaut Louis Breguet up five feet for two minutes—technically the first helicopter flight of man. But all of these machines were so unstable and low-powered as to be totally impractical.

The first real advance toward a functioning helicopter was made in 1923 by the Spanish engineer Juan de la Cierva with the invention of the autogiro, designed to make hovering possible. Strictly speaking, this was not a helicopter at all. It was a conventional propeller-driven airplane with a large rotor on top which was not powered but spun freely in the air as the plane flew. While the inefficient giro was short-lived, it gave others the idea of applying power to the propeller-like rotor. In 1937 the German aircraft designer Heinrich Focke put two powered rotors on the open, wing-like outrigging of a Focke-Achelis FW-61. The craft flew from Bremen to Berlin in one hour and 20 minutes. In 1939 Igor Sikorsky put a big, single-rotor helicopter into sustained flight from a field beside his factory in Bridgeport, Conn. These were the first practical helicopters.

The dual nature of a helicopter's rotor as wings and propeller was, perhaps, the most difficult notion to grasp and to embody in a single efficient structure. Not only was the shape of the wing blades critical, but their rotary motion added to the complexities. To drive the craft forward, the whole rotor had to be tilted slightly forward on its axis, which introduced an imbalance of lift. While one blade was dipping forward at a deep angle of attack, its opposite was receding up and backwards at an angle producing less lift, thus tending to roll the craft over. Cierva solved this problem by hinging the rotor blades. With the proper controls the pitch of the advancing blade could be decreased while that

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HILLER YHJ-1 has a novel propulsive arrangement. At the tip of each blade of its main rotor is a small ramjet. The high fuel consumption of the ramjets limits the cruising range of this machine.

SIKORSKY S-56, bearing the Marine designation XHR2S, has a six-

of the receding blade was increased to equalize lift in all directions of travel except straight up.

Another problem was that of engine torque or twist. As a helicopter's engine shaft whirls the rotor in one direction, torque reaction tends to twist the whole engine and fuselage in the opposite direction like a whirligig. Focke met the problem with his two rotors, turning in opposite directions to cancel torque. Sikorsky employed a small tail rotor, invented by the Dutch engineer A. G. Baumhauer, to exert a counter force against engine twist. This is still the most commonly used device, for besides solving the torque problem in a simple fashion, the small tail rotor also acts as a rudder.

What has mainly held the helicopter back is its small carrying capacity. The load problem derives from the fact that the rotor must perform a double function: it must divide its power between lift and forward motion. To carry as much load as a conventional airplane, a helicopter must have twice as much horsepower. The largest helicopters now flying can carry no more than 30 to 40 passengers, and they seem to be close to the practicable limit for this type of craft when powered by piston engines.

The jet engine, however, has given the machine a new impetus. It offers a big increase in horsepower with little or no increase in weight. Helicopter designers are now busily engaged in harnessing jet engines to helicopters to raise their speed, range and payload.

Probably the simplest helicopter built so far is the Hiller Hornet. It is powered by ramjets, mounted in the tips of the rotor blades, that spin the rotor like a Fourth-of-July pinwheel. This simple system is light, yields high horsepower and, since it removes the engine from the fuselage, eliminates engine torque. But a pure jet such as the ramjet burns fuel so rapidly that the range of the craft at present is no more than 50 to 100 miles.

For heavy-duty helicopters the major interest centers on the gas-turbine type of jet engine [see "The Gas Turbine," by Lawrence P. Lessing; SCIENTIFIC AMERICAN, November, 1953]. There are two general schemes for adapting helicopters to gas-turbine drives. In one the jet stream is led up through the rotor blades and vented out through the tips to provide the same kind of rotary thrust as that in the ramjet installation. The second, and the favored, scheme gears a fixed-shaft gas turbine or propjet directly to the rotor to turn it like a propeller, while the jet's gas stream, usually directed out of the engine's tail pipe, provides residual thrust for additional forward speed.

So many advantages have accrued in the use of the propjet that it seems to be one of those technological answers to many problems at once. In a series of flight tests a helicopter manufacturer compared a 400-horsepower propjet engine with two equivalent piston engines. The jet-driven craft showed a marked reduction in noise, stress and vibration, and its light weight gave it an advantage in performance and payload which amounted to about 80 additional horsepower. In addition the jet engine's simpler construction cut maintenance time in half. It roughly doubled the range of the unloaded craft—from about 300 to 600 miles. It likewise doubled the efficient cruising speed, with equal fuel, to about 170 miles per hour. And it raised the all-important ratio of useful load to gross weight from some 30 per cent to nearly 40 per cent. The jet-powered helicopter weighed only 3,500 pounds, as against 5,500 and 6,100 for the piston-engine machines.

Sikorsky is planning a jet-powered helicopter for 50 passengers and thinks that the 100-seater will not be far behind. The Bell Aircraft Corporation is projecting a huge "flying wing" with rotors on each wing tip and a passenger cabin running along the wing's leading edge. There is also much talk of a "convertaplane"—a stub-winged craft that will rise like a helicopter and then pivot its rotors forward and down to fly like a

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bladed main rotor, retractable landing gear and carries 30 passengers.

SIKORSKY S-59, which bears the Army designation H-59, is propelled by a gas turbine. It holds the three-kilometer speed record of 156.005 miles per hour and the altitude record of 24,500 feet.

conventional airplane or allow forward jet engines to take over so that it flies like an autogiro.

Helicopter travel charms nearly all who have tried it. Even at a cruising speed of 200 miles per hour, which is about the upper limit expected from jet propulsion, the helicopter is a leisurely, low-altitude flyer. Under weather conditions that find all fixed-wing craft grounded, the helicopter flies safely and sturdily. In any emergency it can hover, feel its way and, if need be, land in territory which for other craft would be dangerous or fatal. All who associate with helicopters for any time develop an affection for them.

Early helicopter enthusiasts made the erroneous assumption that, because of its unique maneuverability at low speeds and its ability to take off or land on a cleared space only big enough to accommodate its tricycle wheels and rotor, the helicopter was a personal aircraft *par excellence*. They thought that it would be to aviation what the automobile is to surface travel. It may still work out that way, but probably not before a long period of evolution. For one thing, the helicopter is still too tricky for the average road duffer to fly. It requires a trained hand constantly on the controls to meet the variable conditions of flight. The feel and response are quite different from those in fixed-wing aircraft, and even a seasoned pilot of the latter must undergo training to learn how to manage the whirling wings. Besides this, the cost and upkeep of a helicopter are still well out of reach of most people. The smallest and cheapest helicopter produced today sells for about $5,000, and the average price runs well over $10,000.

The first uses of the helicopter were to reach places otherwise relatively inaccessible. Helicopters have ranged over the jungles of Brazil, taxied men and supplies to offshore oil fields in the Gulf of Mexico, explored and wildcatted for oil in the swamps of Louisiana, raised 200 tons of dam-building equipment up the sheer face of a mountain in British Columbia, mapped well-nigh impassable reaches of Alaska and scouted ice floes in the Bering Sea. Helicopters are rapidly becoming the standard vehicle for agricultural spraying and insect control (the rotor's strong downdraft directs the insecticide onto the crops), for fighting forest fires, for patrolling pipelines and power lines, for making swift geophysical surveys and for sea rescue work.

The helicopter's versatility and uses are formidable and growing, but none of them yet adds up to mass transportation. Since 1945, when production really started, the industry has built 5,000 helicopters. Most of these have been built by four manufacturers: the Sikorsky Aircraft Division of the United Aircraft Corporation, the Piasecki Helicopter Corporation, the Bell Aircraft Corporation and Hiller Helicopters. The majority are one- or two-seaters. The largest built so far is the Piasecki YH-16, a twin-engine troop transport that carries 40 men. Most of the helicopters produced have been for the military. The helicopter proved itself a real pack horse on the battlefields of Korea. But when all is said and done, it will not really be considered to have reached maturity until it becomes a vehicle of regular commercial transportation.

Europe has done the pioneering in scheduled helicopter flying despite the pre-eminence of the U. S. in helicopter design and production. The British European Airways established the first regular helicopter passenger service in 1950 between Cardiff and Liverpool. It is now also running a passenger line between the London Airport and Southampton. In 1953 Belgium's Sabena Air Line inaugurated daily service between midtown Brussels, Antwerp, Rotterdam, Lille, Liége, Maastricht, Cologne and Bonn. It uses 8-seater Sikorsky planes. This line has clocked more passenger miles by helicopter than any other operator; it carried more than 25,000 passengers its first year. Brussels demolished its old Allée Verte railway sta-

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PIASECKI YH-21, especially equipped for Arctic operations, lowers a sling to a "survivor" during simulated rescue operations conducted on the Greenland ice cap near Thule Air Base.

BELL 47G sprays defoliant on a cotton field near Plano, Texas, after which cotton bolls can be picked from the leafless plants by machine. The downdraft of the rotor aids spraying.

tion in the center of town to make way for a heliport, and most European cities have cleared ground for the new service. The British are just putting into operation the great new South Bank heliport in London.

Few U. S. cities are even thinking about heliports, and what helicopter passenger service there is has been of a generally trivial or luxury nature. One operator since 1950 has been flying tourists up and down the Grand Canyon, another has been transporting racetrack visitors between Miami and West Palm Beach, still another is flying vacationists into the Catskill Mountains' resort towns. The largest U. S. helicopter passenger service is that offered by New York Airways, Inc., which since 1953 has been flying daily out of Newark and Idlewild airports to a string of New Jersey towns, and is now scheduled to make a New Brunswick–Princeton–Trenton run. But 98 per cent of the revenue from these trips is for airmail.

Europe's helicopter passenger services are all government-subsidized, and its dense, closely spaced centers of population are ideally suited to helicopter operations. There are many regions in the U. S. where helicopter taxiing services would be equally appreciated. But helicopter transport is still financially unprofitable, although operating costs have been brought down from $1.38 per mile in 1947 to about 80 cents now. Economical mass transport will not be possible until the load capacity of helicopters is raised.

It is plain, however, that the helicopter has an important future, which assuredly rests on its unique property of being able to take off from the center of a crowded city, overleap the traffic jams of surface travel and land in an equally crowded center. It can do this with good speed and superlative safety. The first big use of the helicopter is likely to be for shuttle service to and from the outlying airports of cities. From that it will be only a short step to intercity traffic between towns 200 to 400 miles apart. Sabena Airlines recently demonstrated that a helicopter cruising at only 75 miles per hour could get passengers from downtown Brussels to London more quickly than a 250-mile-per-hour airliner whose passengers had to taxi to and from the airports.

Finally, as population continues to move from cities out to ever more distant suburbs and satellite towns, the helicopter seems destined to become the commuter "bus" of the future.

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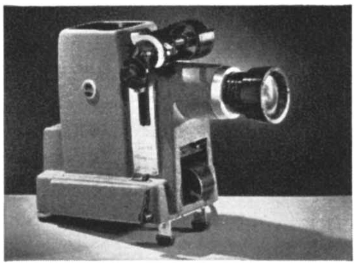
Kodak reports to laboratories on:

telling your story without jump or jerk . . . identifying very meagre samples . . . a radiological safety device

Talking with film

There is a man in your trading area who calls himself an audio-visual dealer. This mid-20th-century addition to the roster of trades is a merchant of various devices for captivating a captive audience into granting access for your message to their minds through their eyes and ears. Assuming you have a message—most successful people nowadays have one—we point here to a new



and advanced example of one of the basic devices which your audio-visual man has for conveying it, the *Kodaslide Signet 500 Projector, Filmstrip Model.*

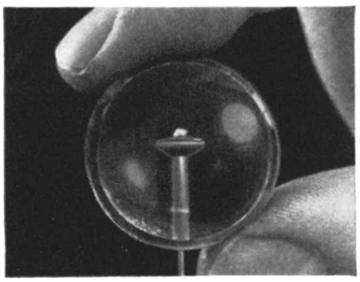
First we ask you to grant that the smoother the mechanical aspects of your presentation, the less likely it is to distract your audience from your subject matter. Therefore we have proceeded on the assumption that the pictures should follow each other instantaneously, quietly, positively, without jumping, without jerking. Instead of holding a lot of engineering conferences on how to accomplish this without resorting to a costly Geneva movement, we went ahead and actually used the Geneva movement and then made the engineers figure out how they could still keep the selling price down to $98.

And, since the customers were to be asked to lay their dough out for a projector, not just a Geneva movement, we had to insist on 1) sufficient brilliance and evenness of illumination to dispense with room darkening in most cases; 2) safeguarding the filmstrip by automatic separation of the glass pressure plates before it can move; 3) fast setup by virtue of drop-in loading for immediate sprocket engagement, a quick framing lever, and a quick rewind device; 4) cool operation of a 500-w lamp with little or no blower noise and no danger of burning a hole in the film; 5) automatic leveling capable of compensating for unevenness of support.

All this they did, our engineers, muttering all the while that sales people are unreasonable; for they knew all along that not only were they expected to come up with a world-beater of a filmstrip machine but also that the $98 package had to include a mechanism that the user could easily insert when he had Kodachrome slides to show!

To have the audio-visual man show you how well they fulfilled the assignment, drop a line to Eastman Kodak Company, Department 8-AV, Rochester 4, N. Y. As for how you prepare the filmstrips in the first place, you can ask in your note for a little pamphlet of helpful hints we call "Making Filmstrips With Amateur Equipment."

Infrared beam squeezer



The lens you see here is not glass but silver chloride, which is transparent all the way out beyond 17μ in the infrared. The speck it magnifies is typical of specks for which we run infrared absorption spectra in the course of solving our daily little problems. We use such lenses not as magnifiers but to constrict one of the beams in a double-beam infrared spectrophotometer so that all its flux can be put through a 0.75mm x 3.5mm aperture. This permits the use of a very small sample. Then a second such AgCl lens collimates the beam again.

The samples, frequently weighing 50 micrograms or less, are handled by grinding the material to be examined with a little potassium bromide and compressing to a narrow strip. Nothing is dissolved in the process, and there is less chance for reactions and extra absorption that might mask the few micrograms of organic material we seek to identify. KBr puts no dips of its own into the chart.

This procedure is much less expensive than working out reflecting microscope optics and hitching them to a spectrophotometer. We got into it in identifying spots on film that our testing department won't let us sell. It might interest others who have only very meagre samples to work with, like those who study blood and other life juices.

Since most infrared spectroscopists aren't as lucky as we in having a great optical factory in the immediate family, we thought it would be a friendly deed if we made up a stock of silver chloride lenses for anybody who wants to try out this wrinkle of ours.

The price is $102 for a set of Kodak Infrared Microsample Optics, *consisting of an unmounted pair of plano-convex AgCl lenses of 24mm diameter and 22mm focal length, coated with a black Ag_2S smoke that cuts out radiation below 1μ, plus a similar plane-parallel plate for the reference beam. The deal is with Eastman Kodak Company, Special Products Sales Division, Rochester 4, N. Y. We'll throw in a set of mounting drawings or give you the name of an infrared equipment manufacturer who supplies the whole assembly ready to slip into his spectrophotometer. We can also supply reprints of our papers on the method.*

Neutron film

We wish to spread upon the record word that any Kodak Industrial Dealer is now prepared to sell for $11.25 a carton containing 150 1¼" x 1⅝" *Kodak Special Nuclear Track NTA Film Packets.* These look just like the paper-sheathed rectangles of x-ray film which we turn out by the millions for dentists. The film is quite different. It measures neutron exposure by revealing individual tracks of protons originating from either fast or thermal neutrons. It is worn in badges.

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

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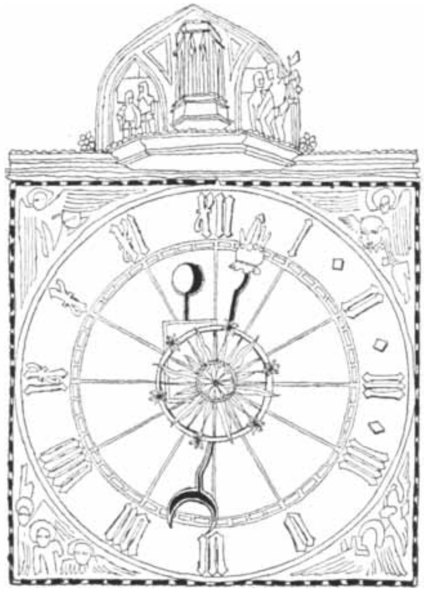

Italian Navigator

Enrico Fermi died of cancer last month at the age of 53. His death came less than two weeks after the Atomic Energy Commission had named him as the first recipient of a $25,000 special award for "especially meritorious contributions" to the development of atomic energy.

Those contributions began in Rome in 1934 when Fermi and his colleagues started to study the effects of bombarding matter with slow neutrons. Trying to make elements heavier than uranium, Fermi fissioned the uranium atom, although he did not realize it at the time. After the fission effect was recognized in 1939, Fermi, who had fled from Fascist Italy to the U. S., began the experiments which led to the construction of the first chain-reacting pile at Chicago in 1942. His success in achieving the chain reaction was communicated to officials of the Manhattan District by the code message: "The Italian navigator arrived at the shores of the new world."

After the war Fermi became professor of physics at the University of Chicago's Institute for Nuclear Studies. He did important theoretical work on meson theory and on the origin of cosmic rays. Earlier he had been a codiscoverer of the "Fermi-Dirac" statistics governing fundamental particles of matter.

Fermi's affliction with cancer was discovered only last September, when it was too late for surgery to help. Too ill to talk to newspapermen after the announcement of the AEC award, Fermi issued the following statement:

"I am deeply honored by the award conferred upon me by the Atomic Energy Commission. I am certainly aware that whatever scientific achievements I may have attained would have been impossible without the help and collaboration of many younger men. Of them, and their fine performance, I think with sincere affection at this time."

The Atmosphere

A chorus of objections to further tests of nuclear weapons sprang up around the world last month. In England Sir Winston Churchill told the House of Commons that an "undue number" of fission and fusion explosions might poison the atmosphere for 5,000 years. In the U. S. the newspaper columnists Joseph and Stewart Alsop reported that military officials were seriously concerned about whether it would be safe to test the latest hydrogen bomb, believed to be several times more powerful than those set off at Eniwetok last March. In estimating the radiological hazards, "the AEC's conclusions are less frightening than the Pentagon's—although the AEC in its secret studies is by no means as reassuring as its official statements on this subject."

Prince Louis de Broglie, the eminent French theoretical physicist, warned that any further H-bomb tests would be reckless. In an article in the *Weekly Review* of the French Science Academy he listed the following "irreversible effects" of fusion explosions: (1) gases given off will upset the chemical balance of the atmosphere; (2) dust clouds will cut off solar radiation, leading to changes in the major wind systems of the earth; (3) radioactivity will last for years. "Any increase in the number of explosions," de Broglie concluded, "will bring unpredictable changes and a growing disequilibrium of the natural conditions to which animal and plant life has slowly adapted itself."

Atomic Progress

The United Nations General Assembly last month produced two notable advances toward international agreement on atomic energy. President Eisenhower's "pool plan" was approved in principle by a unanimous vote, and disarmament talks were revived.

The General Assembly's Political Committee, which includes the Soviet Union,

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adopted a resolution which "notes" that negotiations for establishing an International Atomic Energy Agency are in progress and expresses the "hope" that the agency will be set up as quickly as possible; which suggests that this body then negotiate an "appropriate form of agreement" with the UN, and which calls for an international technical conference under UN auspices to explore peacetime applications, the conference to be held before September, 1955. The U.S.S.R. agreed to attend the conference and to help draw up an agenda.

The debate preceding the adoption of the resolution revolved chiefly around Soviet attempts to bring the proposed agency under the control of the Security Council (thereby making it subject to the veto) and to tie the plan to disarmament proceedings. Both these measures were rejected. The Soviet delegate, although voting for the resolution, said it contained "important" shortcomings and indicated that he was voting for the "principle" of international cooperation.

The U. S. delegation told the General Assembly that it is continuing private negotiations concerning the atomic agency with seven nations (Great Britain, France, Australia, Canada, South Africa, Belgium and Portugal). Chief delegate Henry Cabot Lodge, Jr., announced that the U. S. would contribute 220 pounds of fissionable material to fuel reactors, and Great Britain quickly chipped in 44 pounds more. The U. S. plans to establish a school of reactor technology for the agency, with additional courses in atomic medicine, radiological physics and radio-isotope applications. Lewis L. Strauss, chairman of the AEC, said the 220 pounds of enriched uranium would fuel 15 research reactors.

The break on the disarmament front came when the Soviet Union announced that it was dropping its old demand for an immediate agreement to outlaw atomic weapons as a condition to all other arms negotiations. The Assembly passed a resolution sponsored by the U. S., Britain, France, Canada and the U.S.S.R. reviving the Disarmament Commission.

Stalled Accelerator

On a Saturday afternoon last November the giant cosmotron at Brookhaven National Laboratory gave a slight

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shudder. The operator in the control room immediately threw the switch that shuts off the current to the huge magnet. Looking out of his window, he saw a column of smoke rising from a point on the magnet ring, then a few licks of flame. A few minutes' work with a hand fire extinguisher stopped the blaze, but finding out what had gone wrong was another matter.

The physicists first dismantled the delicate experimental apparatus around the accelerator and removed its concrete shield. Then a repair crew started to take apart the affected section—a quarter of the entire circular track. Each piece of the water-cooled copper tube that carries the electromagnet current had to be unbolted, removed, tagged and stacked in exact order to assure its going back into the right spot. Handling the sections is a 12-man job. The crew worked for two weeks before they got to the damaged spot.

Then they found that one of the copper sections had sprung a leak and the cooling water had spilled out, short-circuiting the leaky section to the one adjacent. The heat had poured a dribble of molten copper on the floor. George B. Collins, chairman of the cosmotron department, estimates that it will take three or four months to replace the two sections and repair the insulation. He is taking advantage of the shutdown to install certain long-desired improvements in the machine. In the two and a half years since the cosmotron started working, demand for its facilities has been so heavy that Brookhaven authorities have been unwilling to take it out of service for alterations. The major change now being made is in the section that controls the frequency of the accelerating voltage. It is hoped that better control will cut down the 80 per cent proton loss during the accelerating cycle.

Sliding Scale

Astronomers' estimates of the age and size of the universe are being revised upward again. Two years ago they decided that they had to double their previous estimates (see "A Larger and Older Universe," by George W. Gray; SCIENTIFIC AMERICAN, June, 1953). That revision was based on a study of the spiral nebula in Andromeda. Now a survey of more distant galaxies with the 200-inch telescope indicates that they are farther away than was thought.

A resurvey of the nebula Messier 81 suggests that its estimated distance must be multiplied by four. On photographing the Virgo cluster of galaxies with the 200-inch, Palomar Mountain astronomers resolved what were thought to be individual stars into regions of bright gas, and the actual stars are much fainter than supposed.

According to Allan R. Sandage the best present guess is that the age of the universe will turn out to be between 3.5 and 7.8 billion years. "In five years," he says, "the solution to this difficult problem will be much closer."

Ill Wind

There has been a good deal of question about the mode of spread of histoplasmosis, a lung disease widely prevalent in the Middle West. Now Carroll E. Palmer of the U. S. Public Health Service thinks he knows at least part of the answer: the fungus that causes the disease may be borne by tornadoes.

Histoplasma capsulatum normally lives a sheltered life in the soil or in old wooden buildings. Palmer reasoned that a windstorm which lifts large quantities of dirt into the air and which can pull apart wooden buildings should stir up the fungus spores. He checked the records of 160,000 persons tested for histoplasmosis against the Weather Bureau's records of tornadoes during the past decade. Areas in the paths of these storms proved to have a much higher incidence of the disease afterward than before. After a tornado that hit Tulsa in 1950 the histoplasmosis rate rose from almost nothing to 40 per cent among lifetime residents of the city. There was no such increase in nearby counties.

Palmer plans to test his theory by on-the-spot examinations after the next tornado.

Regimented Bacteria

Life tends to be disorderly, but a British biologist has just discovered that bacteria can be made to take the orderly form of a crystal. (Viruses were known to be crystalline, but there is some debate about whether they are alive.)

R. J. Goldacre of the Royal Cancer Hospital in London came accidentally upon some rod-shaped bacteria spontaneously arrayed in parallel rows, and he succeeded in stacking them up in three-dimensional "crystals." He discovered them in drops of a salt solution. They lined up naturally, but he found he could also make them do so by stroking the drop surface with a needle point—a trick like that chemists sometimes employ to induce crystallization in a supersaturated solution. When Goldacre treated the drops with dilute glycerol and let

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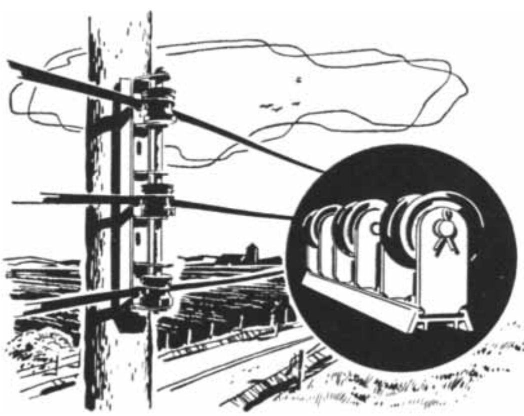
BUSINESS IN MOTION

To our Colleagues in American Business . . .

This is called a rack. It is fastened to electric light poles to hold wires from pole to pole, and from pole to house. Perhaps you may have noticed racks on poles, but unless your electric company has recently replaced them on the lines in your vicinity you have not seen anything quite like this. It is made of aluminum, instead of galvanized steel, and is assembled almost entirely of extruded shapes.

Naturally you will think that aluminum was chosen in order to save weight, and as a matter of fact, lightness plus strength is a factor. The aluminum rack is five to six pounds lighter, and that is appreciated by the linemen who have to put the rack on the pole after they have climbed it. However, lightness is not the main consideration. Long life is the big advantage. Modern methods of treating poles with preservatives make it reasonable to assume that a pole will last for 50 to 60 years. Now for the first time there is a rack or bracket, as it is sometimes called, that should outlast the pole. As soon as aluminum is exposed to the air, a thin film of oxide forms, and this is a protection against further action by air and rain. As for price, the aluminum rack costs a little more, but this is compensated, many times over, by the increased years of service.



There are some interesting features of design that are worth noting. The extruded shape that forms the base of the rack is adequately ribbed for strength, and in addition, provides a channel into which the arms are slid after having been notched and bent at right angles. The channel and the arms together take the pull of the wires; the rivets are used just for positioning. Incidentally, the rack has to withstand a total pull of 6,000 pounds. The arms are formed with a slight longitudinal camber or bow and have rounded edges, because linemen pull the wires across them, and the camber and edges protect the insulation from damage. The rod on which the insulators are threaded is extruded aluminum. One final detail, which is not easy to see in the drawing; the bottoms of the base are toothed, to hold to the pole better.

Revere takes especial satisfaction in this new and superior rack, because the Technical Advisory Service, the Mill, and the customer worked so closely together. There was a joint attack on the problem of developing a product that would not only be better, but could be assembled simply and economically. Suppliers to industry are not only well informed regarding their materials, but glad to cooperate with customers and prospects on matters concerning specification and fabrication. Revere suggests that you call upon your suppliers not only to fill orders, but to place their skill and knowledge at the disposal of your designers and production people.

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And now, in our humble way, we place on the altar of science at the epicenter of the Billenium our intellectual contribution for posterity. We are memorializing one of our staunchest researchers, who has reduced to hitherto unknown limits of accuracy, the measurement and observation of energy loss (or FRICTION), both magnetic and mechanical.

The New Unit is equal, for obvious reasons of national pride, to the friction overcome when the Battleship Missouri was pulled off the mud. As with the farad, in ordinary use, it is prefixed micro, or micro-micro, and for export to Europe, pica. It is the mccarthy (micromccarthy, micromicromccarthy, picamccarthy). M. K. S. and C. G. S. adherents may obtain metric conversions from Navy BuShips data on the big Mo. Absolute units are of course the abmccarthy and the statmccarthy.

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them stand for a few days, the bacteria obligingly arrayed themselves in a three-dimensional lattice.

In an article in *Nature* he relates that when he pushed the rows closer together, they sprang apart; when he pulled them farther apart, they separated permanently. The bacteria in the array do not touch one another. Apparently there is a long-range force which regulates their spacing and their geometrical relationship. Goldacre believes that this force, nature still unknown, may operate in other biological processes such as the behavior of chromosomes during cell division.

Radicals under Glass

Free radicals, the fleeting intermediate products of certain fast chemical reactions, are hard to catch. Irwin Norman and George Porter of the University of Cambridge report in *Nature* that they have found a way to capture and preserve them for study indefinitely.

The British chemists dissolve the material to be treated in transparent liquid hydrocarbons and chill the solution with liquid nitrogen so that it becomes rigid but not crystallized. They then shine light through this "glass," splitting the dissolved substance into atoms or radicals. The glass's high viscosity prevents the resulting fragments from coming together again, and the very low temperature prevents them from reacting with the solvent.

Norman and Porter first tried the idea on iodine, whose molecule consists of two iodine atoms joined together. A cold iodine solution turned colorless when exposed to light from a mercury vapor lamp, indicating that the molecules had been split into separate atoms. As long as the solution was kept cold it remained colorless; as soon as it was heated, the atoms recombined and the iodine color reappeared. In later experiments ethyl iodide, carbon disulfide, chlorine dioxide and a number of benzene derivatives were similarly split.

The new technique should have important applications, its inventors believe. In many instances the chemical action of light and other radiation is not completely understood because the primary products of the reactions cannot be identified. Now these products can be captured and recognized.

Submerged Third

The hazards of illness and accident seem to fall disproportionately on a small minority of the population. A recent study of the health records of tele-

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Dr. Ferd Williams, Ph.D in Phys. Chem., Princeton, has been Head of the *Light Production Studies Section* at the G-E Research Laboratory since 1949. He is shown with the transparent TV tube which, along with electroluminescent single crystals and a light-amplifying phosphor, are recent achievements of that section.

New light on luminescence

General Electric's Dr. Ferd Williams develops equations to predict accurately the role of new activators in phosphors.

For years it has been known from experience that the luminescence of solids is governed by small impurities known as *activators*, but theoretical understanding of these phenomena was lacking. Dr. Ferd Williams and his associates in G.E.'s *Light Production Studies Section* have now worked out theoretical calculations for the role of activators in the luminescence of simple phosphors. They have also been able to reproduce the spectra of excitation and emission that are observed experimentally. For the first time it has become possible to make quantitative determinations of the luminescent properties of a new phosphor in advance of laboratory measurements.

Today the most important applications of phosphors are in fluorescent lamps and in the cathode ray tubes used in radar and television. Tomorrow's applications are still in the lap of the future. But the work of Ferd Williams and his associates at the General Electric Research Laboratory gives promise of a better understanding of all luminescent phenomena and the feasibility of new and improved phosphors.

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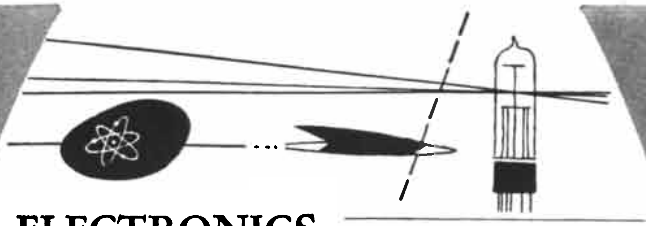

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phone company employees showed that a third of the individuals accounted for about 75 per cent of the total illnesses and 80 per cent of the days missed from work. The study was reported at a Buffalo meeting of the American Public Health Association by Lawrence E. Hinkle, Jr., and Norman Plummer, assistant professors of medicine at Cornell University Medical College.

They had traced the records of 1,297 telephone operators and 1,527 repairmen. All the workers had been screened for physical defects at the time they joined the company; all apparently enjoyed the same adequate standards of nutrition, sanitation and other physical comforts. Yet some suffered a succession of major and minor illnesses, while others remained almost untouched. Those who got sick showed a general susceptibility rather than specific weaknesses. The sickly workers also had more accidents than the others.

Among a sample of the healthy operators, the "average" woman had lost only 33 days in 29 years. In a comparable group of sick operators, the average worker had been out 1,209 days in 26 years. She had had an average of 10 major illnesses, 2.5 operations and seven accidents. The illness figures for men were about half those for women, but the same proportions held.

Hinkle and Plummer found that the healthy workers were generally satisfied with their jobs and their lives; the sick ones were on the whole thwarted and maladjusted. The typical ill operator was a married woman, widow or divorcee who had hoped to be a housewife and mother. Deprived of her husband's support by death, desertion or incompatibility, she had been forced to continue working often while rearing small children. The healthiest operators, on the other hand, tended to be single women with little drive toward marriage and whose ambitions did not go much beyond the modest satisfactions of their jobs.

The Cornell physicians believe that pressures on the sickly workers stemmed largely from external circumstances rather than from inner weakness. These pressures, they suggest, cause the susceptibility to sickness and accident and, probably, other socially crippling afflictions. They quote a number of studies indicating that in general the same fraction of the population is "responsible for most community health and medical problems, most of the divorces and problems of personal maladjustment, most of the crimes and most of the referrals to welfare agencies."

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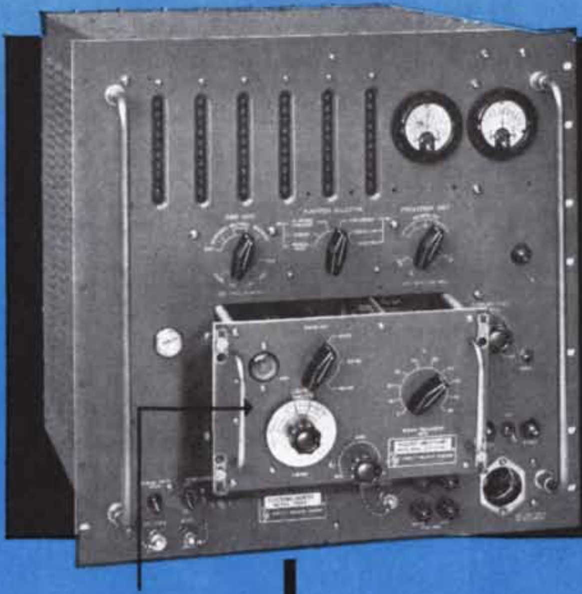

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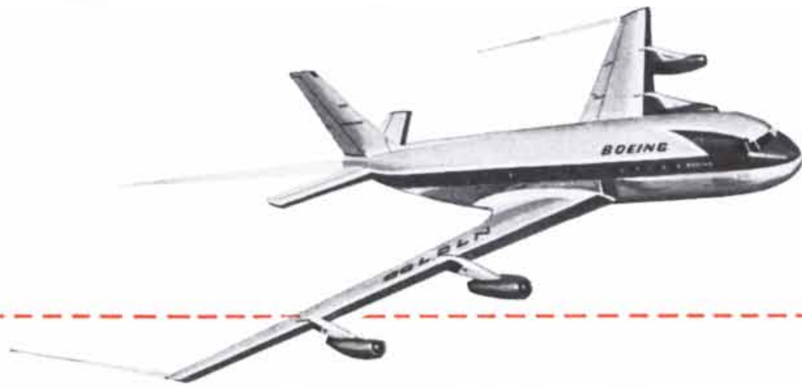

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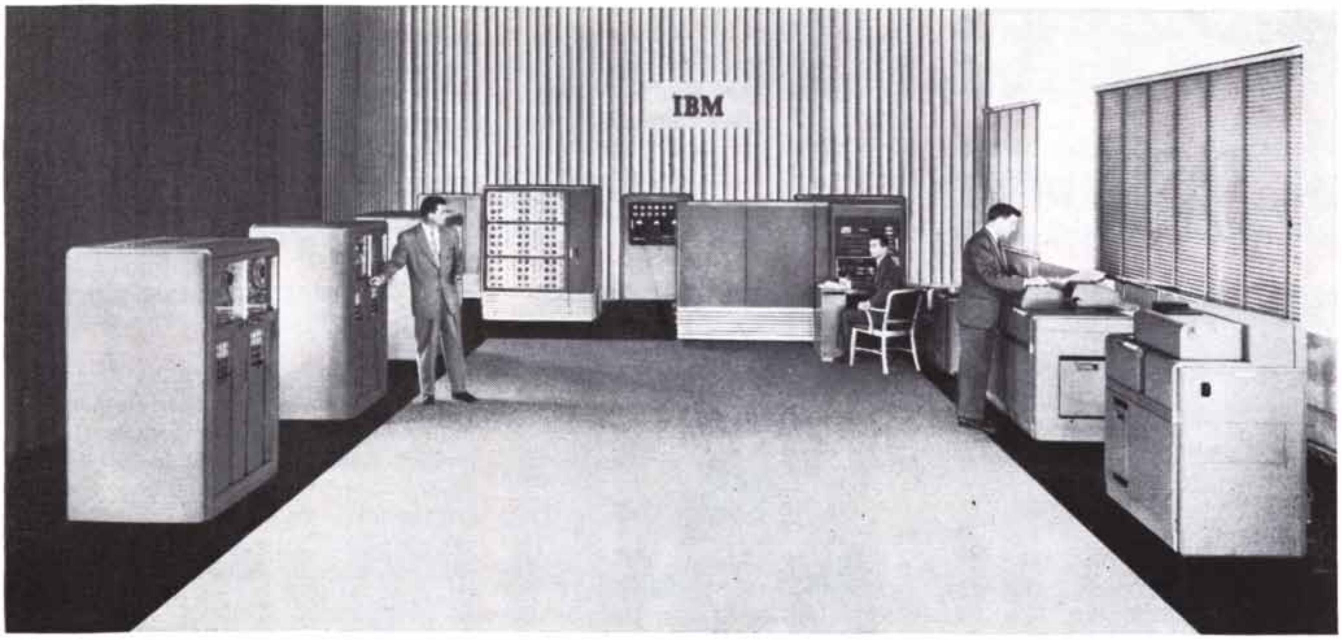

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STEROIDS

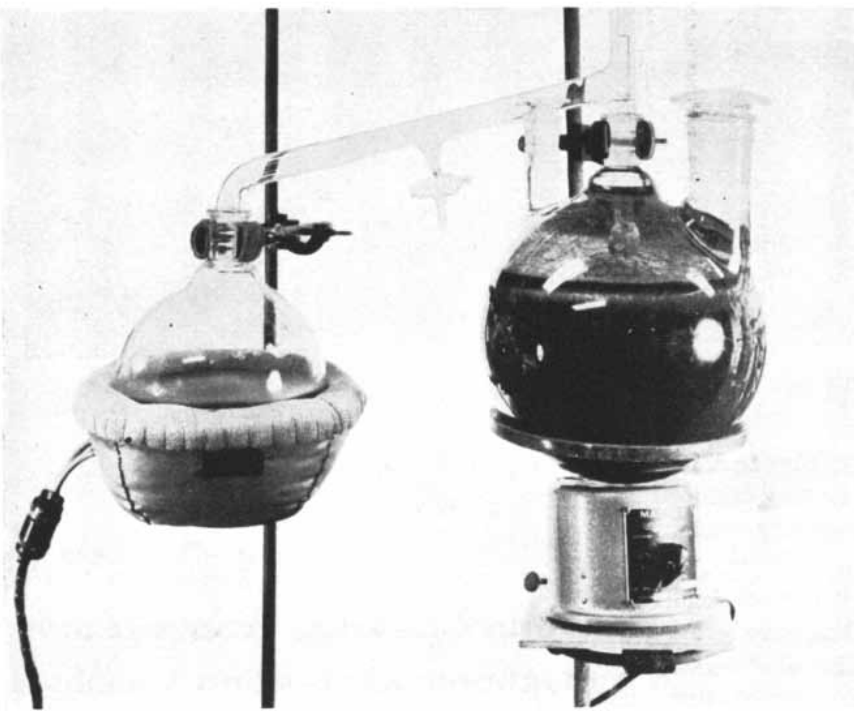
Substances as diverse in their effects as vitamin D, the sex hormones and cortisone are chemically very much alike. Their study has been one of the major efforts of modern chemistry

by Louis F. Fieser

The story of the steroids is one of the great epics of chemistry. Part of the story has come to public attention in the last few years as a result of the well-publicized struggle to synthesize the steroid hormone cortisone. But cortisone is only an episode in an enthralling history of research and discovery that has occupied more than half a century.

The steroids are a family of substances critically important to plant and animal life. They include the adrenal cortical hormones, the sex hormones, some of the vitamins, plant sterols such as ergosterol and animal sterols such as cholesterol. This array of substances, though so alike chemically that it is often difficult to tell them apart, exhibits a prodigious range of different activities.

The bile acids, for instance, aid digestion by emulsifying fats so that they can pass through the walls of the intestines. An interesting illustration of this function is that, if the normal flow of bile is obstructed by a tumor, the patient's blood does not absorb enough antihemorrhagic vitamin K_1 from his food, and an operation on such a patient is attended by the hazard that he may bleed to death unless he is given doses of the vitamin and bile salts to promote its absorption. A very different steroid function is illustrated by digitalis, a plant steroid obtained from foxglove, which stimulates the heart; still another example is a plant steroid alkaloid recently put on the market for treating high blood pressure. Certain other plant steroids rupture red blood cells and are therefore highly toxic to animals, even in extremely high dilutions. Yet many of these plant steroids, while capable of acting as powerful drugs in animals, seem to perform no direct function in the plants themselves.



STEROIDS ARE EXTRACTED from a mixture of plant materials in the flask at the right. The flask at the left contains ether, in which steroids are soluble. When the flask at the left is heated, ether vapor rises in a distillation column above the flask at the right. As the ether condenses it flows through a tube to the bottom of the flask at the right and rises through the heavier plant material. It then fills the flask at the right and, bearing the steroids, overflows into the flask at the left. The cycle of extraction may be repeated for days.

Cholesterol presents a still more interesting question. This substance appears in nearly all the tissues of vertebrate animals; it is particularly abundant in the brain and spinal cord. The higher animals synthesize considerable amounts of cholesterol and have an efficient chemical mechanism for delivering it to the tissues by way of the blood. Hence it would be reasonable to suppose that cholesterol carries out some vital function. If any direct function exists, it has not yet been discovered—though cholesterol does seem to play a harmful role in hardening of the arteries. In the absence of evidence of any direct function, it has been assumed that cholesterol serves as a precursor for building the usable steroids.

Animals may obtain steroids by eating other animals, but not by eating plants, because plant sterols are not absorbed through the intestinal wall. However, an animal readily makes its own sterols. It is capable of rapidly synthesizing the complex cholesterol molecule even from simple compounds such as acetic acid.

A sterol is a white, solid, fatty sub-

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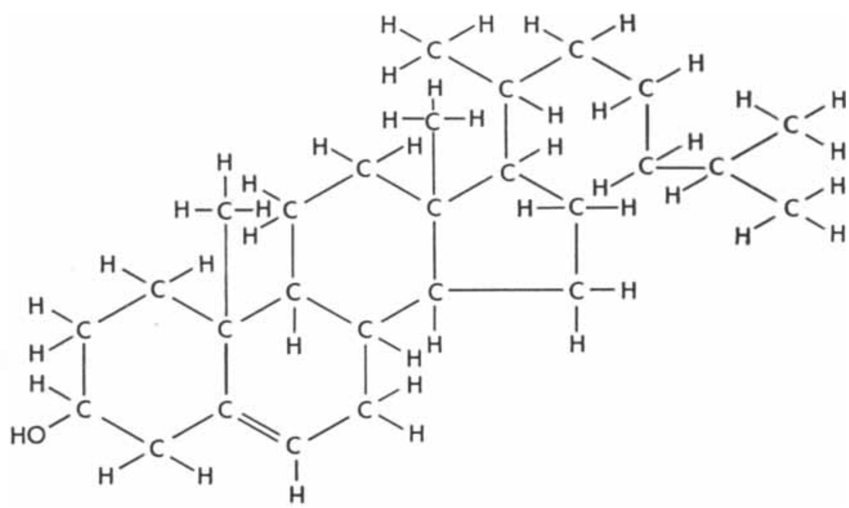
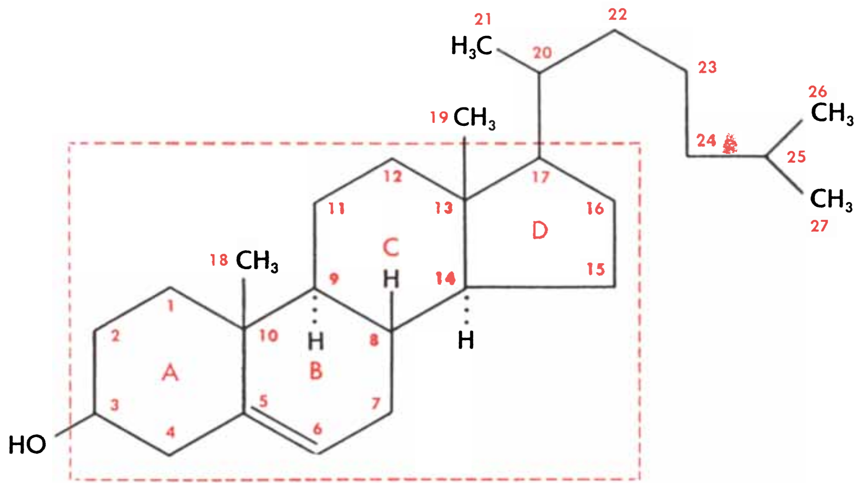
stance—a crystalline alcohol—which can be extracted from animal or plant tissues by a process requiring several steps. First the tissues' lipids (fatty materials not soluble in water) are extracted by an oil solvent. This extract is then boiled with alkali, which splits some of the lipids into glycerol and soap. The remaining "nonsaponifiable" lipids, which are principally sterols, are then captured by removal with an organic solvent. Cholesterol of about 98 per cent purity can be isolated with comparative ease from the brains or spinal cords of animals or from human gallstones, another rich source of the substance.

The subject of this article is the story of the achievement of chemists in elucidating the structure and shape of the various steroid molecules. The task presented a series of problems as baffling and complex as any encountered in the whole history of organic chemistry. Solution of the major problems came only after the concerted efforts of a large number of investigators working over a period of many years. The subject was so important and the achievements so brilliant that no fewer than six investigators in this field received Nobel prizes.



COMPLETE MOLECULAR STRUCTURE of cholesterol, a steroid abundant in the brain and spinal cord, consists of atoms of hydrogen (H), carbon (C) and oxygen (O). Seventeen of the 27 carbon atoms comprise the four rings that are characteristic of steroids.



ABBREVIATED MOLECULAR STRUCTURE of cholesterol emphasizes its salient features. The four rings are labeled with letters and the 27 carbon atoms with numbers. The solid lines indicate bonds that project upward; the dotted lines, atoms projecting to rear.

The Cholesterol Molecule

The father of sterol chemistry is Adolf Windaus of Germany, who, now 75 and retired, holds the admiration and affection of present workers in the field he pioneered. Beginning at the University of Freiburg in 1903, he devoted his career to sterol research. At the University of Göttingen he built up the world's leading school of sterol chemistry, and produced a succession of able students who, stimulated by his skill, enthusiasm and leadership, accounted for many of the discoveries and triumphs that followed his own.

Windaus started with cholesterol, partly because this substance had been isolated as early as 1770 and partly because it was the most easily obtainable of all the steroids. The formula of the cholesterol molecule is $C_{27}H_{46}O$. To understand the steroid problem it is necessary to picture the arrangement of this molecule and to review some of the fundamental concepts of organic chemistry. The cholesterol molecule is shown in the diagrams above, with the positions of its 27 carbon atoms numbered in the conventional way. (The numbering sequence is not entirely logical, because it was adopted at a time when the structure was not fully known.) Four rings of carbon atoms, plus a side chain branching from the fourth, form the skeleton of the molecule. One of the major complications of steroid research is that the same skeleton is present in a host of different sterols, which differ only in the way that hydrogen or oxygen atoms or groups of them are attached to the frame; indeed, there are many variants (isomers) of cholesterol with precisely the same total number of carbon, hydrogen and oxygen atoms.

In a carbon compound the four atoms or groups of atoms attached to each carbon atom are not in one plane but are angled from it in a three-dimensional arrangement; even in the simplest case, the methane molecule, they form a tetrahedral figure. Whenever the four atoms or groups attached to the four-valent carbon atom are all different, the molecule can have two mirror-image forms, known as optical isomers. A good example is the existence of two forms of lactic acid (in milk and in muscle), which are identical in all properties except that one rotates plane-polarized light to the right and the other rotates it to exactly the same degree to the left [*see models on page 55*].

The cholesterol skeleton has eight centers of asymmetry where such variations may occur. As a result there are 256 possible optical isomers of this molecule.

Cholesterol itself has four groups of atoms projecting on the front side of the molecule (upward from the plane of the paper as it is diagrammed here) and two hydrogen atoms projecting to the rear. The array of projecting groups on the front side forms a canopy protecting the

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molecule on that side. Hence most of its chemical and biological reactions occur by attack from the rear.

Dismemberment of the Molecule

At the turn of the century Windaus attacked the problem of unraveling the then unknown cholesterol molecule by breaking it down with oxidizing reactions. He found that he could open the first two rings for exploration by oxidizing respectively the hydroxyl (OH) group in the first ring and the double bond in the second ring. He also discovered two methods of splitting the side chain attached to the fourth ring: first he split off the entire eight-carbon chain with one method of oxidation, and later he found a way to remove just the three-carbon fragment at the end of the chain [*see diagram below*].

The latter reaction left a molecule with a five-carbon acidic side chain. And here Windaus came to a common ground with Heinrich Wieland of Freiburg, who for several years had been investigating the structure of the bile acids of cattle. The two men discovered that the five-carbon side chain Windaus obtained when he split the end group from cholesterol was identical with the side chain of bile acid. The bile acids, indeed, proved to be like sterols in most respects, differing from the sterols with which Windaus had been working only in details of arrangement of functional groups in the various rings.

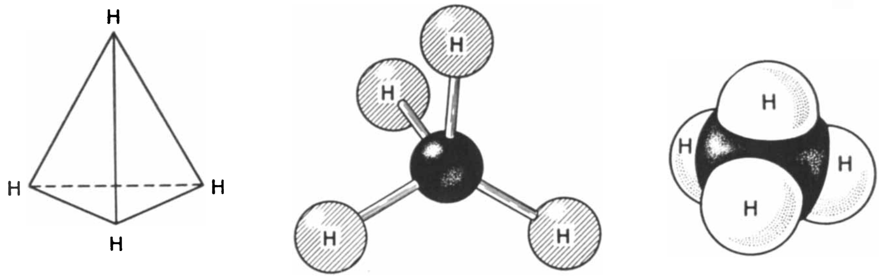
From this point on, Windaus' and Wieland's lines of research helped each other at every step forward. Although the road was hard and the going slow and uncertain, the two intrepid investigators held unwaveringly to their course. They indoctrinated a number of students in the new line of chemistry and made steady progress. By 1928 they were able to propose a tentative structural outline of the cholesterol molecule for which they jointly received the Nobel prize in chemistry.

Their formulation, as it turned out, was incorrect. The first indication that drastic revision was needed came from an unexpected source. Windaus and Wieland had supposed that the first three rings were clustered around a common carbon atom holding them together, which meant that the molecule should have a globular shape. But in 1932 the British physicist J. D. Bernal discovered by X-ray studies that the sterol molecule was long and thin. With this clue other English workers and Wieland himself were able by the end of the year to work out the correct structural formula.

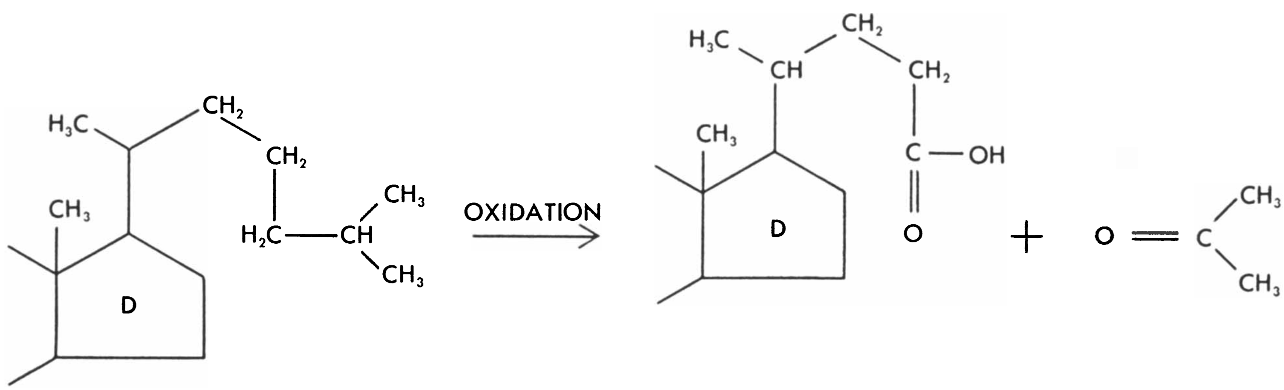
Vitamins

By this time sterol chemistry had emerged from the realm of purely academic interest to a position of practical importance in medicine. It entered into medicine in connection with vitamin D, the anti-rickets vitamin. It had been discovered that the active principle of this vitamin, found in fish-liver oils, was probably a steroid, and also that foods irradiated with sunlight could counteract a deficiency of the vitamin. The question arose: Would irradiation of an ordinary sterol convert it into an antirachitic steroid like the one in cod-liver oil?

Windaus and the Göttingen physicist R. Pohl attacked this problem with the help of ultraviolet spectroscopy, then just coming into use as a powerful tool for identifying molecular structures. They found that a substance present in minute amounts in some samples of cholesterol could be made active against rickets by irradiation, and that this activatable substance had an absorption spectrum very similar to that of ergosterol, a sterol in yeast. Windaus, and independently a research team at the National Institute for Medical Research in London, proceeded to isolate from irradiated ergosterol a new substance of high potency against rickets which was named vitamin D_2 [*see formulas on page 56*]. Irradiation of ergosterol effects a series of chemical changes yielding vari-



METHANE MOLECULE illustrates the fact that atoms attached to carbon project in three dimensions. The four hydrogen atoms of methane (CH_4) are arranged in a tetrahedron (*left*). The arrangement can be represented with pegs and balls (*center*) or with spheres made to conform to the known distances between the atoms of carbon and hydrogen (*right*).



OXIDATION OF CHOLESTEROL provided much information about its structure. When cholesterol (*partly diagrammed at left*) was oxidized in one experiment, it yielded acetone (*right*) and a substance with an acid side chain of five carbon atoms (*center*).

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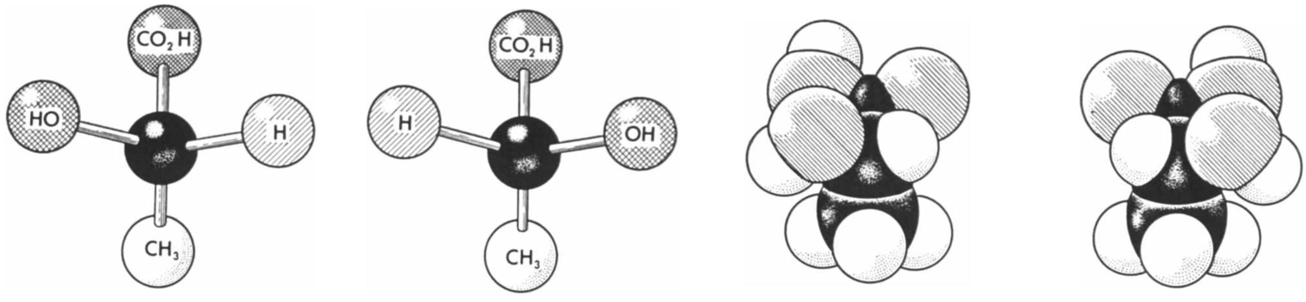


LACTIC ACID MOLECULES illustrate geometrical isomers. The peg-and-ball model at the left represents the molecule of lactic acid ($C_3H_6O_3$) as it is found in milk; the peg-and-ball model second from the left represents the molecule of lactic acid as it is found in muscle. The corresponding sphere models are third and fourth. The two molecules are chemically and physically identical except that one rotates plane-polarized light to the right and the other rotates it to the left. In short, the molecules are mirror images of each other.

ous isomers, of which only vitamin D_2 is active against rickets.

It seemed reasonable to suppose that D_2 was identical with the active principle in fish-liver oils, until Windaus and his associates showed that certain variants differing only slightly from D_2 were just about as potent. The most interesting variant was one prepared from cholesterol by a series of chemical operations which involved placing a double bond at the 7,8 position, as in ergosterol, and then irradiating this molecule (7-dehydrocholesterol). The product [*formula at lower right on next page*] had an antirachitic activity comparable in strength to that of D_2, as measured by bio-assay in rats. It was named vitamin D_3.

Was the natural vitamin in fish-liver oils more closely related to cholesterol than to ergosterol? This question, posed by Windaus' synthesis of D_3 and by biological investigations in the U. S., was brilliantly resolved in 1936 by Hans Brockmann of the Göttingen laboratory. By means of the sensitive method of chromatography, he isolated the vitamin of tuna-liver oil and proved that it was identical with Windaus' vitamin D_3.

Vitamins D_2, made from ergosterol, and D_3, made from cholesterol, have about the same activity against rickets in rats, but in chicks D_3 is far more potent. D_2 is still used for treating children with rickets, because it is easier to make and has satisfactory potency in human beings; however, for chickens, which are susceptible to rickets, D_3 is now manufactured in substantial quantities, both from cholesterol and from fish-oil concentrates.

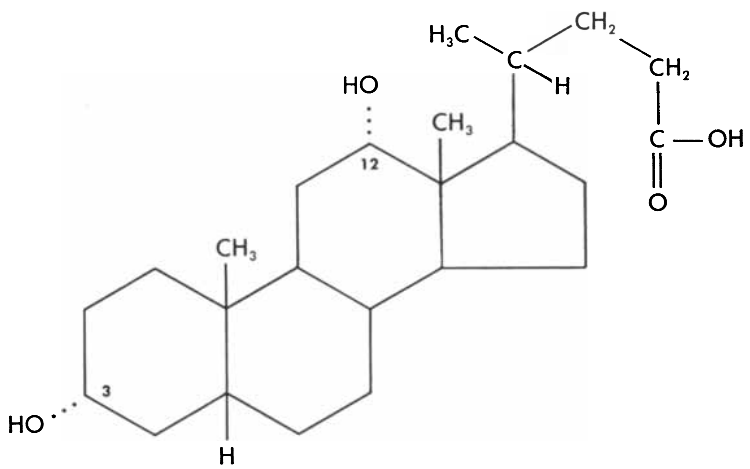
The Sex Hormones

The road to chemical identification of the sex hormones was opened in 1927 when S. Aschheim and Bernhard Zondek, then in Berlin, discovered that the urine of pregnant women contained considerable amounts of a hormone which produced sexual heat when tested in mice or rats. Windaus was asked by a German chemical firm to explore this substance. Involved at the time in the vitamin D research, he elected to turn over the new problem to a promising young student named Adolf Butenandt. The student plunged into the task of isolating the hormone with the help of a young biologist, Erika von Ziegner, who later became his wife. In the meantime Edward A. Doisy, of the St. Louis University School of Medicine, also set out to identify the active substance. Working independently, both Butenandt and Doisy succeeded in 1929 in isolating the first known sex hormone—estrone.

With keen insight Butenandt proceeded by a roundabout route to arrive at a shrewd guess concerning the chemical structure of estrone. In pregnancy urine there was found an inactive companion of estrone, called pregnanediol. Butenandt proved that pregnanediol was related to cholic acid, a component of bile, by breaking both down to a common product. Thus he showed that pregnanediol was a steroid. By further adroit experimentation he related its companion, estrone, to bile acid and then deduced the correct structure of estrone.

It developed that estrone was not the true estrogenic hormone secreted by the ovaries but a transformed product of it excreted in the urine. The actual hormone, first made from estrone and later isolated from sow ovaries by Doisy (who extracted 12 milligrams of the substance from four tons of ovaries), is believed to be estradiol [*see formulas at top of page 57*].

The discovery and analysis of the male sex hormone testosterone followed a similar pattern. In 1931 Butenandt and Kurt Tscherning isolated from 15,000 liters of male urine 15 milligrams of a hormonal substance which they named androsterone. From this tiny pile of crystals, hardly enough to cover the tip of a small spatula, Butenandt derived a great deal of information about the nature of the molecule. He tentatively deduced its structure, and his deduction was independently proved correct by Leopold Ruzicka of Zurich, who produced androsterone by splitting off the eight-carbon side chain from a deriva-



STRUCTURE OF CHOLIC ACID, found in the bile of cattle, includes the same side chain found in the oxidation product of cholesterol. The bile acids resemble steroids in other ways.

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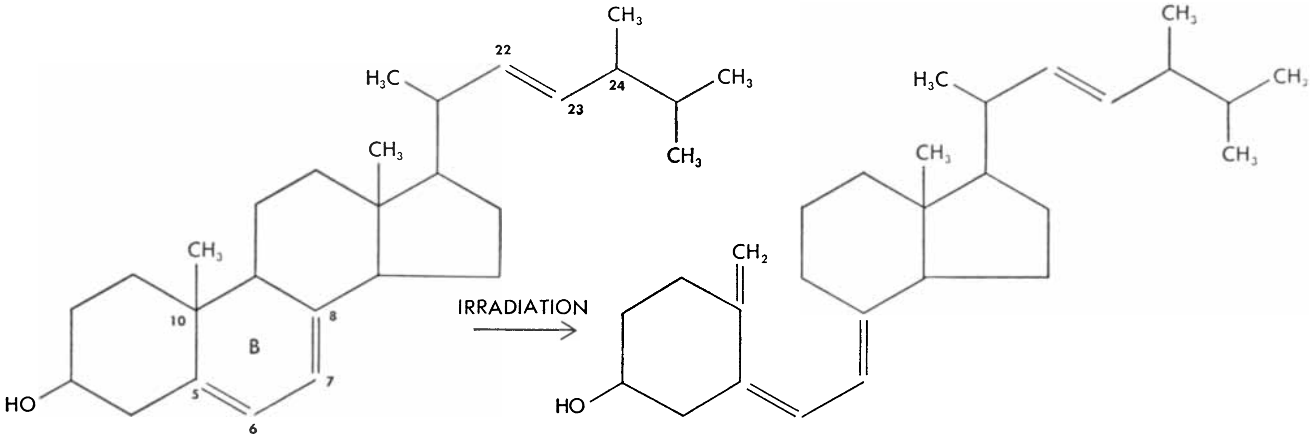
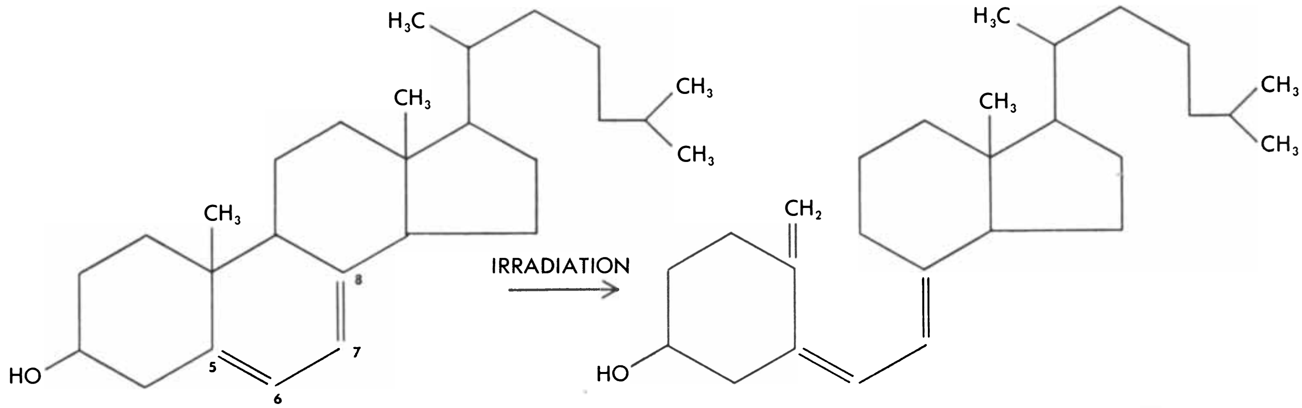


VITAMIN D_2 (*right*) was made from ergosterol (*left*), a steroid found in yeast, by exposing it to ultraviolet radiation. Ergosterol differs from cholesterol in having an extra methyl group (CH_3) at position 24 and double chemical bonds at positions 7, 8 and 22, 23.



VITAMIN D_3 (*right*) was made from 7-dehydrocholesterol (*left*), also by exposing it to ultraviolet radiation. The 7-dehydrocholesterol was prepared synthetically from cholesterol by a process adding a double chemical bond between positions 7 and 8.

tive of cholesterol through oxidation.

Androsterone was obtainable only in very small amounts, either by synthesis or by extraction from urine, but Butenandt, Ruzicka and others soon succeeded in synthesizing a related substance which could be produced in more plentiful yield. This substance, named dehydroepiandrosterone, was made from cholesterol by burning off the side chain while the essential hydroxyl group attached to the first ring and the double bond at the 5,6 position in the second ring were protected by stable chemical combinations at those positions. With the more plentiful working material at hand, the investigators were able to synthesize a number of interesting products, some of which proved more potent than androsterone in hormonal activity. Meanwhile Ernst Laqueur in Amsterdam reported that he had isolated from steer testes a potent hormone which he called testosterone. Butenandt and Ruzicka shortly afterward synthesized testosterone from dehydroepiandrosterone. It became clear that testosterone was the true hormone; androsterone and dehydroepiandrosterone were metabolites of the hormone excreted in the urine [*formulas in center on opposite page*]. A practical method is now available for converting dehydroepiandrosterone into testosterone in 81 per cent yield.

In 1934 four research groups isolated from the corpus luteum tissue in sow ovaries the pregnancy hormone—progesterone. Butenandt obtained 20 milligrams of the hormone from the ovaries of 50,000 sows. The structure of progesterone, very similar to that of testosterone [*formulas at bottom of opposite page*], was soon inferred from its chemical properties and ultraviolet analysis. Butenandt promptly synthesized progesterone by two methods, one of which was the oxidation of a substance called pregnenolone, a by-product of the production of testosterone from cholesterol.

Hormones from Plants

At this dramatic point in the development of the chemistry of the sex hormones, there came a break in another field which was to open a more fertile route for production of the hormones. The plant steroids had been relatively neglected, though Windaus and others had published occasional reports on them. After the establishment of the structure of cholesterol in 1932, however, the new surge of intensive research embraced active substances in plants as well as in animals. Attention was focused on the cardiac glycosides—extracts from plants which had been known for centuries as poisons. Particularly interesting was digitalis, the heart stimulant that had been used since 1785, when it was introduced as a treatment for dropsy. It was believed that a part of the active principle of this drug might be a steroid, and Windaus delegated the problem to one of his pupils, Rudolf Tschesche. At the Rockefeller Institute for Medical Research W. A. Jacobs and R. C. Elderfield also investigated the same question.

Within two years the two independent investigations established that steroids

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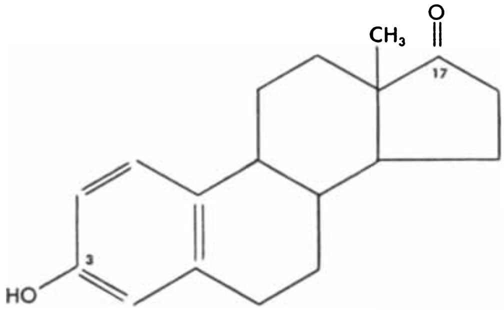
were indeed present in the active components of digitalis. The steroid here is attached to a sugar. Digitoxin, for example, contains a steroid of 24 carbon atoms to which is linked the rare sugar digitoxose (making the large molecule somewhat soluble in water). The steroid part has a skeleton like that of a bile acid, but one major difference is that the side chain is coiled into a ring [*see formula on next page*].

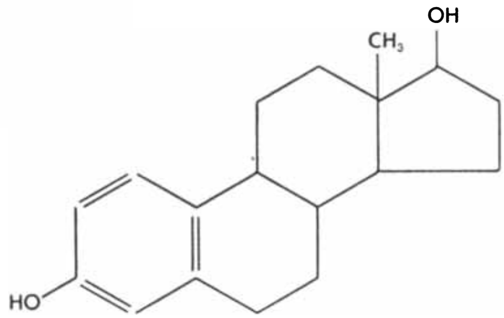
The digitalis steroids are rather special, but steroids with sugars attached are very common in the plant world. One class of these substances is known as the saponins, because water solutions of them foam like soap when shaken. The steroid part of a saponin is called a sapogenin. The structure of sapogenins, on which Windaus and his pupils and successors had worked for many years, was finally clarified by Russell E. Marker and his group at the Pennsylvania State College in an extraordinary series of studies between 1939 and 1947. The most interesting of these substances is diosgenin, which has a skeleton remarkably like that of cholesterol, with 27 carbon atoms and a double bond between the fifth and sixth carbons [*see formula at bottom of page 59*]. The discovery of this structure at once suggested that diosgenin would be useful for producing sex hormones, for which more and more uses had been found in medical therapy.

The possibility of manufacturing the hormones from plant extracts excited Marker. Production of these hormones from animal sources was still difficult and expensive, in spite of new methods of synthesis that had been discovered by various investigators. Diosgenin was abundantly available from yams (plants of the genus *Dioscorea*), and Marker in field trips to the southern U. S. and Mexico had found many other plant sapogenins (which he whimsically named for current friends and enemies: rockogenin for the late Dean Frank "Rocky" Whitmore of Pennsylvania State College, kammogenin for Oliver Kamm of Parke Davis & Company, nologenin for Carl R. Noller of Stanford University, fesogenin for the writer of this article).

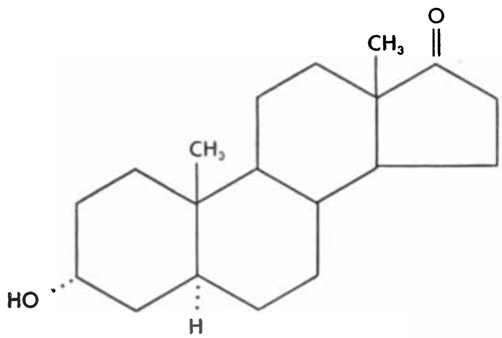
Marker showed that diosgenin could easily be converted into pregnenolone, already known as a building material for progesterone. A Mexican firm named Syntex was set up to manufacture progesterone from Mexican yams. Before long Marker fell out with the management of the company and was replaced by Georg Rosenkranz, a young Hungarian-born chemist who had trained



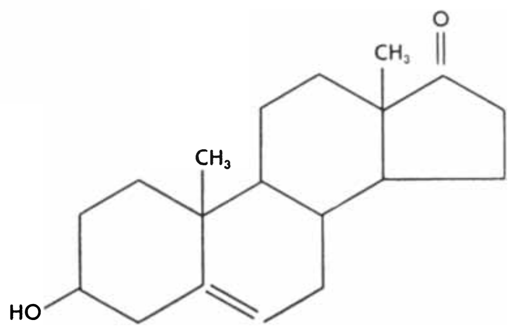
ESTRONE



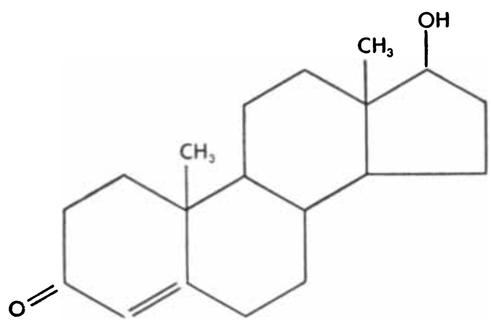
ESTRADIOL



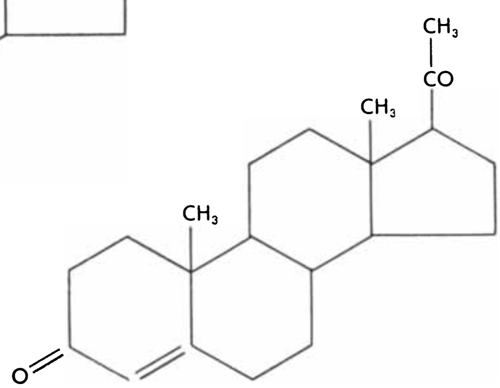
ANDROSTERONE



DEHYDROEPIANDROSTERONE



TESTOSTERONE



PROGESTERONE

SEX HORMONES share the steroid configuration. Estrone is a female hormone. Estradiol is a variant of it with higher potency. Androsterone, dehydroepiandrosterone and testosterone are male hormones. Progesterone is the female hormone found in pregnant women.

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with Ruzicka in Zurich. Since Marker had not disclosed some of the essential bits of know-how to his associates, Rosenkranz had to work out the process anew. He succeeded in rediscovering the missing links, developed a system of chemical manufacture based on the training of unschooled young women to perform specific operations, and soon achieved production of progesterone on a scale surpassing previous performance. He also found a way to produce testosterone, as well as progesterone, from pregnenolone.

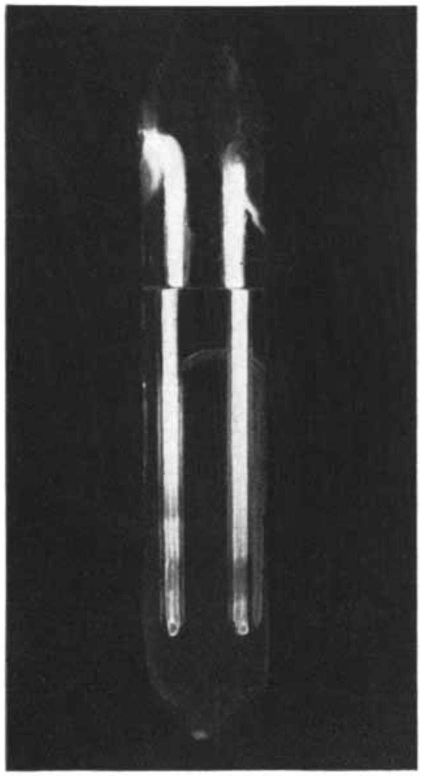
Rosenkranz recruited an able research staff of Mexican and foreign chemists, and he brought in as his lieutenant Carl Djerassi, a young chemist born in Bulgaria and trained at the University of Wisconsin. A first fruit of the pioneering research instituted by Rosenkranz and Djerassi was a new process for production of estrone, which involved conversion of the male hormone testosterone into the female hormone estradiol.

Cortisone

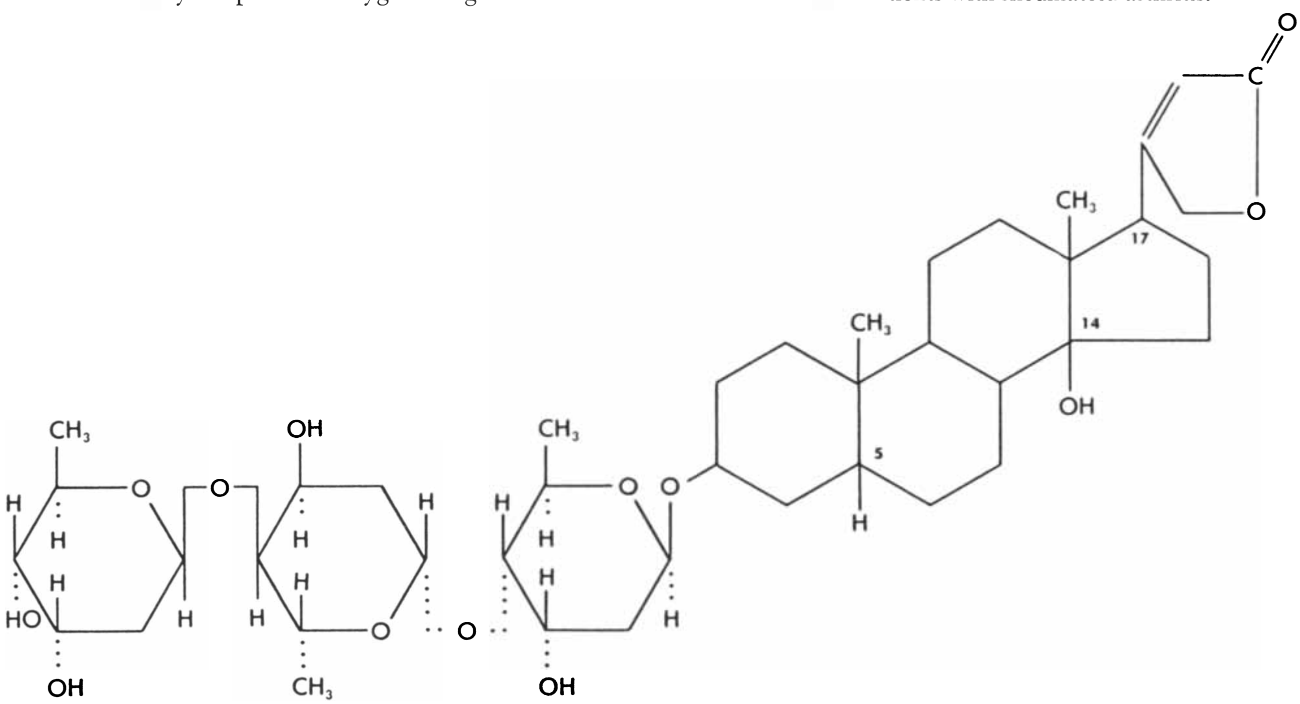
The story of the adrenal cortical hormones is so well known that I need not go into it at length here [see "Cortisone and ACTH," by George W. Gray; Scientific American, March, 1950]. Ever since the most active of these substances, now known as cortisone, was isolated in the laboratory of E. C. Kendall at the Mayo Clinic in 1936, the key problem in its synthesis has been to find some nonlaborious way to place an oxygen atom at the comparatively inaccessible 11 position in the third ring [*see formula on page 60*]. Several workable solutions are now at hand, but for close to a decade the armies of researchers who attacked the problem found it completely baffling.

In 1942 vague rumors (now known to be unfounded) that the Luftwaffe was employing adrenal cortical hormones to improve pilots' endurance and resistance to blackout prompted the National Research Council to contract with several laboratories for research on the synthesis of Compound E (cortisone). The first objective was to introduce oxygen at position 11. Desoxycholic acid from bile seemed the best starting material for this purpose, because it carries a hydroxyl group at position 12, offering the possibility that the oxygen atom might be transposed to the neighboring 11 position. A practicable method of effecting the transposition, involving some amazing new chemistry, was devised by Kendall and his group. This made feasible production of Kendall's Compound A, which contains oxygen at position 11 but does not have Compound E's added feature of a hydroxyl group at position 17. But when, after considerable effort and expense, Merck & Company produced a quantity of Compound A by this method, the substance proved completely useless in clinical tests.

Meanwhile Lewis H. Sarett, a young Princeton-trained chemist at Merck, devised a method of introducing oxygen at position 17 and succeeded in synthesizing cortisone. After more than two years of further research and chemical labor, Merck produced enough cortisone for medical trial. The result was the now classical investigation of Kendall and Philip S. Hench at the Mayo Clinic which produced dramatic relief of patients with rheumatoid arthritis.



IRRADIATION of steroids is accomplished in vessel containing two ultraviolet lamps.



DIGITOXIN, a plant extract used in the treatment of heart disease, consists of a sugar (*left*) and a steroid (*right*). The steroid resembles a bile acid except that the side chain is a ring, and the carbon atom at position 14 bears an OH group and is differently oriented.

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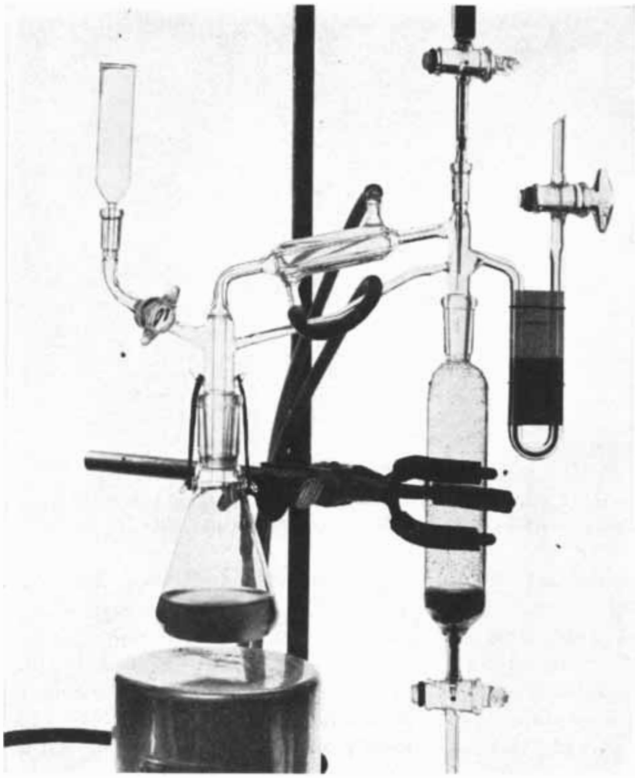
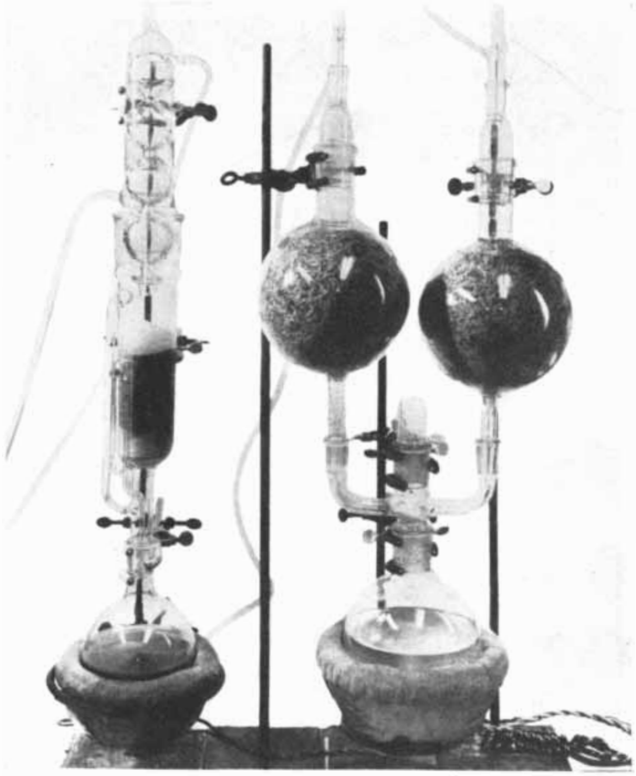
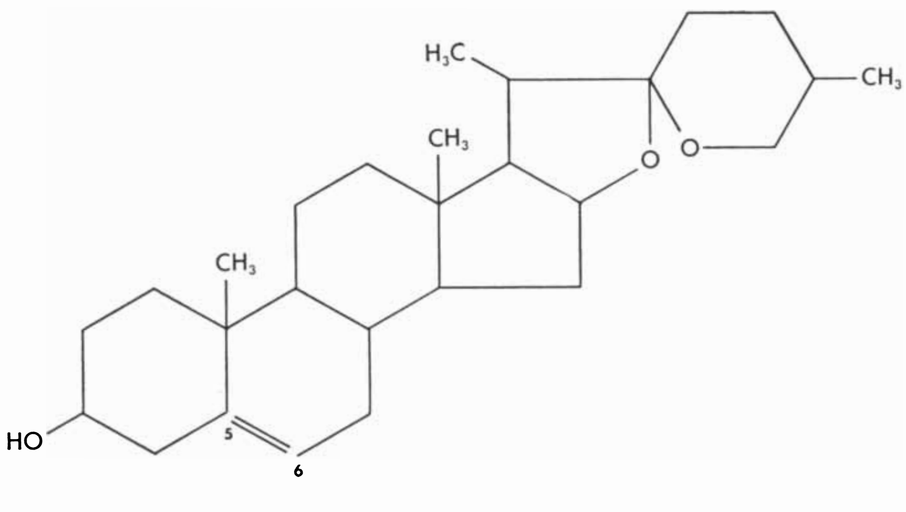


HYDROGENATION of a steroid in the vessel at left measures the number of double bonds, which take up hydrogen, in the molecule.



EXTRACTION of steroids in cranberry skins is accomplished in this apparatus. The skins are in the round vessels at upper right.

Although the yield of cortisone from animal bile was pitifully small, Merck at once undertook plant-scale production. The task was without precedent in modern chemical technology. The process, starting with bile acid and ending with pure cortisone, involved 32 separate steps. Max Tishler and his development group at Merck performed miracles of chemical technology, first to produce cortisone at all, and then to introduce a succession of improvements which reduced the price from $200 per gram to less than $20 per gram.



DIOSGENIN is also found in plants. Because the skeleton of its molecule is the same as that of cholesterol, it is uniquely useful for the synthetic production of animal hormones.

But the demand for cortisone increased and the supply of available bile began to run out. Consequently a problem already brilliantly solved had to be attacked again from some new angle. How synthesize cortisone from something other than a bile acid? Workers in the field grasped at a substance called sarmentogenin, which had been isolated in 1929 from some unknown plant seed. This molecule carries a hydroxyl group at the mystical position 11, and presumably it could be converted into cortisone without great difficulty. Expeditions to South Africa in search of sarmentogenin went out from the Swiss laboratory of Tadeus Reichstein, a leader in cortisone research, from the U. S. Public Health Service, from the National Institute of Medical Research in London, from the Merck laboratory. A plant source of sarmentogenin was found, and Reichstein recently reported its conversion to cortisone, but interest in it has diminished because of the emergence of more promising approaches.

Several groups sought a route to cortisone from the abundantly available natural sterols, particularly cholesterol, ergosterol and diosgenin. From these substances Windaus had produced certain compounds with double bonds at the 7,8 and 9,11 position. In retrospect it seems that it should have been easy to

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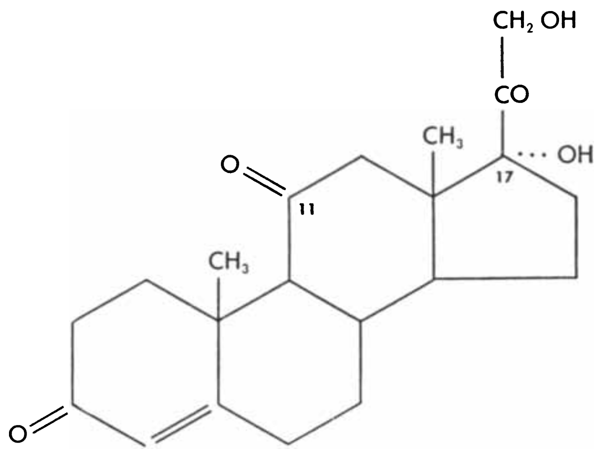

CORTISONE also has the steroid skeleton. It is characterized by the double-bonded oxygen atom attached at position 11 and by the OH group projecting to the rear at position 17.

make use of the double bond to attach an oxygen to the 11 position, but many chemists worked on the problem for two years before, in May, 1951, it suddenly broke. Within a few months success in attachment of oxygen at position 11 by various processes starting with Windaus' compounds was reported by five research teams—the writer's at Harvard University and groups at Merck, Syntex, Zurich and Glasgow.

In the same year Robert B. Woodward and his associates at Harvard made a break-through toward total synthesis of cortisone from simple materials. Woodward synthesized a steroid, the first ever manufactured outside a living organism, with a double bond at the 9,11 position. Then he carried the synthesis three steps further to form a type of molecule which, as it happened, my associates S. Rajagopalan and Hans Heymann had already succeeded in endowing with an oxygen at the 11 position. From there it did not take long to achieve total synthesis of cortisone. A year later Sarett and his group at Merck reported another total synthesis, beautiful and efficient, which extends all the way from simple starting materials to synthetic cortisone identical in every respect with the natural hormone isolated from the adrenal gland.

But all these approaches yield at present to new processes which have enlisted microorganisms to do the critical work of placing oxygen at position 11. The Upjohn Company was the first to announce discovery of a specific fungus that converts steroids into 11-ketosteroids (oxygenated at the 11 position). Then Syntex and E. R. Squibb & Sons found other microorganisms capable of the same performance.

The six chemists who received Nobel awards for their work in steroid research were Windaus, Wieland, Ruzicka, Butenandt, Kendall and Reichstein. Their efforts and those of the great army of their fellow workers, only a few of whom could be mentioned in this brief review, have cleared up the chemistry of practically all the known steroid hormones and vitamins. But the steroids still present many thorny challenges. How the body manufactures sterols and steroid hormones remains a mystery; it has just begun to be studied by tracer methods. Nothing is yet known about how steroids combine with their protein carriers for transport in the blood. The whole question of how the chemical structure of steroids is related to their physiological activity remains a subject for exploration.

An important unsolved problem is the function of cholesterol in the animal body. If cholesterol is the essential building material for the bile acids, steroid hormones and vitamin D_3, why does the body produce huge amounts of the precursor to make only trace amounts of the final products? Is cholesterol perhaps just an incidental by-product of the manufacture of the hormones and vitamins? There are some indications that cholesterol or a derivative of it may be involved in degenerative diseases. Cholesterol is found deposited along the walls of blood vessels in victims of hardening of the arteries and of atherosclerosis. Several recent reports suggest that a high level of cholesterol or of a cholesterol-protein complex in the blood may lead to this type of disease. Other lines of experimentation have suggested the possibility that under certain circumstances cholesterol or a companion substance may initiate cancerous growth.

It seems reasonable to hope that advances in the field of preventive medicine may emerge in the next chapter of steroid research.

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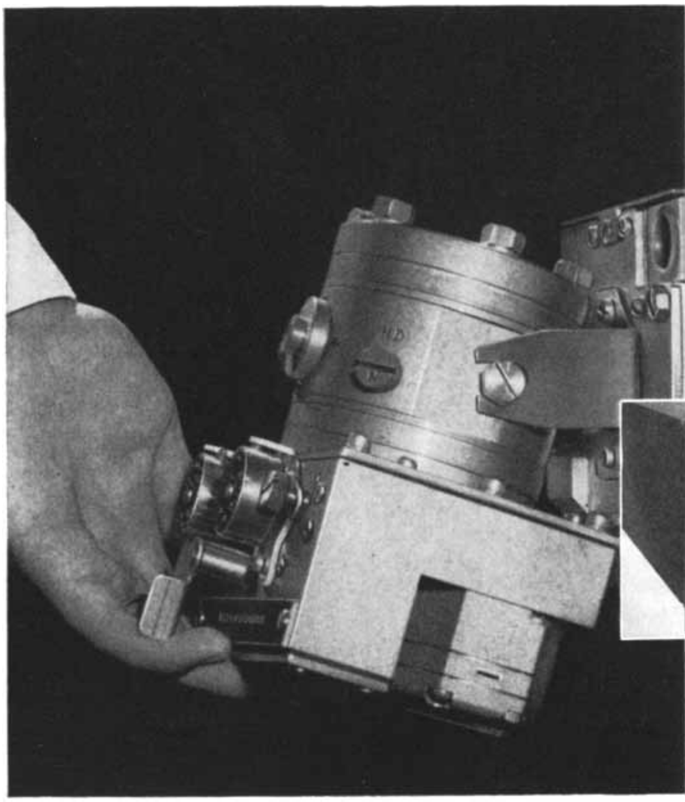

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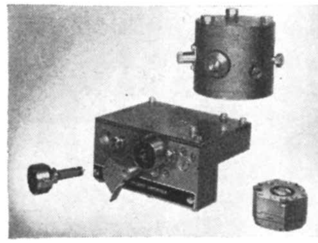

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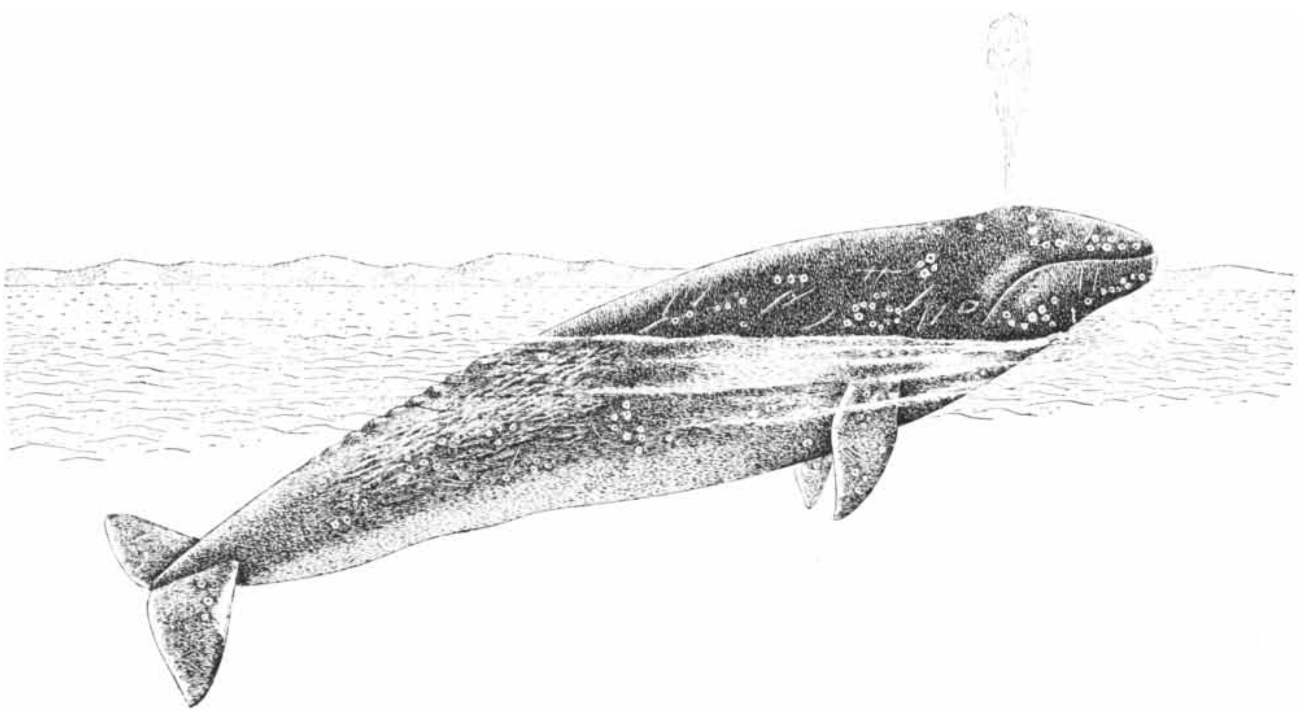
The Return of the Gray Whale

All winter long these smallish whales parade down the Pacific Coast to their breeding grounds. They have twice come back from the brink of extinction, which presents several interesting biological questions

by Raymond M. Gilmore

On almost any clear weekend day this winter, hundreds of people will gather on the high summit of Point Loma over San Diego Bay to watch a rare sight. What they see is a succession of small puffs of vapor spurting from the sea, the rounded line of a long, dark back, perhaps the flirt of a sharp, black butterfly-tail. These signs mark the passage of a gray whale. Nowhere else in the world can city dwellers see at their doorstep a natural spectacle such as the Public Whale Watch at San Diego sponsored by the National Park Service. All winter long, from late December through February, the gray whales parade by in a long line, a mile or so offshore. They are coming home to breed, after a journey of 12,000 miles or more to their Arctic summer feeding grounds and back.

Twice almost exterminated by man, the gray whale is back by the thousands again. If it is an object of fascination to the spectators on Point Loma, it is no less so to marine biologists and conservationists. How did the gray whale survive and rebound to such numbers, after being reduced by whalers to a population of probably no more than 100 only 20 years ago? Why does it make its tremendously long spring migration to the Arctic, when there seems to be plenty of food in its mating grounds off Lower California—or why does it come back each breeding season, when a relative,



GRAY WHALE (*Rhachianectes glaucus*) is about 40 feet long. The color of its mottled skin ranges from very light gray to almost black. It feeds on plankton by filtering water through blades of whalebone or baleen hanging down from each side of its upper jaw.

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the Arctic right whale, stays in the North? Will the gray whale population continue to multiply, now that it is protected from hunters by international law? Students of the species have recently looked into some of these questions closely, even to taking censuses of the gray whales from the shore and from the air by plane and helicopter.

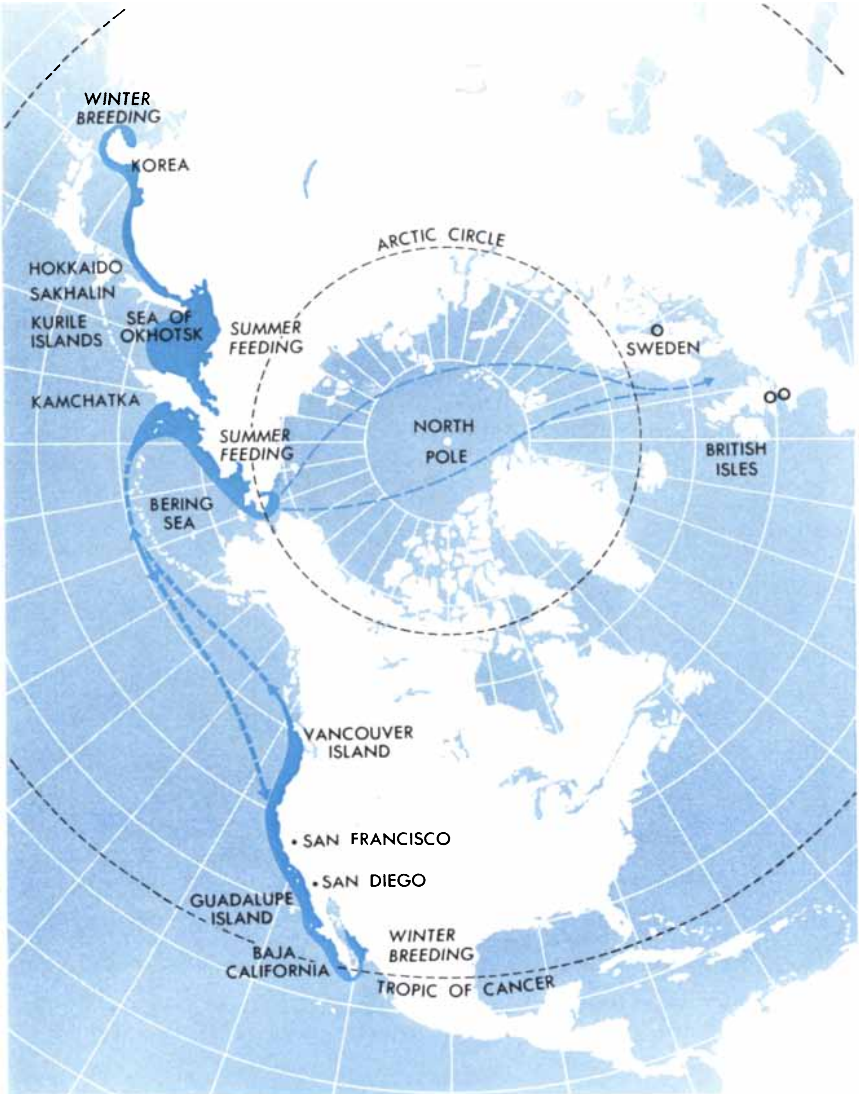
The gray whales concentrate their reproduction each spring in certain bays and lagoons of northwestern Mexico. One of the peculiarities of the creatures is that they mate and calve only within those few retreats. Their long-range survival therefore seems somewhat in doubt, since a fall of only a few feet in the sea level, drying up their breeding places, might wipe out the species unless it changed its breeding habits.

The gray whale is a moderate-sized cetacean about 40 feet long—considerably smaller than the giant blue and finback species. It is a hardy animal, as its long, difficult yearly travels testify. All summer the gray whale lives in the polar waters off Kamchatka and the Bering Straits. There it fattens on the abundant large plankton, especially euphausiid shrimps. When the days shorten and late autumn's cold settles down, the whales set off for the Mexican waters some 6,000 to 7,000 miles away. As to why they make this tremendous journey, we can find no answer better than that their inherited habits must be stronger than the environment.

The whales push through storm and calm across the vast northern Pacific toward the North American coast, wasting little time to feed in transit. This part of their trip has never been observed by man. Their route is figured out simply by putting together the two ends of the puzzle: gray whales disappear from the Bering Sea and as mysteriously reappear off the North American coast. They hit the coast at Oregon and northern California and thereafter hug it closely all the way down to Mexico, probing the shoreline for the entrances to their accustomed breeding lagoons.

Just why they come in near the coast so far north of their destination is a question. Their route follows almost exactly a great circle course from the Aleutians; perhaps they are accurate navigators. On the other hand, it is possible that they used to breed along the coast north of their present places in warmer times.

After the gravid females have relieved themselves of their ponderous burdens (a full-term calf is 12 to 14 feet long), and the other females and adult males



DISTRIBUTION of the gray whale is outlined in dark blue on this map. There are two separate populations of gray whales: the Korea population and the California population. The latter migrates (*heavy dotted lines*) between the Bering Straits area, where it feeds, and Lower California, where it breeds. Remains of gray whales (*small circles*) have been found in Europe, suggesting that at one time some migrated across the Arctic (*light dotted lines*).

have performed the vital act of procreation, the gray whales set forth again to the Arctic in March and April. They have taken almost no rest, and are much thinner than when they arrived. On the way north along the coast they scatter more widely than on the way down, because they are no longer searching the coast for their havens. But many rendezvous in a great mass off Vancouver Island before they disappear into the northern Pacific.

One might suppose that the arduous annual migration would be a weak link in the life cycle of the species—that many would fall by the wayside. But there is no evidence of any high mortality during the gray whale's journeys. A much more vulnerable part of its cycle is its dense yearly concentration—almost unparalleled among whales—along the California and Lower (Baja) California coasts. In the late 19th century men in whaleboats slaughtered the gray whale in its calving lagoons and its narrow coastal migration path. Again in the 1920s and 1930s, when the herd had begun to come back, it was all but destroyed, this time more efficiently, by whaling factory-ships shooting explosive harpoons from cannon.

From an estimated population of more than 25,000 in 1840 the herd was reduced to perhaps about 100 by the late 1930s. In its current comeback it now numbers some 3,000 and is increasing. For the present the species seems safe,

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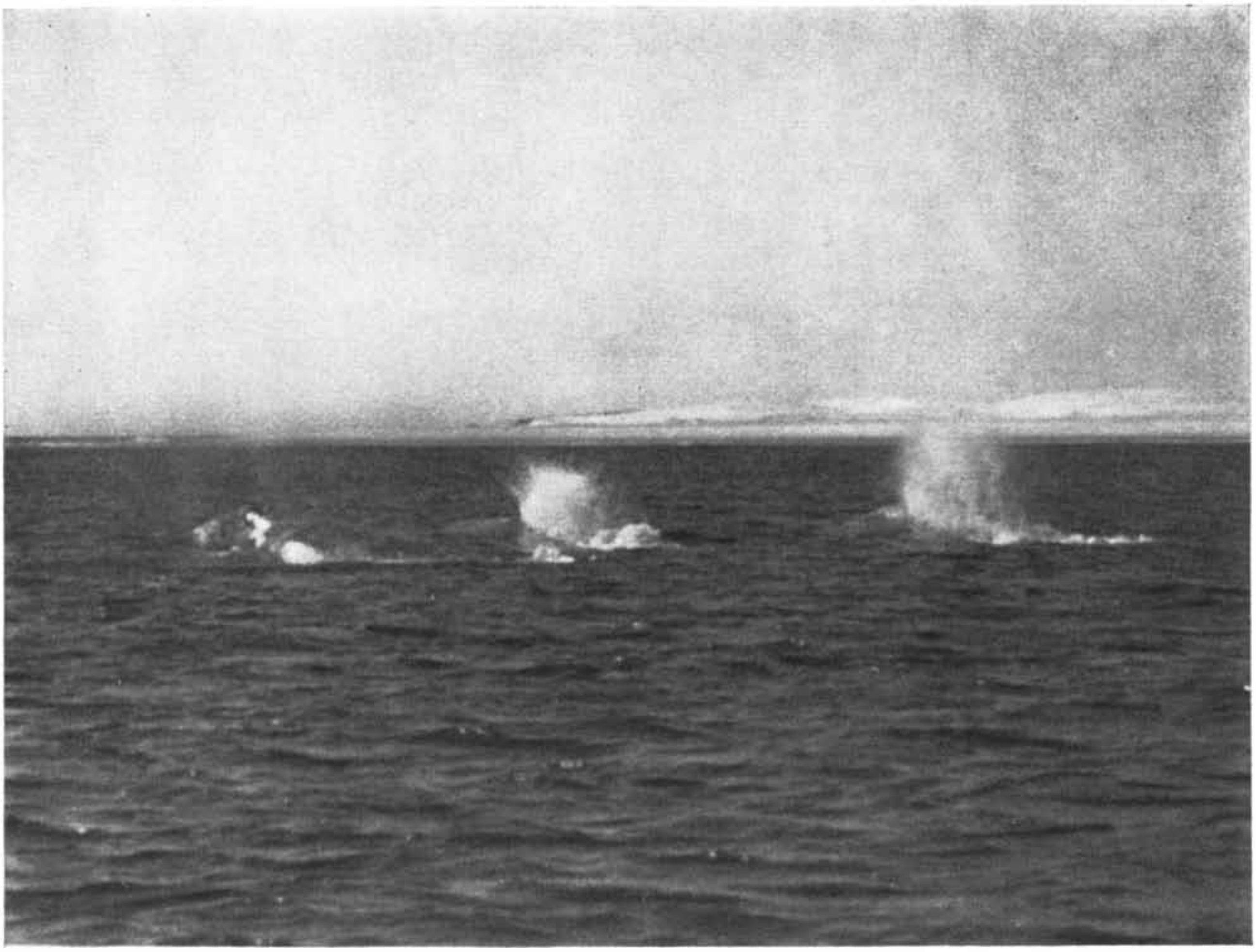
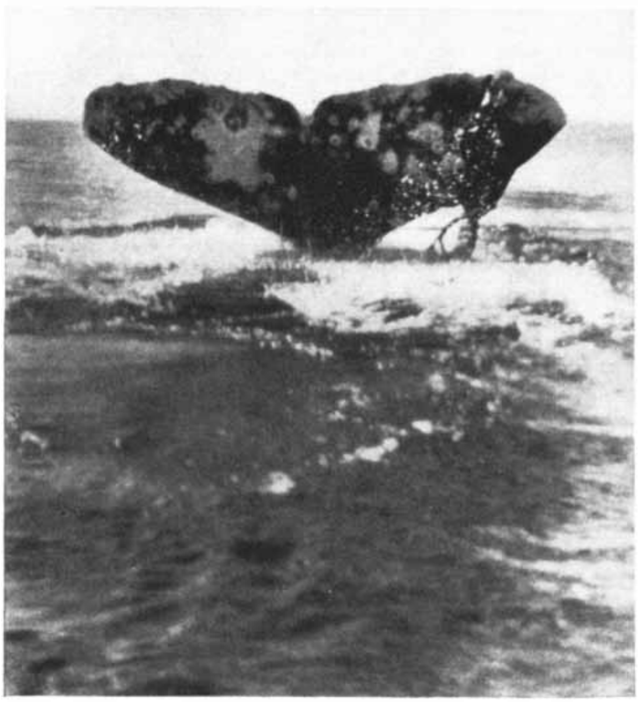


THREE GRAY WHALES, two of them emitting their characteristic puffs of vapor, were photographed by Gilmore as they fled across Scammon Lagoon on the Pacific coast of Lower California. He was pursuing them in a rowboat propelled by an outboard motor.



FLUKES of a gray whale flip into the air off La Jolla, Calif. They are encrusted with barnacles and actually overgrown with kelp.

HEAD of a gray whale bobs out of the water as it peers curiously at a rowboat in Scammon Lagoon. The lower jaw is to the left.

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thanks to the prohibition against hunting it and to its secure havens in the sheltered lagoons that fringe the uninhabited deserts of Lower California. But its situation remains fundamentally precarious. Its breeding lagoons are smaller than they once were; some of them today are salty wastelands left by the receding water to dry in the burning sun. Moreover, the whales have been driven from three of its largest bays by heavy boat traffic. Indeed, the gray whale is a relict species in a shrinking environment.

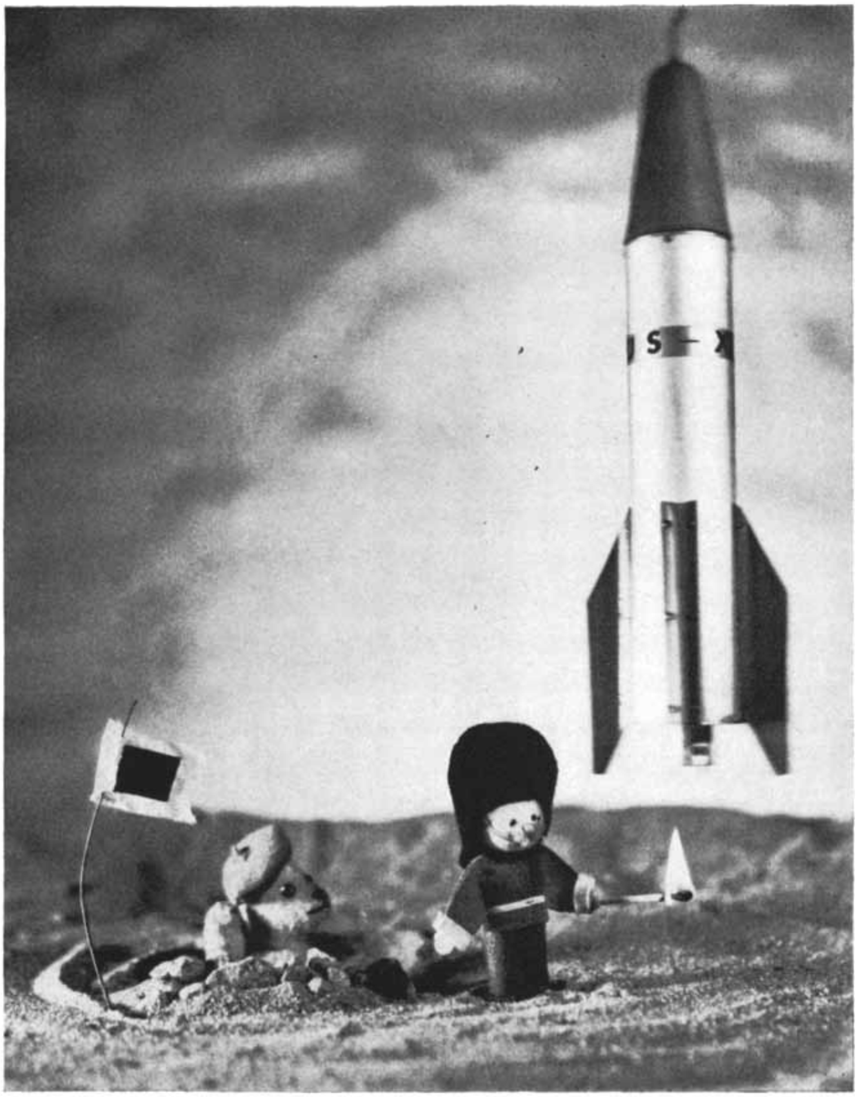
The species might well survive, however, even if it were pushed out of its shelters. Newborn calves have been seen outside the lagoons, suggesting that they were born in the open sea, and the members of a small isolated herd of gray whales off Korea are known to calve in unsheltered waters.

Right now we are attempting to find out how many gray whales there are, and to project a curve of probable population growth into the future. There are two censuses, one from the air and the other from land. They were started by Gifford C. Ewing and Carl Hubbs of the Scripps Institution of Oceanography, and have been carried on by the cooperating Fish and Wildlife Service. The air census counts all the adults and calves visible on the water's surface over the entire breeding range; the land census counts the adults in the migration procession as they pass Point Loma and the Scripps Institution at La Jolla 10 miles to the north. It is estimated that the censuses catch from one third to one half of the total population.

The two counting methods have given surprisingly close results. The count in 1953 was 1,156, including 190 calves; in 1954 it came to 1,200 adults and 200 calves. Allowing for those missed, it is estimated that the total population numbers between 2,500 and 3,000.

Where does this figure fit into a growth curve of the population? We have two earlier points of reference: a high point of more than 25,000 in the mid-19th century and a low point of perhaps 100 in the 1930s. In its recovery from the low point the population will probably follow the classical "logistic" or Verhulst-Pearl curve of population growth, which was derived from studies of laboratory cultures and of human populations. This is a smooth S-curve, starting with a slow rise, then climbing steeply and finally leveling off after a saturation point is reached.

The present breeding grounds of the gray whale could accommodate a population of about 25,000. It is not likely, however, that its numbers will ever at-



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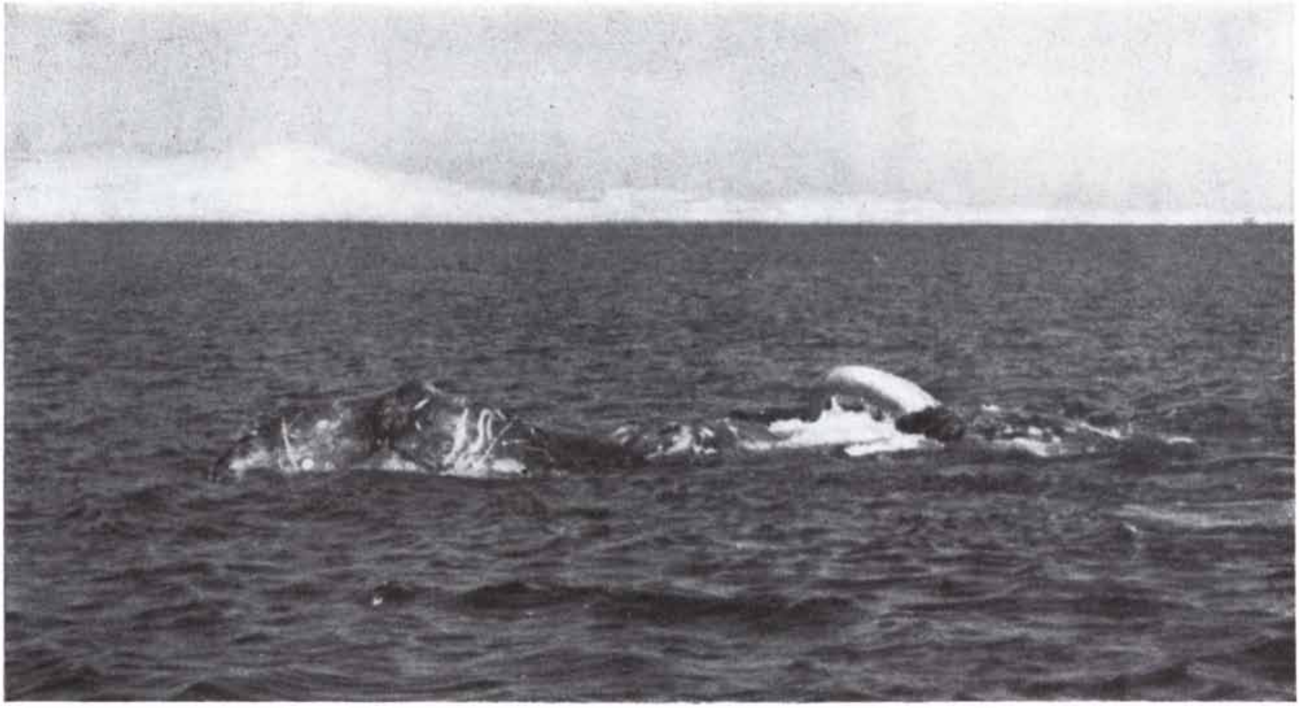
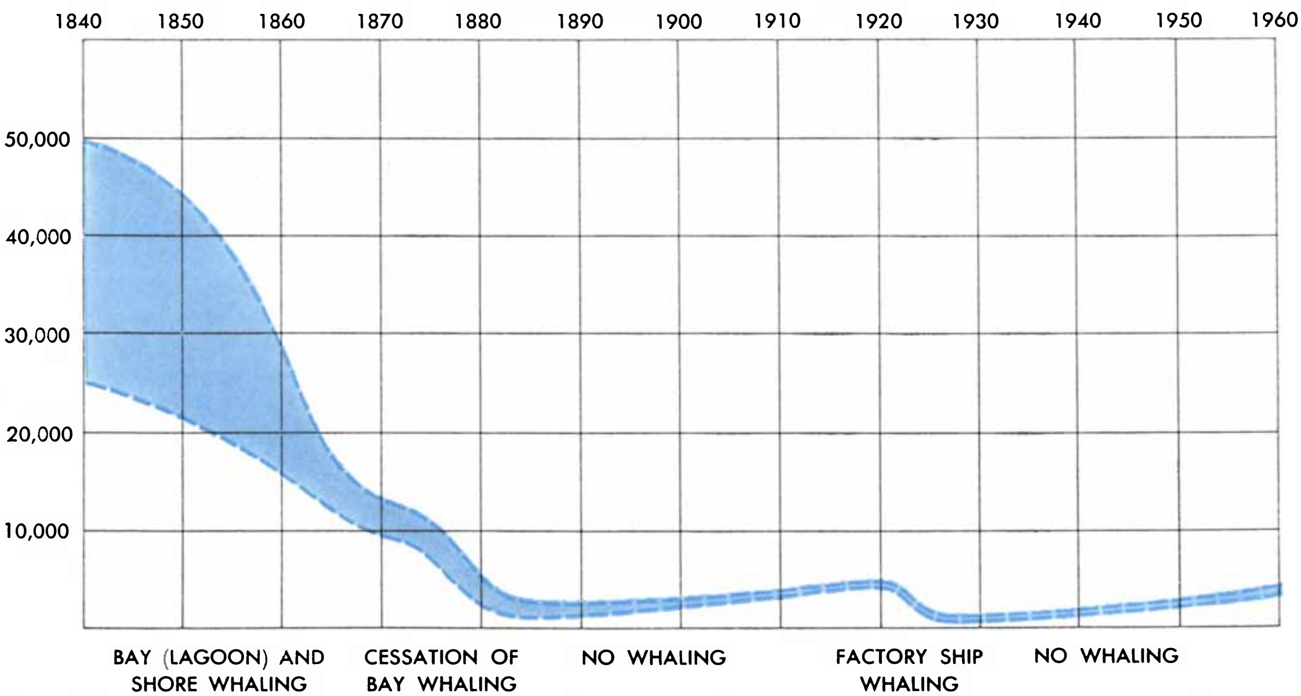


MALE AND FEMALE whales were photographed by Gilmore in Scammon Lagoon as they rolled about in the water before mating. The flukes of the female may be seen at the left. The male is at the right. The females also give birth to their calves in these waters.

tain the saturation level, because in coming decades the demand for the protein food the whale can supply will be too great. We must therefore modify the curve to provide for some whaling [*see chart below*]. It is to be hoped that the annual catch, suitably apportioned among all the interested nations, will be restricted to a level which will assure the perpetuation of the species.

Without much doubt, the North Pacific has always been the heartland of the gray whale. But evidence has recently come to light that herds of the species once lived in the North Atlantic also. Remains of gray whales have been found in Pleistocene or recent deposits in estuaries of Sweden, southern England and the Netherlands. Their presence in estuaries indicates that in ice-age times, as now, the species was accustomed to



DECLINE AND RISE of the gray whale is shown by this curve. The thickness of the curve represents the uncertainty of the population estimate. The population in 1840 is thought to have been at least 25,000. It fell to no more than 100 and is now about 3,000.

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mate and calve in sheltered waters to which it retired in season.

Presumably during interglacial periods, when the Arctic Ocean melted, gray whales spilled over from the Pacific population across the Arctic into the Atlantic. Some cetologists believe that the gray whale survived along our Atlantic seaboard until historic times; one even insists that it still exists there today, though in such small numbers that it has not been discovered. The evidence for its recent presence off this coast depends heavily upon a report in 1725 by one Paul Dudley, who in the *Philosophical Transactions* of London described a New England whale which may have been a gray:

"The Scragg Whale is near in kin to the Finback, but instead of a Fin upon his Back, the Ridge of the Afterpart of his Back is scragged with half a Dozen Knobs or Nuckles; he is nearest the Right Whale in Figure and for Quantity of Oil, his Bone (baleen) is white, but won't split."

The Dutch authorities A. D. Diense and G. C. A. Yunge are convinced that the New England "scragg" was a gray whale. But it seems more probable that the scragg was merely an undersized right whale; the early New England whalers applied the name scragg to any runty right or humpback whale. William Schevill of the Woods Hole Oceanographic Institution has described Dudley's report as a "literary curiosity." I would not be surprised to see fossil remains of gray whales come to light on the New England or Canadian coast, but I doubt that man has ever laid eyes on a living member of the species in that region of the world.

Why did the gray die out in the Atlantic? Some drastic change in conditions must have done it in completely, for the species has shown in the Pacific a remarkable capacity to come back from extremely low numbers. The whale is not a very rapid breeder, as the animal kingdom goes. In its lifetime of 15 to 20 years a female gray whale may deliver from five to eight young, since it normally calves every second year after maturity. What may stand greatly in the species' favor is its inborn habit of herding each year in the intimacy of its few traditional lagoons—which assures that boy will meet girl, however scarce they may be.

The mighty drama of the gray whale's comeback, a drama which we are witnessing from excellent seats on the California coast, is a moving sight. Let us hope that it will have a happy ending.

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MAGNETIC MATERIALS

Recent advances in the theory of magnetism have explained why some substances can be magnetized while others cannot. Better magnets may soon result from the new understanding

by Richard M. Bozorth

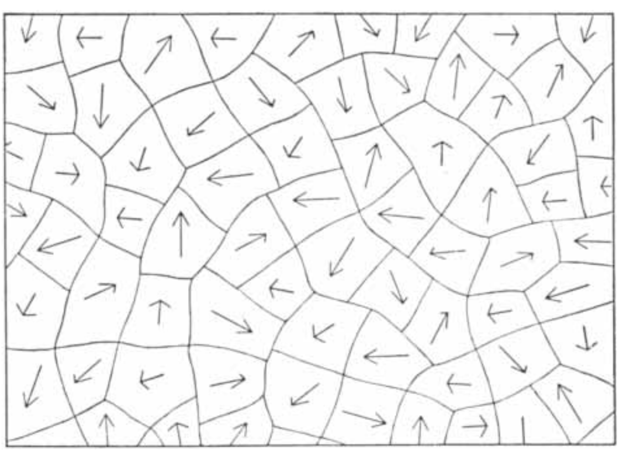
What makes a material magnetic? One would think the answer should be in any physics textbook. Our whole electrical technology is based on magnetism: without magnets we would have no electric power generators, no electric motors, no radio, radar or television, no telegraph or telephone, none of the countless other creations that depend on electricity. Yet magnetism itself is still full of mystery. Only in the last decade or so have we learned enough about the basic nature of the phenomenon to begin to have some idea of why just a certain few materials, notably iron, are magnetic and what happens to such a material when it is magnetized. One result of these studies has been the discovery of two new kinds of magnetic materials, the ferrites and the pressed-powder magnets, which are now attracting a great deal of attention.

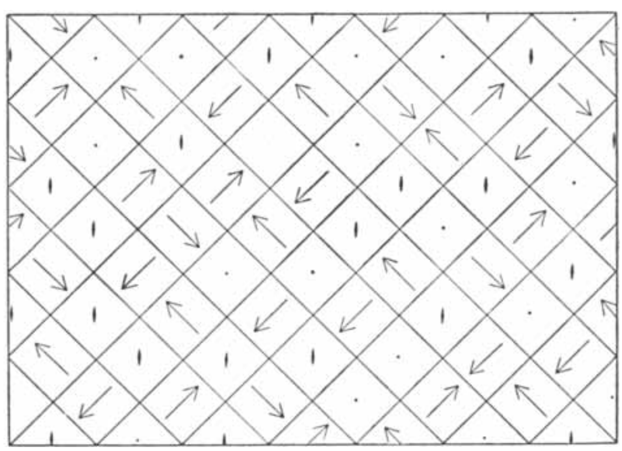
Magnetism in matter stems basically from the spin of electrons. Each spinning electron is a tiny permanent magnet; its strength is called one Bohr magneton. The electronic magnetisms commonly neutralize each other, because electrons in atoms tend to go in pairs, spinning in opposite directions. The atom as a whole can become a magnet only when there is an imbalance of electronic spins. This is the case, of course, whenever the atom has an odd number of electrons, and it also occurs when groups of electrons spin the same way instead of pairing off in opposite directions. Thus the third shell of electrons in the iron atom has a subshell whose electrons like to spin in the same direction; five of the six electrons in the subshell have plus spins and one minus, yielding a net magnetism of four Bohr magnetons.

The fact that a piece of matter contains atomic magnets does not necessarily make the material itself magnetic. Again the reason is that the little atom magnets tend to neutralize one another; their spins are knocked about in random directions by the normal thermal motions of the atoms. To make the material magnetic some force stronger than the thermal agitation must align the atom magnets in the same direction. Think of a pile of compass needles in a box: if they are shaken up so that they point in all directions, the box will not be magnetic; but stack them all with their north-seeking poles in one direction and the box will act as a large magnet.

What is the directing force that lines up atomic magnets to make a material magnetic? The theory of quantum mechanics has attempted an "explanation." Werner Heisenberg suggested that there is an "exchange force" acting between atoms at short range. When the atoms are a certain distance apart, this force holds the atomic spins in directions opposite to each other. At a certain distance farther away, it lines them up parallel. Within these distances the interatomic quantum mechanical force is powerful enough to overcome the disordering heat motions of the atoms at ordinary temperatures. When the material is heated to the point where the thermal energy becomes stronger, it loses its magnetism. In iron this critical temperature is 1420 degrees Fahrenheit.

The known magnetic materials are iron, cobalt, nickel, gadolinium and many alloys and compounds containing





DOMAIN STRUCTURE of unmagnetized material was at first believed to have the completely random arrangement of the diagram at left (*arrows show direction of magnetization within the domains*). Then it was realized that each domain would tend to be magnetized along a crystal axis, as in the middle diagram (*dots and diamonds represent arrows going in and out of paper*). A domain

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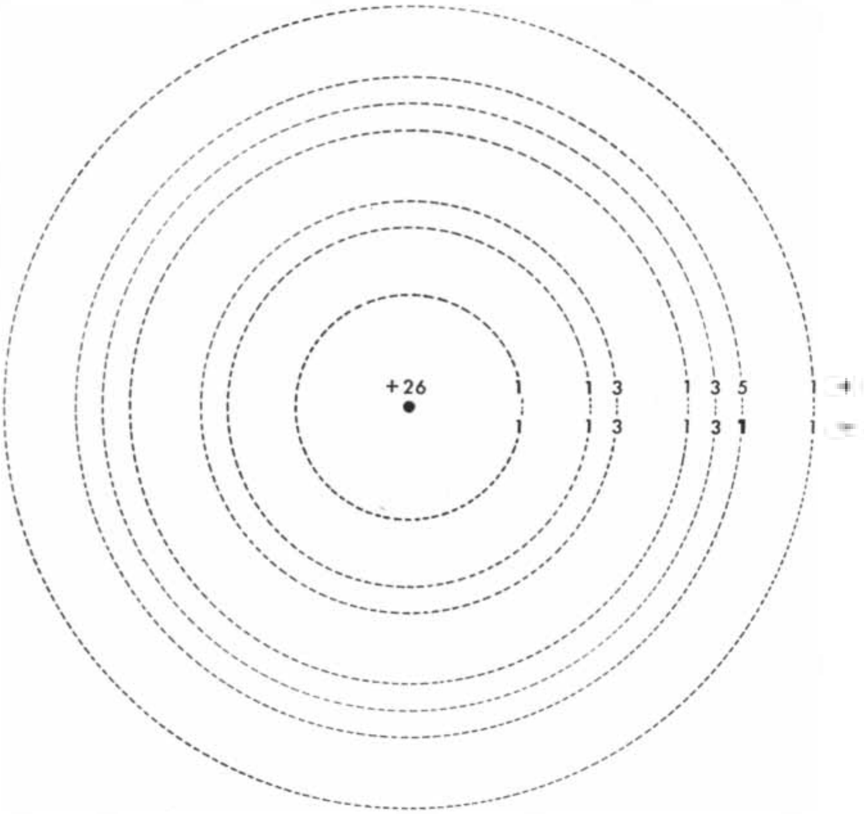
these elements as well as manganese, chromium and some others. In most of these cases the quantum mechanical forces seem to be of the right kind to account for the magnetic property.

Still, interatomic forces do not quite explain magnetism. If these forces are the whole story, why does not a piece of iron spontaneously become a magnet? Why does it act as a magnet only after it has been magnetized by another magnet or a strong electric current? To account for this, students of the problem carried the idea of neutralization a step further. Just as electron magnets and atom magnets neutralize each other, so larger units within the piece of iron may do so. The idea, first suggested by Pierre Weiss of France many years ago, is that the iron is composed of many small magnetized regions, called "domains" [*see two diagrams on opposite page*]. Ordinarily these point in every possible direction parallel to the axes of the iron crystals, so that they cancel one another and the net magnetism of the piece of iron is zero. The domains, each consisting of many millions of atoms, correspond to the individual needles in our box of mixed-up compass needles. The iron becomes magnetized when a force from outside lines up the domains in the same direction.



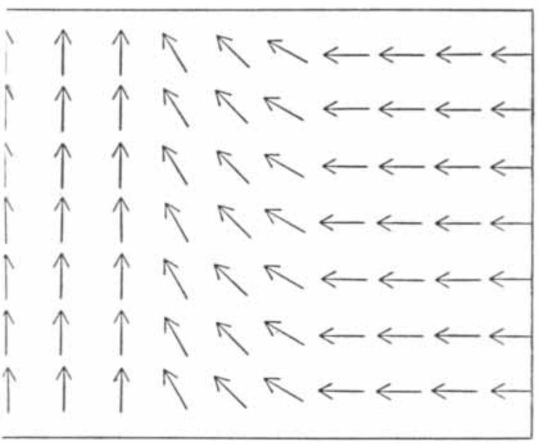
STRUCTURE OF IRON ATOM demonstrates why iron is magnetic. Around the nucleus, containing 26 protons, are an equal number of electrons distributed in "shells" (*concentric dotted circles*). The electrons spin on their own axes in either of two directions, designated plus and minus, and form tiny magnets. In all except the next to the outermost shell, positive and negative spins are counterbalanced and the magnetism cancels out. In this shell, however, five plus spins are countered by a single minus, leaving a net magnetic effect.

Physicists reasoned that it should be possible to make the boundaries of the domains visible, just as one can see a crack or discontinuity in a magnet by sprinkling iron filings on it. They sprinkled very fine powder over a magnet and looked at it under a microscope. The first experiments failed to show anything significant. But after World War II a group at the Bell Telephone Laboratories improved the technique and succeeded in outlining the domains with particles of iron oxide in colloidal suspension. It then became possible to observe the behavior of the domains when they were subjected to various experimental manipulations—in short, to see what goes on inside a magnet. We can literally watch the process of magnetization, and much of what we see is explainable by the known general laws of physics.

The domains are separated by "walls" —transition regions where the atoms turn from the direction of one domain to that of the next [*diagram at left on this page*]. When a weak magnetic field is applied to a piece of iron, it shifts the domain walls, enlarging the domains where the atomic magnets are most nearly parallel to the field and lining up all the newly included atoms in that direction. These domains grow at the expense of those oriented less favorably, and the latter shrink [*see photographs at bottom of next page*]. Thus more of the material is aligned in the same direction and the whole piece of iron becomes magnetized.

What governs the formation and structure of domains? This problem has been worked out by considering four hypothetical structures and calculating their relative stability from the standpoint of the energy that would be needed to maintain them [*see diagrams on page 72*]. If a block of iron were magnetized as a single large domain [*upper left*] it would have a strong external field—and would require the input of a considerable amount of energy. Such a structure would be highly unstable. Nature, as everyone knows, favors structures requiring the least energy.

If we supposed the block to be divided into two domains, magnetized in opposite directions [*upper right*], the energy requirement would be greatly reduced, but it would still be far above the possible minimum. We can imagine a somewhat more stable structure in which there are four domains, magnetized in opposite horizontal and vertical directions parallel to the crystal axes [*lower left*]. However, it introduces a new kind of energy requirement. When a piece of material is magnetized, its dimensions change slightly—a phenomenon called magnetostriction. As a result the domains magnetized in the horizontal direction in this structure would not quite fit the spaces between the domains magnetized



wall (*above*) is not a geometrical plane but a region, up to thousands of atoms thick, where direction of magnetization changes.

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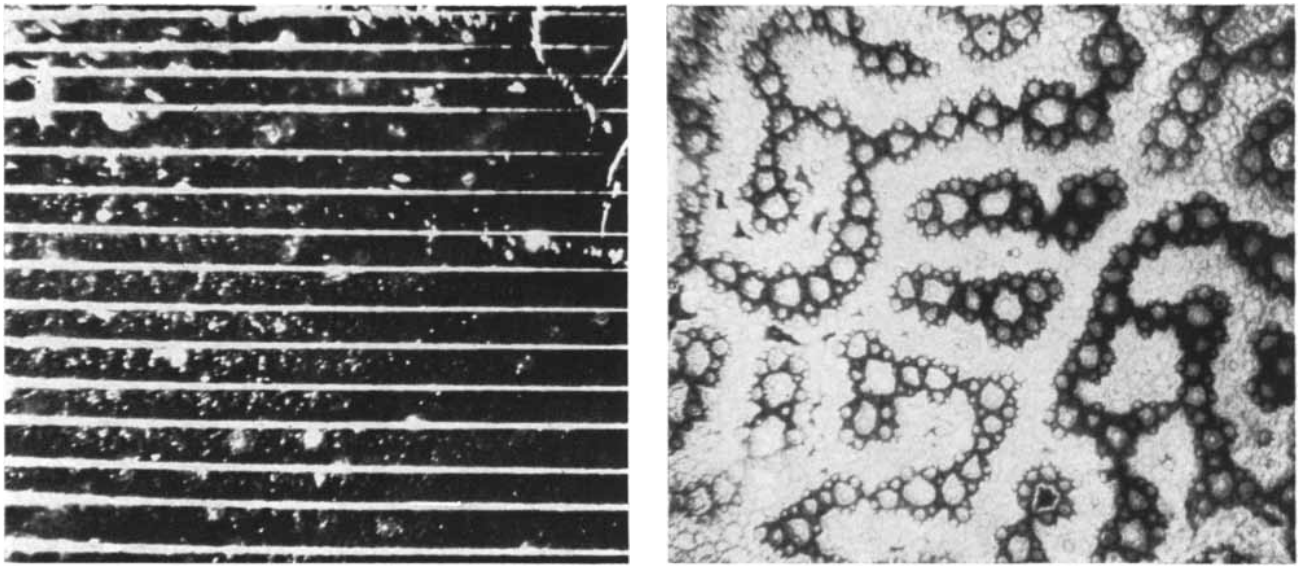


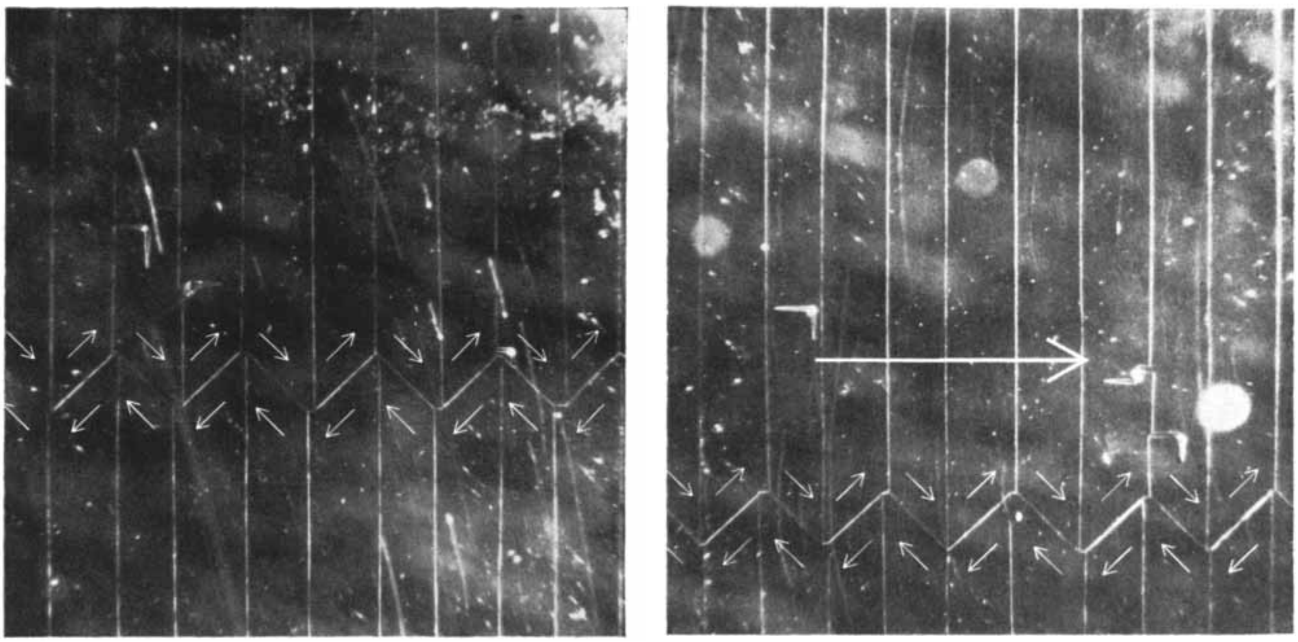
COBALT DOMAINS are shaped like needles whose long dimension runs in the direction of cobalt's hexagonal crystal axis. The powder pattern at the left shows the domains looked at from the side. The pattern at right shows the same structures viewed end-on.

in the vertical direction, and the structure would be strained, or deformed, requiring a certain amount of energy to maintain itself. Besides this, there is the energy required for the domain walls, which in iron is about one or two ergs per square centimeter.

Seeking to minimize the magnetostriction energy, we would arrive theoretically at the fourth structure shown [*lower right in illustration at top of page 72*], which adds some wall energy but more than compensates for this by the reduction in the amount of strained material. This structure requires the least energy of the four possible ones considered. And the pattern of domains observed in magnetized iron proves, indeed, to be very close to this theoretical construction [*photograph at bottom of page 72*].

Cobalt has a different domain pattern. Its crystals are hexagonal, and it has only two directions of stable magnetization instead of the six permitted to the cubic crystals of iron. These are the two opposite directions along the axis of the hexagon. The domain structure of a magnetized piece of cobalt is like a bundle of needles pointing alternately in opposite directions. The two photographs above show a cobalt crystal cut along the axis so that the domains are seen lengthwise and another cut crosswise so that the needlelike domains are seen end-on.

We can now consider the two new types of magnetic materials. Let us take first the powder magnets. Their promise depends on the fact that extremely small particles (one millionth of an inch or less in diameter) must be



IRON DOMAINS are revealed in photomicrographs of crystals dusted with fine powder. Straight white lines are domain walls. Small arrows show the directions of domain magnetization. At left the original magnetic structure is seen. At right the crystal has been placed in a magnetic field, indicated by the large horizontal arrow. The zigzag boundary line has moved down, so that the upper series of domains, which are magnetized most nearly in the direction of the field, are enlarged at the expense of the domains underneath.

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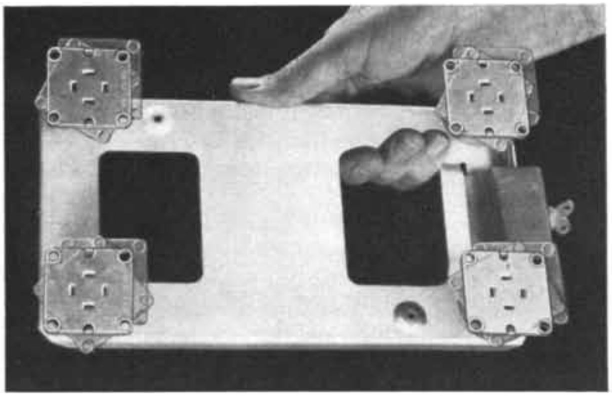

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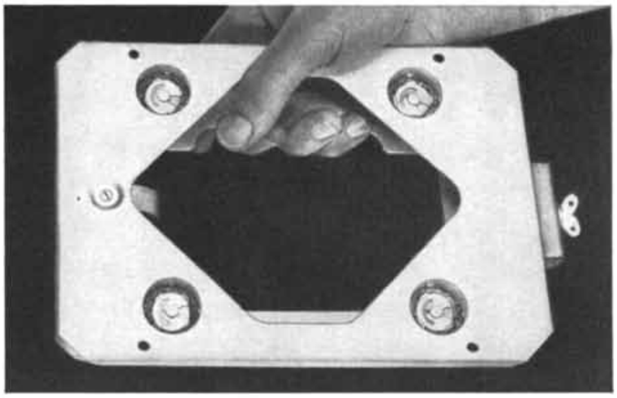

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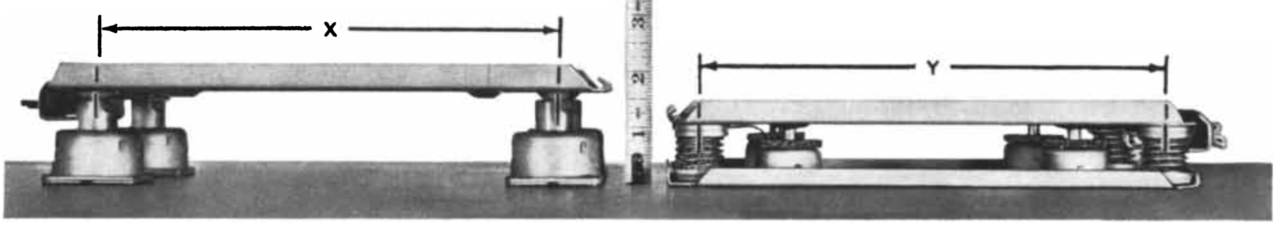

Excessive height required. Unit mount bulk imposes reduced spacing (X) between support centers, resulting in impaired stability (critical in lateral direction). Greater sway space required.

Note reduction in mounting height. Important space saved. Maximum spacing (Y) of resilient elements at extreme corners provides stability. Less sway space required.

Well Designed Electronic Equipment, *If Poorly Mounted,* Too Often Operates Inefficiently and Unreliably

Failure also can result from use of inadequate mountings which are not engineered for the particular equipment and purpose. Conventional shock mounts or so called "isolators", reasonably effective when installed under ideal laboratory conditions, become dangerous trouble makers when installed by usual production line methods.

Attachment of a base plate to unit mounts to achieve spacing control is a makeshift arrangement resulting in excessive weight with no height reduction.

Failure also can result from obsolescent unit mounts employing internal rubber, organic or synthetic materials which deteriorate rapidly and are susceptible to temperature and environmental changes.

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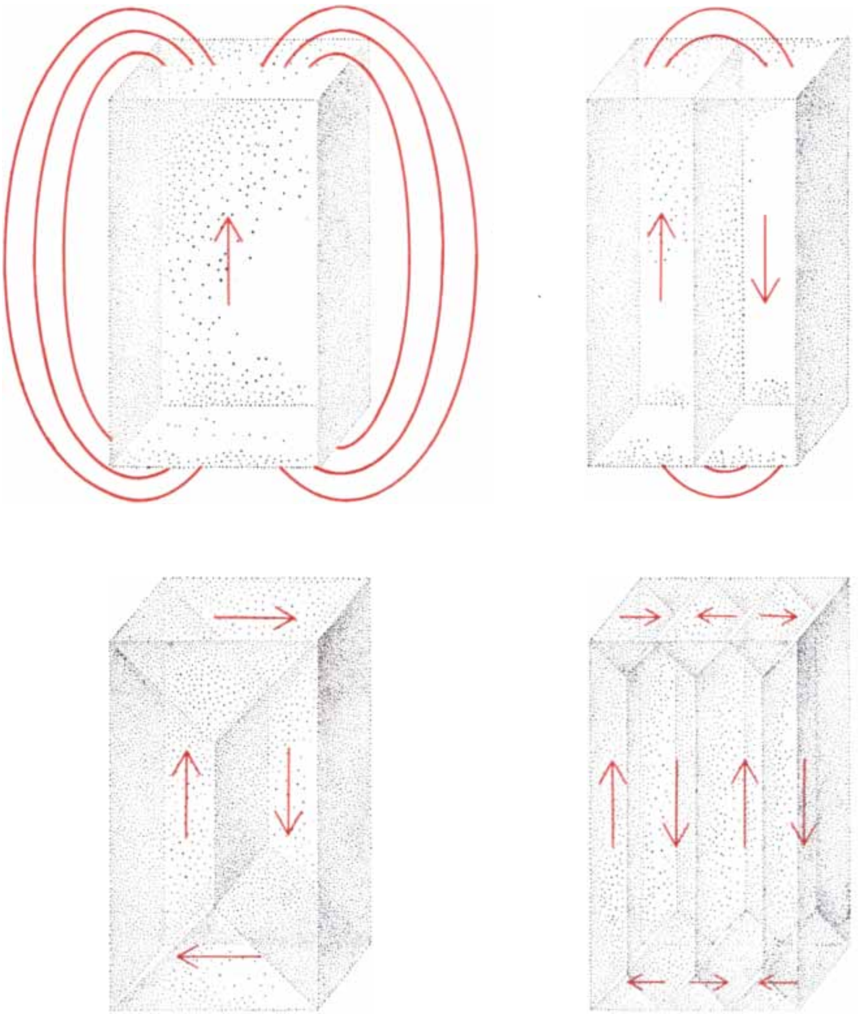
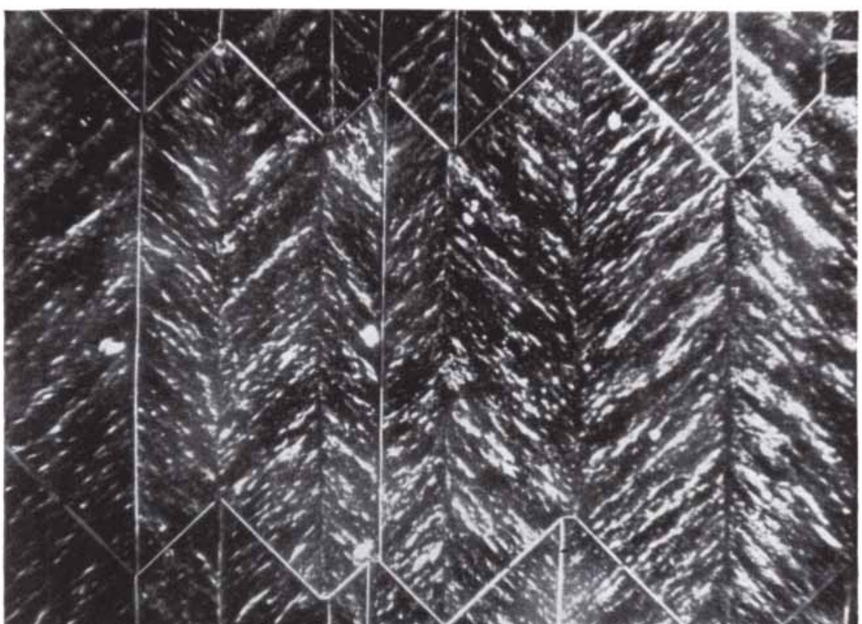
single domains, because they are smaller than the thickness of a wall between domains. As we have seen, domains prefer to be magnetized in certain directions—six directions in the case of iron and two in the case of cobalt. They may be aligned in less stable directions by the shifting of domain walls, but when the particles are small enough to be single domains without walls, it takes a much stronger magnetic field to change their direction. This tenacity is just what is required of a so-called permanent magnet.

Some small-particle magnets are made of very fine powders pressed into desired sizes and shapes. The best magnets manufactured today, however, are alloys in which nature forms the fine particles. When certain amounts of iron, cobalt, nickel, aluminum and copper are cast into an alloy, tiny domains are isolated from one another by thin films of somewhat different composition.

The theoretical work on domain structures suggests that there is still a good deal of room for improvement of powder magnets. For example, much stronger and better permanent magnets will be made when a way is discovered of forming particles of iron in needle shape and packing them parallel in tight bundles approaching the density of solid iron.



TOTAL ENERGY of a magnetic structure is made up of the energy stored in the external fields, in the domain walls and in magnetic distortion of the material. The arrangement at the lower right is the compromise among all these forms which gives the smallest total.



NATURE'S ARRANGEMENT of magnetic domains is the one that involves the smallest possible energy. Photographs of actual domain structures such as this one show that they resemble closely the optimum theoretical configuration illustrated at the top of the page.

The ferrites, iron oxides combined with oxides of other metals, offer a great advantage over simple metals as a magnetic material. Not only do they make very powerful magnets, but as oxides they have extremely high electrical resistivity. This property is important in an application such as the magnetic core of a transformer. In a transformer the alternating magnetic field from the primary coil produces eddy currents in the core which waste power. If the core can be made of a material with high electrical resistance, the eddy currents are minimized. The ferrites answered this need: their resistivity is more than a million times as great as that of the best material previously available.

In the field of communications, where the transmission of energy at high frequencies requires a great deal of power, ferrite magnets have already begun to replace other types. They are being manufactured in increasing quantities for use in radio, television and other instruments of communication.

It was the theoretical work on magnetism that suggested the possibility of making magnets from metallic oxides. The ferrites were first developed in the Netherlands during World War II; some of the work was done by Dutch physi-

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IONS	SPIN	FIRST SHELL	SECOND SHELL	THIRD SHELL	BOHR MAGNETONS
Fe^{+++}	+ −	1 1	1,3 1,3	1,3,5 1,3,0	5
Mn^{++}	+ −	1 1	1,3 1,3	1,3,5 1,3,0	5
Fe^{++}	+ −	1 1	1,3 1,3	1,3,5 1,3,1	4
Co^{++}	+ −	1 1	1,3 1,3	1,3,5 1,3,2	3
Ni^{++}	+ −	1 1	1,3 1,3	1,3,5 1,3,3	2
Cu^{++}	+ −	1 1	1,3 1,3	1,3,5 1,3,4	1
Zn^{++}	+ −	1 1	1,3 1,3	1,3,5 1,3,5	0

MAGNETIC CONTRIBUTIONS of the ions which make up various ferrites can be easily computed from the electronic shell structure. The table above summarizes the information.

cists under the unsuspecting eyes of the Germans, who were in control of the laboratories.

The theory of ferrite magnets was suggested by the French physicist Louis Néel. When iron oxide (Fe_2O_3) is combined with nickel oxide, it forms a nickel ferrite whose formula can be written $NiFe_2O_4$. The oxygen atoms, being the bulkiest, form the framework of the solid structure; they are piled together like billiard balls, and the more compact nickel and iron atoms are tucked away in holes between them. In some holes a metal atom has four equidistant neighbors; in others it has six. These have been named respectively the A and B positions. In nickel ferrite half of the iron atoms are in the A positions and the other half in B positions; all of the nickel atoms are in B positions.

Now Néel suggested that the atoms in the A and B positions were magnetically opposed; that is, the magnetism of A atoms pointed in one direction and that of B atoms in the opposite direction. Using arrows to indicate the magnetic directions, we can picture the molecule schematically as follows:

$$\underset{\longrightarrow}{\overset{A}{Fe^{+++}}} \quad \overset{B}{(\underset{\longleftarrow}{Ni^{++}}\ \underset{\longleftarrow}{Fe^{+++}})} \quad O_4^{--}$$

The signs next to the metal atoms show that the iron atoms have a triple positive charge (they have given three outer electrons to the oxygen atoms), and the nickel atoms are doubly ionized. The magnetisms of the two iron ions cancel each other. Consequently the net magnetism of the whole molecule is simply that of the nickel ion. The strength of this magnetism can easily be deduced from an analysis of the nickel atom's electronic shell structure. It amounts to two electronic units, or two Bohr magnetons.

Similarly we can calculate the theoretical net magnetisms of other ferrites, those of manganese, cobalt, copper, zinc and doubly ionized iron [*see table above*]. The magnetisms of the metal ions range from five Bohr magnetons down to zero for zinc, which must therefore be nonmagnetic. Actual measurements of the molecular magnetisms of the various ferrites come close to the predicted values, showing that the theory is substantially correct.

Ferrite magnets are made by powdering the oxides, pressing the powder to the required shape and firing it. The magnet is hard, strong and refractory to heat. The technology of these magnets is just beginning, but it is developing rapidly. As answers come to the many still unanswered questions about the nature of magnetism, it may soon be possible to make magnets of still undreamed-of properties.

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RICKETTSIAE

These microorganisms cause epidemic typhus and other serious infectious diseases. They intrigue the microbiologist because of their evolutionary position between the viruses and bacteria

by Marianna R. Bovarnick

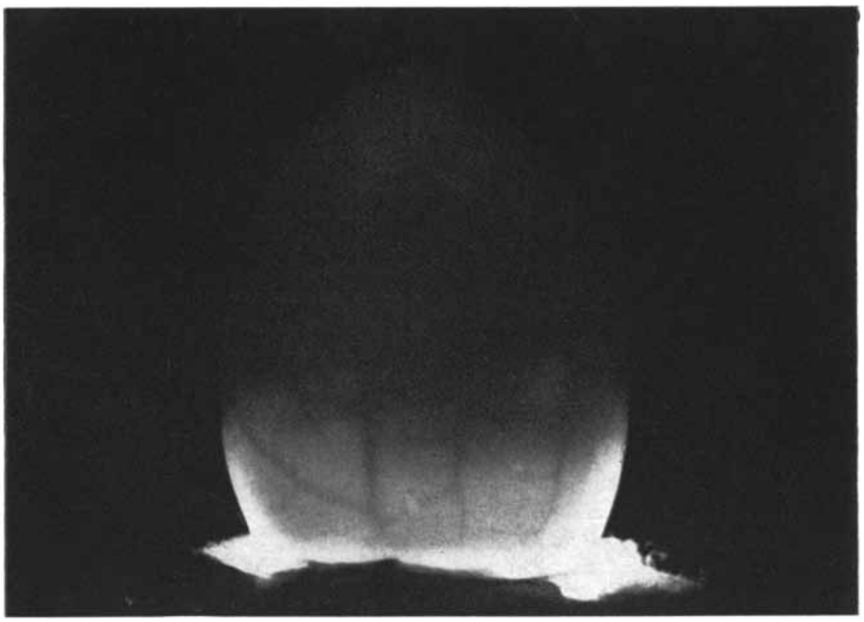
Rickettsiae are of interest not only as a major cause of human disease but also as a new kind of organism for biologists to study. They are in the realm of life between the bacteria and the viruses: like viruses they are parasites that can multiply only within a living host cell, but in size, complexity and metabolic powers they approach the free-living bacteria. Where do they fit into the scheme of evolution? Can they tell us anything about the origin of viruses and of bacteria?

One rickettsial disease, epidemic typhus, has been for centuries a great scourge of mankind. It has been closely associated with wars and the attendant human wretchedness, as attested by some of its names—jail fever, camp fever, hospital fever. The disease was first recognized during the 15th-century wars of Granada in Spain. Afterward it swept over the entire continent of Europe. Hans Zinsser credits epidemic typhus with determining the outcome of at least one war: in the 16th century it defeated the attempt of Francis I to wrest Italy and the papal power from the grasp of Charles V, ruler of Spain. During the wars of succeeding centuries, typhus frequently killed more people than actual combat. As recently as World War I it wrought havoc in parts of Eastern Europe; immediately after that war it afflicted some 30 million in Russia and killed three million. During World War II outbreaks of typhus occurred in the Mediterranean area, in German prison camps and in the Far East; there was a severe epidemic of some 26,000 cases shortly after the war in Japan and Korea. But the disease is so well understood today that it need no longer take any such toll of death as in the past.

Besides epidemic typhus the rickettsial diseases include Rocky Mountain spotted fever, scrub typhus and murine typhus. All of these diseases are characterized by a rash and a fever. Scrub typhus, or tsutsugamushi disease, found in Japan and other parts of the Pacific, created a considerable military problem during World War II until methods were worked out for its prevention and treatment. Murine typhus, which occurs in many parts of the world including the U. S., is comparatively mild but closely related to epidemic typhus; an attack by one confers immunity after recovery against both.

The infectious rickettsia is transmitted by an insect carrier. The first to discover this was the French bacteriologist Charles Nicolle, who found that epidemic typhus was carried from person to person by the louse. Not long afterward it was demonstrated that Rocky Mountain spotted fever was transmitted to man by ticks, which are not only the carriers but also the natural reservoir of the microorganism. The natural hosts of scrub typhus and murine typhus proved to be rats and field mice; scrub typhus is carried to man by mites and murine typhus by the rat louse.

The discovery that lice transmit epidemic typhus made it easy to understand why the disease spread like wildfire in times when everyone from the highest to the lowest wore one set of clothing day and night without change all winter. But it was not so easy to understand why the disease persisted from one great epidemic to another in the absence of any apparent reservoir. Since the infection is



EGG IS CANDLED to determine the condition of the chick embryo inside, which has been inoculated with the rickettsiae of epidemic typhus. The circulatory system is visible within.

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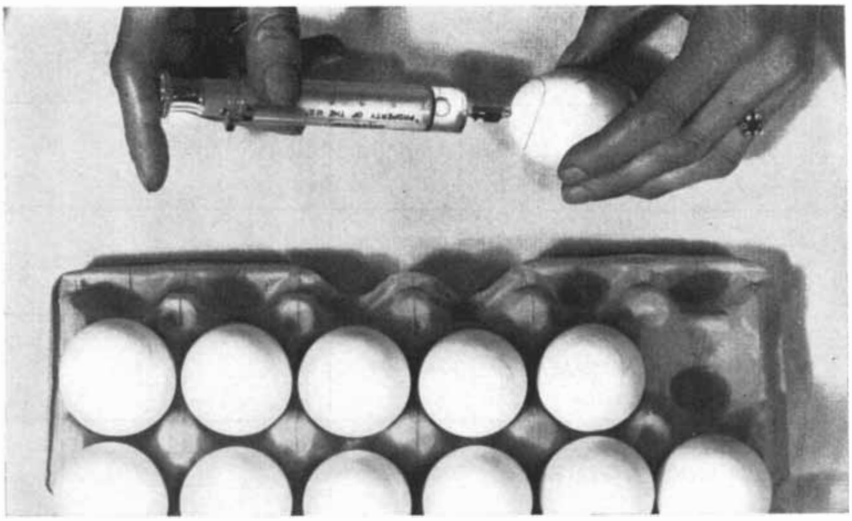
inevitably fatal for the louse, one would suppose that the disease should disappear after an epidemic had subsided and the infected lice had died off. What was the reservoir that preserved the infective agent? This puzzle was solved after Dr. Nathan E. Brill of New York City observed sporadic cases of a relatively mild disease similar to typhus in patients who had had no recent contact with lice. Epidemic typhus had never been found in New York. Zinsser, studying the records, noted that most of the patients with Brill's disease, as it came to be known, were immigrants from Eastern Europe. He suggested that they may have had attacks of epidemic typhus in the old country and that the disease may have returned because the patients had preserved the rickettsiae in some quiescent state in their own tissues. Recent studies by E. S. Murray and J. C. Snyder have shown that lice fed upon such patients become infected by rickettsiae indistinguishable from epidemic typhus strains.

The rickettsiae themselves were identified early in this century. The epidemic typhus organism was seen under the microscope in stained smears of the intestines of infected lice. It was called *Rickettsiae prowazeki* in honor of the first two investigators who described it, Howard T. Ricketts and Stanislas von Prowazek, both of whom died of typhus contracted during their studies.

Preventive vaccines against rickettsial diseases were eventually prepared, at first from infected lice and later from cultures of rickettsiae grown in the yolk sacs of chick embryos. These vaccines, consisting of killed organisms, reduce the mortality from rickettsial infections practically to zero. Moreover, there are now several antibiotics—aureomycin, chloramphenicol and terramycin—which are extremely effective against the rickettsial diseases.



EGG IS INOCULATED with the rickettsiae of murine typhus by pushing the needle of a syringe into the yolk sac of the fertilized egg. Rickettsiae can grow only in living cells.

RICKETTSIAE ARE HARVESTED by removing the yolk sac from the egg. The yolk is then ground and refrigerated at minus 94 degrees Fahrenheit. This embryo is 15 days old.

Interest is now concentrated on the nature and behavior of the organisms. Several methods for quantitative assay of their multiplication and virulence in animals have been developed. These usually take longer than similar work with viruses or bacteria, because the rickettsiae grow rather slowly. There is one rapid method, however, in the case of the typhus strains. Injection of a high concentration of typhus rickettsiae into the tail vein of a mouse kills the animal within a few hours. Apparently the quick death is due not to overwhelming multiplication of the rickettsiae, but to a toxin. This toxin has so far defied isolation from the organisms, but its existence has been virtually demonstrated by the fact that biological inactivation of the rickettsiae by ultraviolet irradiation does not reduce their toxicity to the mice.

One important issue in biology on which the rickettsiae may shed light is this: Are viruses aberrant derivatives from cells or are they degenerate end-products of an evolution from some higher form? According to the first theory, the viruses originally evolved from some portion of living host cells, perhaps the genes. According to the second, they evolved from more complex microorganisms, perhaps bacteria; in the process they lost all the metabolic abilities of bacteria and became completely dependent upon the cells they invade for all the reactions and chemical syntheses necessary for their reproduction. Now in rickettsiae we seem to have a link between viruses and bacteria: like the viruses they can grow only in living cells, but they also appear to have some of the metabolic capabilities of bacteria.

To investigate the metabolic activities of rickettsiae we had to find a way of keeping these highly unstable organisms alive and active outside their host cells. Our study of the factors affecting the stability of typhus rickettsiae led to the discovery of several interesting facts con-

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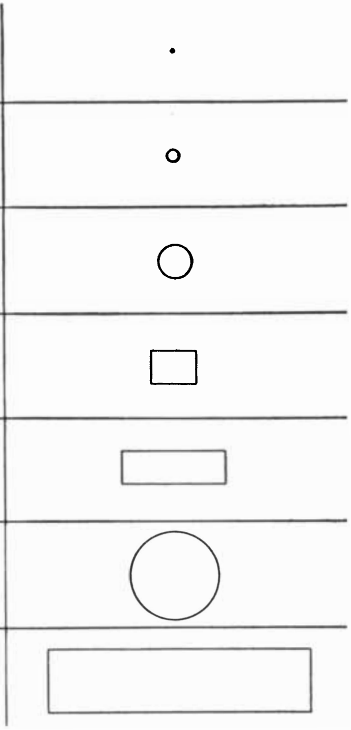
POLIOMYELITIS VIRUS	12	
INFLUENZA VIRUS	100	
PSITTACOSIS VIRUS	400	
SCRUB TYPHUS RICKETTSIAE	300 x 400	
EPIDEMIC TYPHUS RICKETTSIAE	300 x 1000	
STAPHYLOCOCCUS AUREUS	900	
BACTERIUM COLI	600 x 2500	



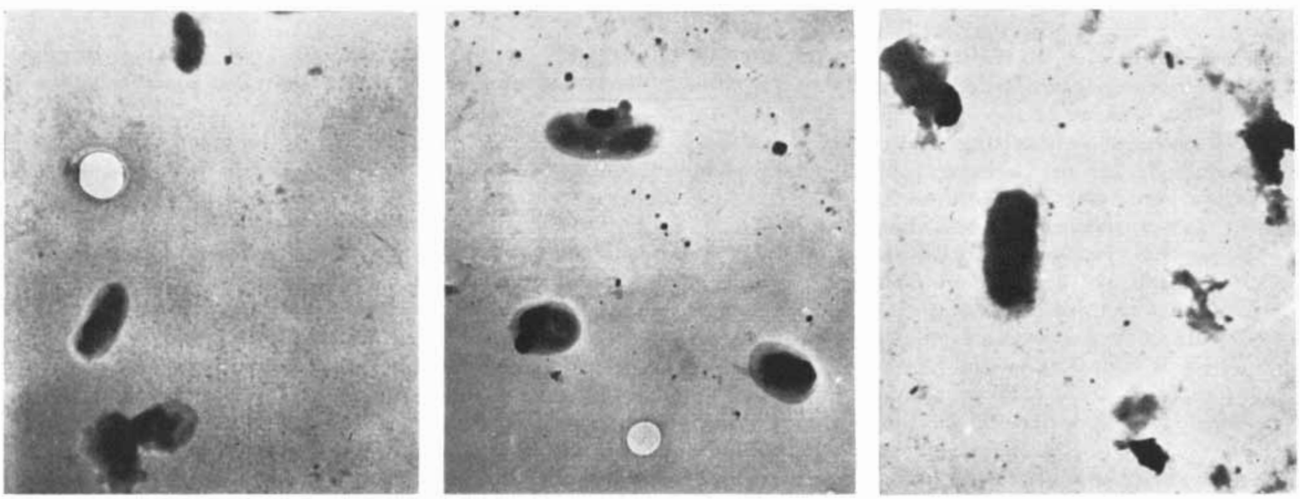
SIZES of some viruses, rickettsiae and bacteria are compared. The rickettsiae are of intermediate size. The dimensions of the various bodies (*center column*) are given in millimicrons.

cerning their biochemical capability.

In these experiments rickettsiae were incubated for a specified time at 93 degrees Fahrenheit in various nutrient solutions and then assayed for the relative numbers remaining. In a nutrient broth in which bacteria thrive, the rickettsiae lost all activity within a few hours. But they survived moderately well for several hours in relatively simple salt solutions similar to the fluids in the cells of an animal's body. The first studies also disclosed that the vitality of rickettsiae, as measured by their infectivity, was markedly increased if glutamic acid, an amino acid, was added to the salt solution. Follow-up tests soon showed that the organisms could metabolize glutamic acid. They also proved capable of oxidizing slowly two other substances, pyruvate and succinate, which, like glutamic acid, are oxidized by most animal and plant tissues. Of many substances tried, these three were the only ones typhus rickettsiae could utilize in any significant amount. However, W. H. Price of the Johns Hopkins University School of Hygiene and Public Health has recently found that spotted fever rickettsiae can oxidize three other substances: ketoglutarate, fumarate and oxaloacetate.

All of these compounds are participants in the well-known citric acid cycle of reactions. This cycle is carried out by mitochondria, small particles in the cells of animals. In the final stages of the cycle the mitochondria take up inorganic phosphate to form the energy-rich compound adenosine triphosphate (ATP), which supplies the energy for many activities of animal cells. Now there are indications that the entire citric acid cycle may also take place in rickettsiae. For example, their oxidation of glutamic acid is dependent on the presence of inorganic phosphate, although it has not been possible to show that they convert the inorganic phosphate to ATP during these oxidations. The difficulty in these investigations lies mainly in the fact that no one has yet succeeded in preparing active extracts of rickettsiae that retain their enzymatic activity.

The similarity of rickettsiae to mitochondria emerged in another highly interesting series of experiments. We tested the behavior of the organisms toward coenzymes, the smaller partners whose cooperation many enzymes require to carry out their functions as catalysts. It turned out that the rickettsiae very definitely used the coenzymes known as DPN (diphosphopyridine nucleotide) and coenzyme A, both of which are essential for many oxidation reactions in animal cells. In further experiments it also developed that these two coenzymes had a remarkable ability to restore rickettsiae that had been inactivated by freezing to minus 94 de-



ELECTRON MICROGRAPHS show rickettsiae of epidemic typhus (*left*), murine typhus (*center*) and Rocky Mountain spotted fever. They were published in 1943 in *The Journal of Experimental Medicine* by T. F. Anderson, L. A. Chambers, H. Plotz and J. E. Smadel.

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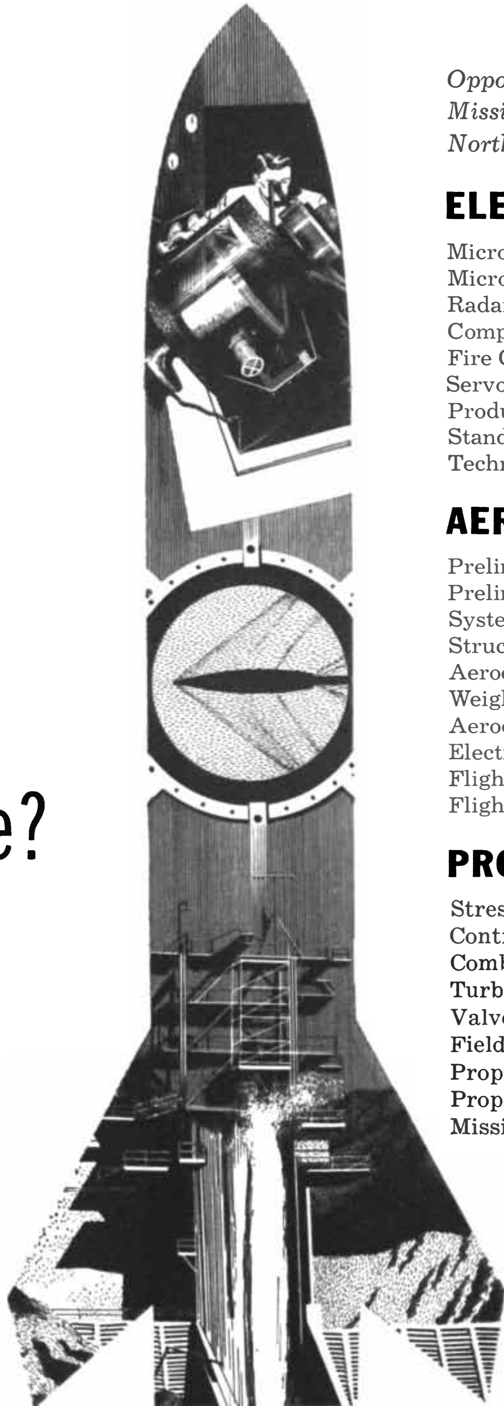

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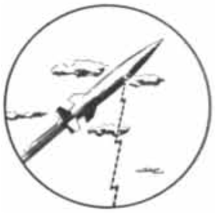
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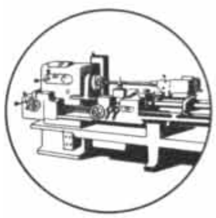
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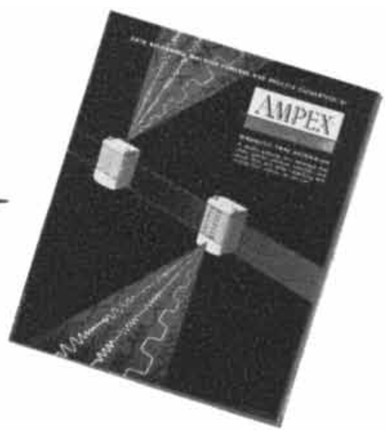

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grees Fahrenheit. Ordinarily such rickettsiae, when thawed, show a loss of nearly all their infectivity. But when incubated with DPN and coenzyme A for a few hours at 93 degrees F., they regained a large proportion of the original activity; the gain often amounted to as much as 10-fold.

The most probable explanation was that the rickettsiae normally contain these coenzymes but lose them through the cell membrane when the membrane is damaged by freezing. Further experiments involving analysis of extracts of the rickettsiae for DPN showed that this was indeed the case.

That rickettsiae should require DPN for oxidation was not surprising, since it is necessary for so many oxidative reactions in other cells. That the organisms' infectivity also should depend upon the presence of DPN did seem surprising, because any host cell could supply them with that substance. Possibly the explanation is that rickettsiae need DPN to penetrate into the host cells.

A quite different type of reversible change has been observed in spotted fever rickettsiae. Ticks infected with a virulent strain of this rickettsia usually kill from 25 to 50 per cent of guinea pigs into which they are inoculated. The rickettsiae lose this lethal power if the infected ticks are kept for several months in a refrigerator, though guinea pigs inoculated with them do become immune. However, the refrigerated organisms regain the ability to produce severe disease in guinea pigs if they are warmed for several days at 93 degrees F. Price has recently shown experimentally that refrigerated rickettsiae retain their infectivity for eggs while they lack infectivity for guinea pigs.

These findings recall the cases of the patients with Brill's disease, who apparently harbored quiescent typhus rickettsiae in their tissues for years. It is tempting to speculate that, just as the loss of DPN deprives the rickettsia of all activity, the loss of some other substance may strip it of part of its capacities, such as the ability to penetrate or to multiply in some of its usual host cells.

From the microbiologist's point of view the most interesting fact is that mitochondria show the same elements of behavior as rickettsiae on freezing. Mitochondria that have been frozen in a salt medium no longer can carry on their usual oxidations. Addition of DPN restores at least a part of their original activity, and it has been shown that they also normally contain bound DPN,

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which escapes on freezing. Moreover, both rickettsiae and mitochondria can be protected against loss of their activity by the addition of sucrose to the liquid in which they are frozen.

The similarity between mitochondria and rickettsiae, both in their biochemistry and in their appearance, suggests that the rickettsiae might have evolved from the mitochondria. But this seems doubtful. It is known that the rickettsiae contain desoxyribonucleic acid, which is not found in the mitochondria. The mitochondria can oxidize many substances, in particular fatty acids, which typhus rickettsiae apparently cannot.

If rickettsiae evolved from mitochondria, and viruses from genes, there should be sharp lines of demarcation between bacteria, rickettsiae and viruses, corresponding to the distinctions that exist between cells, mitochondria and genes. The contrary is the fact: there appears to be a continuous gradation in size and chemical complexity from the smallest through the largest viruses and on through the rickettsiae and the bacteria. The bacteria themselves have a wide spectrum of growth requirements, ranging from just inorganic salts to growth factors even more complex than the higher animals require.

The more attractive hypothesis is that first the rickettsiae, then the viruses, evolved gradually from the bacteria by increasing loss of the enzymes necessary for functions rendered superfluous by development of a parasitic mode of existence. As they evolved they borrowed more and more of the enzymatic apparatus of their host cells, until for many viruses the host cell appears to provide all of the reactions for multiplication.

The chief distinctions between rickettsiae and bacteria are far from completely clear cut. Some organisms fully as complex as the bacteria, such as the malaria parasites, can grow only in living cells. On the other hand, at least one virus, the influenza virus, can carry out a chemical reaction: it catalyzes a cleavage of a complex compound in the membrane of the cells that it invades. It seems probable to the author that the distinctions between bacteria, rickettsiae and viruses as types of organisms may disappear as more is learned about them; that some of the reactions which take place in rickettsiae may be found in the large viruses, and that it may prove possible to grow rickettsiae outside a living cell by supplying them with the necessary complex molecules.

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Projective Geometry

Renaissance painters created it to represent three-dimensional reality in two dimensions. Their invention finally transcended Euclidean geometry and today forms an integral part of physics

by Morris Kline

In the house of mathematics there are many mansions and of these the most elegant is projective geometry. The beauty of its concepts, the logical perfection of its structure and its fundamental role in geometry recommend the subject to every student of mathematics.

Projective geometry had its origins in the work of the Renaissance artists. Medieval painters had been content to express themselves in symbolic terms. They portrayed people and objects in a highly stylized manner, usually on a gold background, as if to emphasize that the subject of the painting, generally religious, had no connection with the real world. An excellent example, regarded by critics as the flower of medieval painting, is Simone Martini's "The Annunciation." With the Renaissance came not only a desire to paint realistically but also a revival of the Greek doctrine that the essence of nature is mathematical law. Renaissance painters struggled for over a hundred years to find a mathematical scheme which would enable them to depict the three-dimensional real world on a two-dimensional canvas. Since many of the Renaissance painters were architects and engineers as well as artists, they eventually succeeded in their objective. To see how well they succeeded one need only compare Leonardo da Vinci's "Last Supper" with Martini's "Annunciation" [*see opposite page*].

The key to three-dimensional representation was found in what is known as the principle of projection and section. The Renaissance painter imagined that a ray of light proceeded from each point in the scene he was painting to one eye. This collection of converging lines he called a projection. He then imagined that his canvas was a glass screen interposed between the scene and the eye. The collection of points where the lines of the projection intersected the glass screen was a "section." To achieve realism the painter had to reproduce on canvas the section that appeared on the glass screen.

Two woodcuts by the German painter Albrecht Dürer illustrate this principle of projection and section [*see below*]. In "The Designer of the Sitting Man" the artist is about to mark on a glass screen a point where one of the light rays from the scene to the artist's eye intersects the screen. The second woodcut, "The Designer of the Lute," shows the section marked out on the glass screen.

Of course the section depends not only

WOODCUTS by Albrecht Dürer illustrate the principle of projection and section. In the first woodcut the artist is about to mark the point at which a light ray from the scene to his eye intersects a glass screen. In the second a scene is marked out on the screen.

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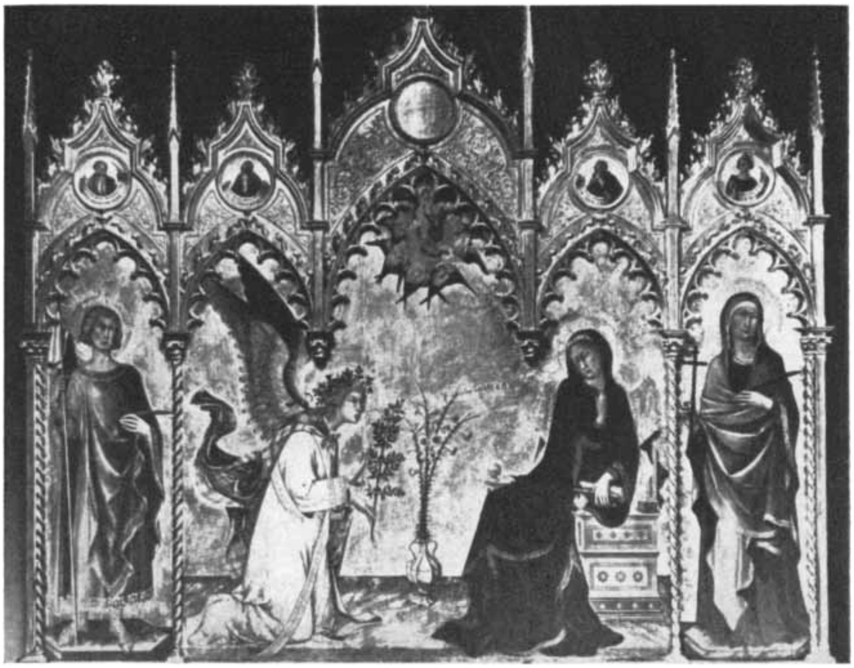
upon where the artist stands but also where the glass screen is placed between the eye and the scene. But this just means that there can be many different portrayals of the same scene. What matters is that, when he has chosen his scene, his position and the position of the glass screen, the painter's task is to put on canvas precisely what the section contains. Since the artist's canvas is not transparent and since the scenes he paints sometimes exist only in his imagination, the Renaissance artists had to derive theorems which would specify exactly how a scene would appear on the imaginary glass screen (the location, sizes and shapes of objects) so that it could be put on canvas.

The theorems they deduced raised questions which proved to be momentous for mathematics. Professional mathematicians took over the investigation of these questions and developed a geometry of great generality and power. Let us trace its development.

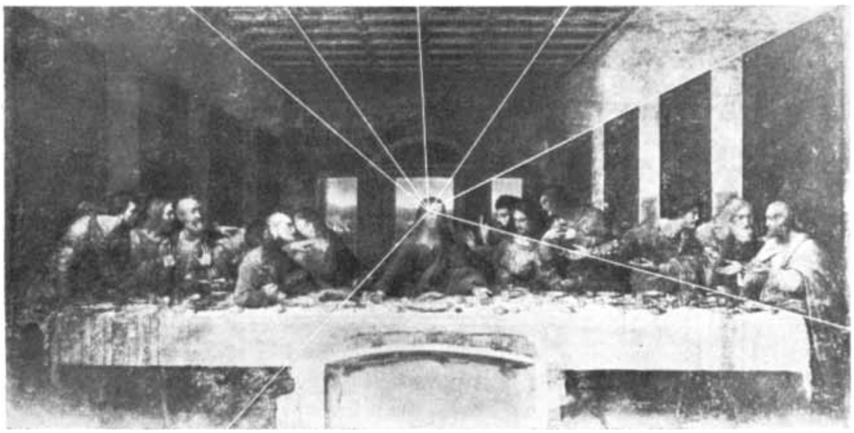
Suppose that a square is viewed from a point somewhat to the side [*Figure 1*]. On a glass screen interposed between the eye and the square, a section of its projection is not a square but some other quadrilateral. Thus square floor tiles, for instance, are not drawn square in a painting. A change in the position of the screen changes the shape of the section, but so long as the position of the viewer is kept fixed, the impression created by the section on the eye is the same. Likewise various sections of the projection of a circle viewed from a fixed position differ considerably—they may be more or less flattened ellipses—but the impression created by all these sections on the eye will still be that created by the original circle at that fixed position.

To the intellectually curious mathematicians this phenomenon raised a question: Should not the various sections presenting the same impression to the eye have some geometrical properties in common? For that matter, should not sections of an object viewed from different positions also have some properties in common, since they all derive from the same object? In other words, the mathematicians were stimulated to seek geometrical properties common to all sections of the same projection and to sections of two different projections of a given scene. This problem is essentially the one that has been the chief concern of projective geometers in their development of the subject.

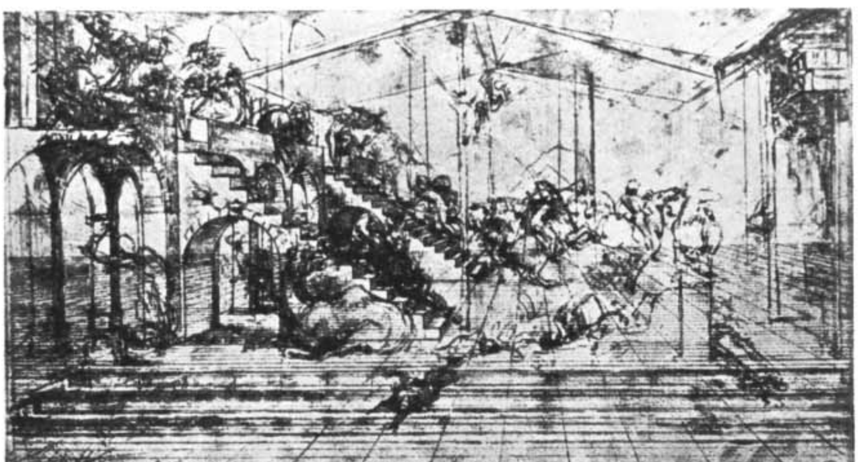
It is evident that, just as the shape of a square or a circle varies in different



THE ANNUNCIATION by Simone Martini is an outstanding example of the flat, stylized painting of the medieval artists. The figures were symbolic and framed in a gold background.



THE LAST SUPPER by Leonardo da Vinci utilized projective geometry to create the illusion of three dimensions. Lines have been drawn on this reproduction to a point at infinity.



DRAWING by da Vinci, made as a study for his painting "The Adoration of the Magi," shows how he painstakingly projected the geometry of the entire scene before he actually painted it.

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sections of the same projection or in different projections of the figure, so also will the length of a line segment, the size of an angle or the size of an area. More than that, lines which are parallel in a physical scene are not parallel in a painting of it but meet in one point; see, for example, the lines of the ceiling beams in da Vinci's "Last Supper." In other words, the study of properties common to the various sections of projections of an object does not seem to lie within the province of ordinary Euclidean geometry.

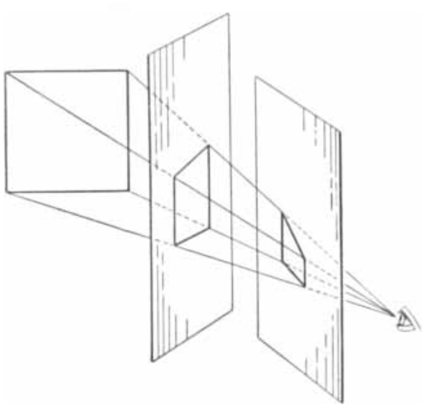

Figure 1 (see text)

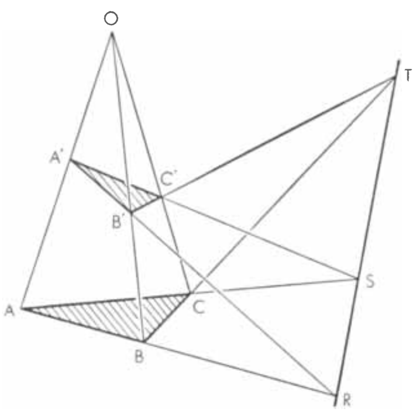

Figure 2

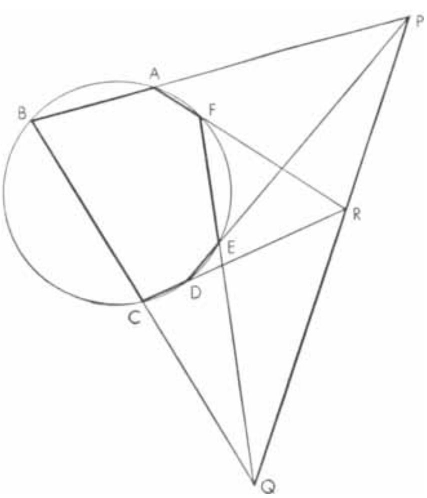

Figure 3

Yet some rather simple properties that do carry over from section to section can at once be discerned. For example, a straight line will remain a line (that is, it will not become a curve) in all sections of all projections of it; a triangle will remain a triangle; a quadrilateral will remain a quadrilateral. This is not only intuitively evident but easily proved by Euclidean geometry. However, the discovery of these few fixed properties hardly elates the finder or adds appreciably to the structure and power of mathematics. Much deeper insight was required to obtain significant properties common to different sections.

The first man to supply such insight was Gérard Desargues, the self-educated architect and engineer who worked during the first half of the 17th century. Desargues's motivation was to help the artists; his interest in art even extended to writing a book on how to teach children to sing well. He sought to combine the many theorems on perspective in a compact form, and he invented a special terminology which he thought would be more comprehensible than the usual language of mathematics.

His chief result, still known as Desargues's theorem and still fundamental in the subject of projective geometry, states a significant property common to two sections of the same projection of a triangle. Desargues considered the situation represented here by two different sections of the projection of a triangle from the point O [*Figure 2*]. The relationship of the two triangles is described by saying that they are perspective from the point O. Desargues then asserted that each pair of corresponding sides of these two triangles will meet in a point, and, most important, these three points will lie on one straight line. With reference to the figure, the assertion is that AB and $A'B'$ meet in the point R; AC and $A'C'$ meet in S; BC and $B'C'$ meet in T; and that R, S and T lie on one straight line. While in the case stated here the two triangle sections are in different planes, Desargues's assertion holds even if triangles ABC and $A'B'C'$ are in the same plane, *e.g.*, the plane of this paper, though the proof of the theorem is different in the latter case.

The reader may be troubled about the assertion in Desargues's theorem that each pair of corresponding sides of the two triangles must meet in a point. He may ask: What about a case in which the sides happen to be parallel? Desargues disposed of such cases by invoking the mathematical convention that any set of parallel lines is to be regarded as having a point in common, which the student is often advised to think of as being at infinity—a bit of advice which essentially amounts to answering a question by not answering it. However, whether or not one can visualize this point at infinity is immaterial. It is logically possible to agree that parallel lines are to be regarded as having a point in common, which point is to be distinct from the usual, finitely located points of the lines considered in Euclidean geometry. In addition, it is agreed in projective geometry that all the intersection points of the different sets of parallel lines in a given plane lie on one line, sometimes called the line at infinity. Hence even if each of the three pairs of corresponding sides of the triangles involved in Desargues's theorem should consist of parallel lines, it would follow from our agreements that the three points of intersection lie on one line, the line at infinity.

These conventions or agreements not only are logically justifiable but also are recommended by the argument that projective geometry is concerned with problems which arise from the phenomenon of vision, and we never actually see parallel lines, as the familiar example of the apparently converging railroad tracks remind us. Indeed, the property of parallelism plays no role in projective geometry.

At the age of 16 the precocious French mathematician and philosopher Blaise Pascal, a contemporary of Desargues, formulated another major theorem in projective geometry. Pascal asserted that if the opposite sides of any hexagon inscribed in a circle are prolonged, the three points at which the extended pairs of lines meet will lie on a straight line [*Figure 3*].

As stated, Pascal's theorem seems to have no bearing on the subject of projection and section. However, let us visualize a projection of the figure involved in Pascal's theorem and then visualize a section of this projection [*Figure 4*]. The projection of the circle is a cone, and in general a section of this cone will not be a circle but an ellipse, a hyperbola, or a parabola—that is, one of the curves usually called a conic section. In any conic section the hexagon in the original circle will give rise to a corresponding hexagon. Now Pascal's theorem asserts that the pairs of opposite sides of the new hexagon will meet on one straight

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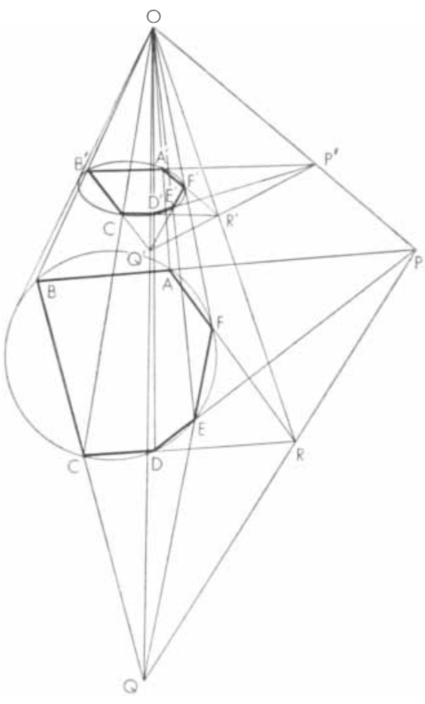

Figure 4

line which corresponds to the line derived from the original figure. Thus the theorem states a property of a circle which continues to hold in any section of any projection of that circle. It is indeed a theorem of projective geometry.

It would be pleasant to relate that the theorems of Desargues and Pascal were immediately appreciated by their fellow mathematicians and that the potentialities in their methods and ideas were eagerly seized upon and further developed. Actually this pleasure is denied us. Perhaps Desargues's novel terminology baffled mathematicians of his day, just as many people today are baffled and repelled by the language of mathematics. At any rate, all of Desargues's colleagues except René Descartes exhibited the usual reaction to radical ideas: they called Desargues crazy and dismissed projective geometry. Desargues himself became discouraged and returned to the practice of architecture and engineering. Every printed copy of Desargues's book, originally published in 1639, was lost. Pascal's work on conics and his other work on projective geometry, published in 1640, also were forgotten. Fortunately a pupil of Desargues, Philippe de la Hire, made a manuscript copy of Desargues's book. In the 19th century this copy was picked up by accident in a bookshop by the geometer Michel Chasles, and thereby the world learned the full extent of Desargues's major work. In the meantime most of Desargues's and Pascal's discoveries had had to be remade independently by 19th-century geometers.

Projective geometry was revived through a series of accidents and events almost as striking as those that had originally given rise to the subject. Gaspard Monge, the inventor of descriptive geometry, which uses projection and section, gathered about him at the Ecole Polytechnique a host of bright pupils, among them Sadi Carnot and Jean Poncelet. These men were greatly impressed by Monge's geometry. Pure geometry had been eclipsed for almost 200 years by the algebraic or analytic geometry of Descartes. They set out to show that purely geometric methods could accomplish more than Descartes's.

It was Poncelet who revived projective geometry. As an officer in Napoleon's army during the invasion of Russia, he was captured and spent the year 1813-14 in a Russian prison. There Poncelet reconstructed, without the aid of any books, all that he had learned from Monge and Carnot, and he then proceeded to create new results in projective geometry. He was perhaps the first mathematician to appreciate fully that this subject was indeed a totally new branch of mathematics. After he had reopened the subject, a whole group of French and, later, German mathematicians went on to develop it intensively.

One of the foundations on which they built was a concept whose importance had not previously been appreciated. Consider a section of the projection of a line divided by four points [*Figure 5*]. Obviously the segments of the line in the section are not equal in length to those of the original line. One might venture that perhaps the ratio of two segments, say $A'C'/B'C'$, would equal the corresponding ratio AC/BC. This conjecture is incorrect. But the surprising fact is that the ratio of the ratios, namely $(A'C'/C'B')/(A'D'/D'B')$, will equal $(AC/CB)/(AD/DB)$. Thus this ratio of ratios, or cross ratio as it is called, is a projective invariant. It is necessary to note only that the lengths involved must be directed lengths; that is, if the direction from A to D is positive, then the length AD is positive but the length DB must be taken as negative.

The fact that any line intersecting the four lines OA, OB, OC and OD contains segments possessing the same cross ratio as the original segments suggests that we assign to the four projection lines meeting in the point O a particular cross ratio, namely the cross ratio of the segments on any section. Moreover, the

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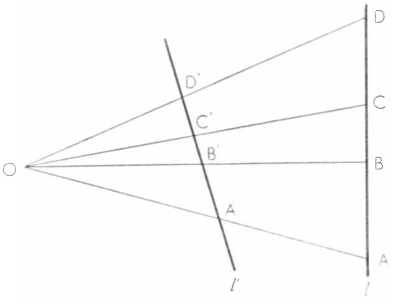

Figure 5

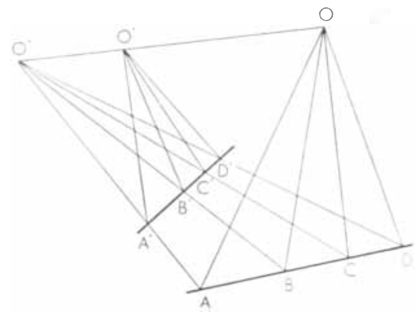

Figure 6

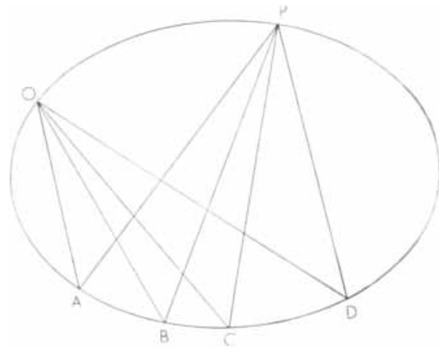

Figure 7

cross ratio of the four lines is a projective invariant, that is, if a projection of these four lines is formed and a section made of this projection, the section will contain four concurrent lines whose cross ratio is the same as that of the original four [*Figure 6*]. Here in the section $O'A'B'C'D'$, formed in the projection of the figure $OABCD$ from the point O'', the four lines $O'A'$, $O'B'$, $O'C'$ and $O'D'$ have the same cross ratio as OA, OB, OC and OD.

The projective invariance of cross ratio was put to extensive use by the 19th-century geometers. We noted earlier in connection with Pascal's theorem that under projection and section a circle may become an ellipse, a hyperbola or a parabola, that is, any one of the conic sections. The geometers sought some common property which would account for the fact that a conic section always gave rise to a conic section, and they found the answer in terms of cross ratio. Given the points O, A, B, C, D, and a sixth point P on a conic section containing the others [*Figure 7*], then a remarkable theorem of projective geometry states that the lines PA, PB, PC and PD have the same cross ratio as OA, OB, OC and OD. Conversely, if P is any point such that PA, PB, PC, and PD have the same cross ratio as OA, OB, OC and OD, then P must lie on the conic through O, A, B, C and D. The essential point of this theorem and its converse is that a conic section is determined by the property of cross ratio. This new characterization of a conic was most welcome, not only because it utilized a projective property but also because it opened up a whole new line of investigation on the theory of conics.

The satisfying accomplishments of projective geometry were capped by the discovery of one of the most beautiful principles of all mathematics—the principle of duality. It is true in projective geometry, as in Euclidean geometry, that any two points determine one line, or as we prefer to put it, any two points lie on one line. But it is also true in projective geometry that any two lines determine, or lie on, one point. (The reader who has refused to accept the convention that parallel lines in Euclid's sense are also to be regarded as having a point in common will have to forego the next few paragraphs and pay for his stubbornness.) It will be noted that the second statement can be obtained from the first merely by interchanging the words point and line. We say in projective geometry that we have dualized the original statement. Thus we can speak not only of a set of points on a line but also of a set of lines on a point [*Figure 8*]. Likewise the dual of the figure consisting of four points no three of which lie on the same line is a figure of four lines no three of which lie on the same point [*Figure 9*].

Let us attempt this rephrasing for a slightly more complicated figure. A triangle consists of three points not all on the same line and the lines joining these points. The dual statement would read: three lines not all on the same point and the points joining them (that is, the points in which the lines intersect). The figure we get by rephrasing the definition of a triangle is again a triangle, and so the triangle is called self-dual.

Now let us rephrase Desargues's theorem in dual terms, using the fact that the dual of a triangle is a triangle and assuming in this case that the two triangles and the point O lie in one plane. The theorem says:

"If we have two triangles such that lines joining corresponding vertices pass through one point O, then the pairs of corresponding sides of the two triangles join in three points lying on one straight line."

Its dual reads:

"If we have two triangles such that points which are the joins of corresponding sides lie on one line O, then the pairs

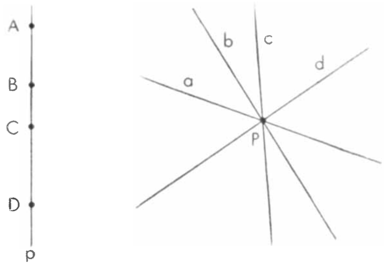

Figure 8

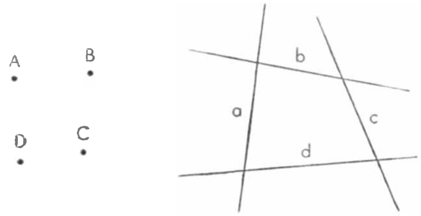

Figure 9

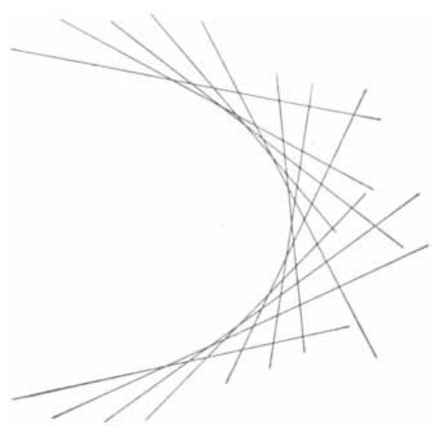

Figure 10

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of corresponding vertices of the two triangles are joined by three lines lying on one point."

We see that the dual statement is really the converse of Desargues's theorem, that is, it is the result of interchanging his hypothesis with his conclusion. Hence by interchanging point and line we have discovered the statement of a new theorem. It would be too much to ask that the proof of the new theorem should be obtainable from the proof of the old one by interchanging point and line. But if it is too much to ask, the gods have been generous beyond our merits, for the new proof can be obtained in precisely this way.

Projective geometry also deals with curves. How should one dualize a statement involving curves? The clue lies in the fact that a curve is after all but a collection of points; we may think of a figure dual to a given curve as a collection of lines. And indeed a collection of lines which satisfies the condition dual to that satisfied by a conic section turns out to be the set of tangents to that curve [*Figure 10*]. If the conic section is a circle, the dual figure is the collection of tangents to the circle [*Figure 11*]. This collection of tangents suggests the circle as well as does the usual collection of points, and we shall call the collection of tangents the line circle.

Let us now dualize Pascal's theorem on the hexagon in a circle. His theorem goes:

"If we take six points, *A*, *B*, *C*, *D*, *E* and *F*, on the point circle, then the lines which join *A* and *B* and *D* and *E* join in a point *P*; the lines which join *B* and *C* and *E* and *F* join in a point *Q*; the lines which join *C* and *D* and *F* and *A* join in a point *R*. The three points *P*, *Q* and *R* lie on one line *l*."

Its dual reads:

"If we take six lines, *a*, *b*, *c*, *d*, *e* and *f*, on the line circle, then the points which join *a* and *b* and *d* and *e* are joined by the line *p*; the points which join *b* and *c* and *e* and *f* are joined by the line *q*; the points which join *c* and *d* and *f* and *a* are joined by the line *r*. The three lines *p*, *q* and *r* lie on one point *L*."

The geometric meaning of the dual statement amounts to this: Since the line circle is the collection of tangents to the point circle, the six lines on the line circle are any six tangents to the point circle, and these six tangents form a hexagon circumscribed about the point circle. Hence the dual statement tells us that if we circumscribe a hexagon about a point circle, the lines joining opposite vertices of the hexagon, lines *p*, *q* and *r* in the dual statement, meet in one point [*Figure 12*]. This dual statement is indeed a theorem of projective geometry. It is called Brianchon's theorem, after Monge's student Charles Brianchon, who discovered it by applying the principle of duality to Pascal's theorem pretty much as we have done.

It is possible to show by a single proof that every rephrasing of a theorem of projective geometry in accordance with the principle of duality must lead to a new theorem. This principle is a remarkable possession of projective geometry. It reveals the symmetry in the roles that point and line play in the structure of that geometry. The principle of duality also gives us insight into the process of creating mathematics. Whereas the discovery of this principle, as well as of theorems such as Desargues's and Pascal's, calls for imagination and genius, the discovery of new theorems by means of the principle is an almost mechanical procedure.

As one might suspect, projective geometry turns out to be more fundamental than Euclidean geometry. The clue to the relationship between the two geometries may be obtained by again considering projection and section. Consider the projection of a rectangle and a

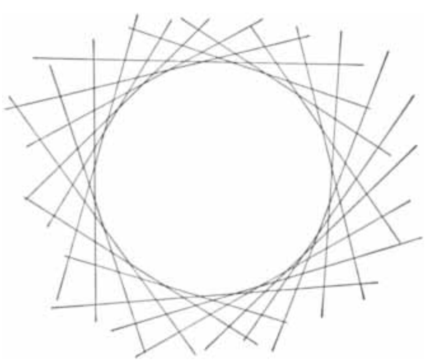

Figure 11

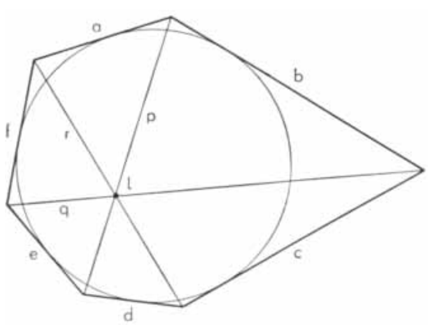

Figure 12

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section in a plane parallel to the rectangle [*Figure 13*]. The section is a rectangle similar to the original one. If now the point *O* moves off indefinitely far to the left, the lines of the projection come closer and closer to parallelism with each other. When these lines become parallel and the center of the projection is the "point at infinity," the rectangles become not merely similar but congruent [*Figure 14*]. In other words, from the standpoint of projective geometry the relationships of congruence and similarity, which are so intensively studied in Euclidean geometry, can be studied through projection and section for special projections.

If projective geometry is indeed logically fundamental to Euclidean geometry, then all the concepts of the latter geometry should be defined in terms of projective concepts. However, in projective geometry as described so far there is a logical blemish: our definition of cross ratio, and hence concepts based on cross ratio, rely on the notion of length, which should play no role in projective geometry proper because length is not an invariant under arbitrary projection and section. The 19th-century geometer Felix Klein removed this blemish. He showed how to define length as well as the size of angles entirely in terms of projective concepts. Hence it became possible to affirm that projective geometry was indeed logically prior to Euclidean geometry and that the latter could be built up as a special case. Both Klein and Arthur Cayley even showed that the basic non-Euclidean geometries could be derived as special cases of projective geometry. No wonder that Cayley exclaimed: "Projective geometry is all geometry!"

It remained only to deduce the theorems of Euclidean and non-Euclidean geometry from axioms of projective geometry, and this geometers succeeded in doing in the late 19th and early 20th centuries. What Euclid did to organize the work of three hundred years preceding his time, the projective geometers did recently for the investigations which Desargues and Pascal initiated.

Research in projective geometry is now less active. Geometers are seeking to find simpler axioms and more elegant proofs. Some research is concerned with projective geometry in n-dimensional space. A vast new allied field is projective differential geometry, concerned with local or infinitesimal properties of curves and surfaces.

Projective geometry has had an important bearing on current mathematical research in several other fields. Projection and section amount to what is called in mathematics a transformation, and it seeks invariants under this transformation. Mathematicians asked: Are there other transformations more general than projection and section whose invariants might be studied? In recent times one new geometry has been developed by pursuing this line of thought, namely, topology. It would take us too far afield to consider topological transformations. It must suffice here to state that topology considers transformations more general than projection and section and that it is now clear that topology is logically prior to projective geometry. Cayley was too hasty in affirming that projective geometry is all geometry.

The work of the projective geometers has had an important influence on modern physical science. They prepared the way for the workers in the theory of relativity, who sought laws of the universe that were invariant under transformation from the coordinate system of one observer to that of another. It was the projective geometers and other mathematicians who invented the calculus of tensors, which proved to be the most convenient means for expressing invariant scientific laws.

It is of course true that the algebra of differential equations and some other branches of mathematics have contributed more to the advancement of science than has projective geometry. But no branch of mathematics competes with projective geometry in originality of ideas, coordination of intuition in discovery and rigor in proof, purity of thought, logical finish, elegance of proofs and comprehensiveness of concepts. The science born of art proved to be an art.

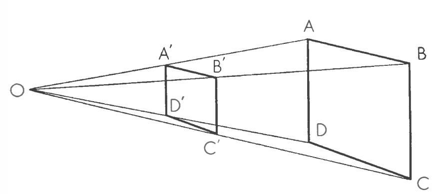

Figure 13

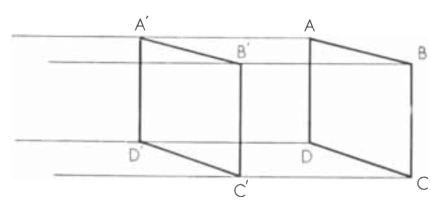

Figure 14

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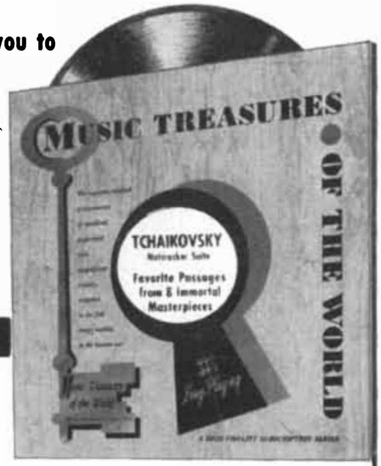

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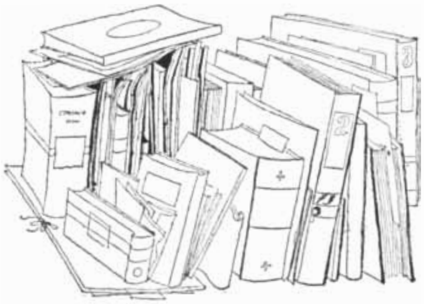

BOOKS

An investigation of how individuals in our society change their opinions

by Reuel Denney

COMMUNICATION AND PERSUASION, by Carl I. Hovland, Irving L. Janis and Harold H. Kelley. Yale University Press ($4.50).

This is not a new book; it was published in 1953. However, it concerns a significant province of social science that has not been discussed in this magazine. Moreover, in the months since the book was published new material has appeared which, in my opinion, considerably enriches any discussion of it. I refer to three publications entitled *Explorations* which record a seminar on communication and culture at the University of Toronto. In effect I shall review both *Communication and Persuasion* and *Explorations*.

As a preamble I should like to define a problem that is common to both works. One of the profound differences between an individual in our society and one in an earlier or more primitive society is the way in which he relates direct experience and indirect experience. What is the difference between direct and indirect experience? All that is meant here is that some experiences lie closer in space and time to the individual (for example, his perception of his own breathing) and some lie farther away (the fact that, as he can learn, it rained yesterday in Samoa). The interesting thing is that, in different societies, these two systems of perception can be linked in different ways. In our industrial society we retain most of the old systems of linkage between direct and indirect experience, but we also employ new linkages that change the context of the old ones.

When a modern infant responds to a dog on television as though it were a real dog, he has obviously learned a linkage unknown to earlier infants. The life of a child can be divided into stages by the way the various kinds of communication to which he is exposed get related to one another. For example, a child younger than three may get additional practice in duplicating language sounds by listening to the television set. As a result his mastery of language may be much greater than that of an Egyptian child in 2000 B.C. The same modern child will continue to reorganize the connections between direct and indirect experience as he grows and learns. Matilda Riley and Samuel Flowerman tell us that, if something goes wrong with a child's feelings of identity with his playmates, he will become disinterested in comic books with people in them and turn to comic books featuring animals. Conversely, if he moves along from comic books about rabbits to those about cowboys, the chances are that his understanding of the group he plays with will accelerate.

The realization that such development is universal has encouraged many social scientists to think that they may be in the early stages of its scientific description. Like Linnaeus in biology they are interested in broad classification of facts. Like Adam Smith in economics they seek a theory of the actions that connect the facts. Like Archimedes they desire to know units of fact and operation and arithmetical relations among them. Perhaps they are more like the transitional experimenters in electricity than anyone else. Like Volta they are much concerned with what it is, if anything, they are observing, if they are observing it. Someday the mere agreement on names will make dull reading of some current arguments in the field.

Meanwhile this matter of the linkage between intimate and remote experience, in an age of mass communication, involves certain constantly recurring issues. One can think of an intimate experience as being equivalent to one that involves unlearned, instinctive behavior; and of a remote experience as being equivalent to one that involves learned behavior. In this view it is as instinctive to perceive your breathing as to breathe, and, in order for an individual to understand the meaning of blobs on a radar screen, it is as necessary to learn something as for the phenomenon of learning to have preceded the invention of radar. Yet, as we shall see in connection with the *Exploration* papers, the remote experiences feed into the definitions employed by an individual to denote his more intimate ones.

The publications discussed here concern the communication systems of man. *Communication and Persuasion* appears at first to be concentrated on the question of learned rather than unlearned behavior. It is subtitled *Psychological Studies of Opinion Change*, and its major interest is in how men move from one opinion to another—an aspect of how they learn. The three issues of *Explorations* analyze the inventions—language, social organization, myth and so on—men have made to regulate their lives. That is, the issues of *Explorations* study the communication techniques that each generation must learn (sometimes quite unconsciously) because preceding generations put them there. This brief description of the two approaches is enough to indicate their theoretical divergence; perhaps it will also suggest how they could complement each other.

These are a few examples of the conclusions offered by Hovland, Janis and Kelley:

"Communications attributed to low credibility sources tended to be considered more biased and unfair in presentation than identical ones attributed to high credibility sources."

"The use of a strong fear appeal, as against a milder one, increases the likelihood that the audience will be left in a state of emotional tension which is not fully relieved when the reassuring recommendations contained in the communication are rehearsed."

"The findings support the general hypothesis that persons who are most strongly motivated to retain their membership in a group will be most resistant to communications contrary to the standards of that group."

"When exposed to a dramatic news event which induces pessimistic opinions

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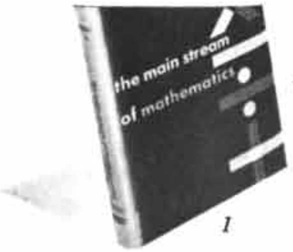

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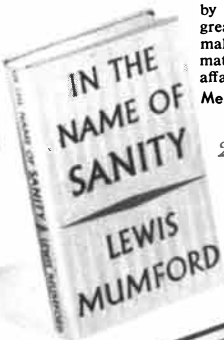

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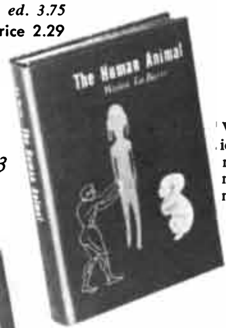

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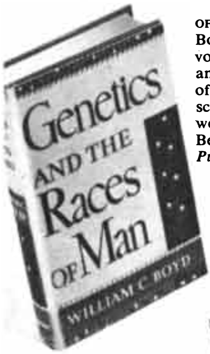

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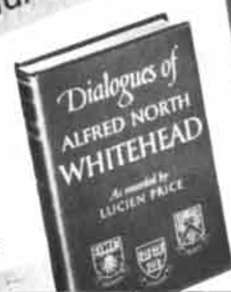

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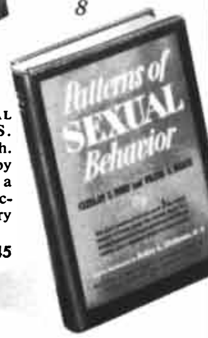

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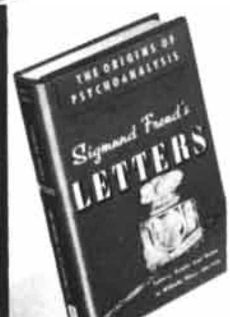

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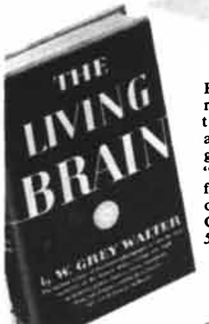

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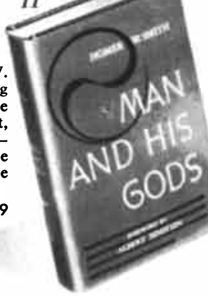

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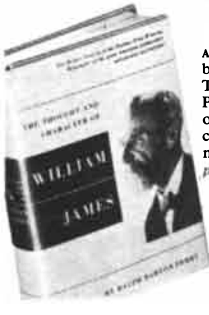

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about the future, an audience will be more resistant to change if previously exposed to a communication that presents grounds for maintaining the opposite opinion."

Upon reading such results some intelligent readers will wonder how anyone could have doubted them, and dismiss the study for that reason. They will be correct in the sense that hardly anyone would disagree with these conclusions upon hearing them stated. They will be incorrect in assuming that the importance of the study lies in the credibility of its conclusions. Undoubtedly the authors would have been pleased to come out with much less credible conclusions—even incredible ones—providing they had gained their own experimental end, which was to arrive at conclusions in their own ingeniously hardheaded way. One senses that their aim was not so much to assert these conclusions as to assert that now, after their experiments, no one dare deny them.

The authors could be regarded, in fact, as being engaged in discovering some of the axioms of persuasion. In experiment after experiment they have proudly excluded many variables, the better to look at the remaining ones. Richness of context was their bugbear and banality was their goal—provided they could endow banality with what by definition it never achieves: the fascination possessed by the obvious when it is rigorously isolated and thoroughly documented. They sought axioms that are independent even if consistent, axioms that are fertile in combination even if unsuggestive when standing apart.

Not all this effort to find the penicillin in the dirt was engineered without a price. The opinions on which the experimenters happened to test opinion change include such matters as the late steel shortage, atomic submarines, the future of monogamy and the threat of tooth decay. The difficulty with such a range of opinions is precisely that it is a range. It is a range of topics that to some people involve opinion. While this presents no problem for any particular experiment reported in the book, it does constitute a problem for all of the experiments taken together. The problem is that people have opinions about topics that involve unimportant opinions and about topics that involve important opinions. The two kinds of opinion might be distinguished as "opinion" and "Opinion." Different people, with different sets of attitudes, make this distinction in different ways. In the U. S. whole class cultures are determined not so much by what opinions their members express on this or that issue, but by whether or not this or that issue as defined by them involves Opinion. In this volume there is no filter that separates an opinion from Opinion. One would have thought that such a strainer would have contributed to understanding. This is not meant to reflect on the stringent modesty with which the investigators have interpreted their data. It is merely to suggest that, if their theorems were to be extended to a wider emotional range of topics, they might prove somewhat brittle.

Perhaps one difficulty here is that, in exploring the relation between the intimate and remote dimensions of personal experience, the authors have oversimplified their notion of it. As men persuaded of persuasion, they have exhaustively studied the side of communication that Elihu Katz and others have called "the campaign"—the deliberate intent to influence some men in some certain direction. Accordingly they do not seem to credit their subjects with ever having learned anything about the variety of things an opinion may be. This difficulty appears to reside in a limitation of their psychological approach. Although there is some evidence that they have tried to take into account Gestalt theory and field theory, their basic orientation approximates the stimulus-reflexive theory of Pavlov. Now it has always been clear that the Pavlovian approach would account for a responsive creature, but it has never been shown that it could cope with an acculturated one. And acculturated men were the subjects of this study.

Such problems are forcibly brought to mind by *Explorations*. In most of these studies what men *must* do and what they *may* do are suspended as possibilities in cultures that could not "get by" with a simple Pavlovian man. Indeed, many of the essays come close to assuming not so much a behaviorism of man as an equally arguable behaviorism of society. They emphasize, in relating the remote to the intimate and the learned to the unlearned, the vast amount of collective rote that enters from the past into the learning of each man in the cultural present.

In pursuit of this theme the essays in *Explorations* attempt to redefine two major areas of study. One area concerns the matter of social memory—the problem of adequately defining the ways in which language and social structure collectively memorize past solutions of social interaction. Why is it necessary, in some societies, to collect another man's head before you can acquire a name? Why is it necessary in some societies to believe, not that your character is *like* that of your namesake grandfather, but that it *is* his character? What, moreover, is the varying weight of the term "necessary" in these observations? These issues point in turn to the second major area of interest—the definition of the "self" as it appears in various cultures.

In the first area the essays isolate a question that will someday be of direct relevance to studies such as *Communication and Persuasion*. In some way men get hold of culturally specific distinctions between the intimate and the remote in their experience. The American newspaper reader can respond to the remoteness of the Presidency by evincing a learned ability to identify intimately with some aspects of it. This follows from the way in which he relates his most direct experiences with his more vicarious ones (seeing the President on television). By contrast the Anatolian peasant, even when literate and even when presented with an equally well-written newspaper in his own language, can do nothing of the kind. In the studies of Daniel Lerner the peasant responds to the remoteness of the Turkish Presidency by evincing a trained incapacity to identify intimately with any important aspect of it.

Many of the essays in *Explorations* are soundings of this theme. They raise questions of the following kind. How many people cannot enjoy a movie based on one of Shakespeare's plays because of preconceptions gained by reading them? Where this kind of "cultural lag" occurs, how does it work out in the competition of speech and writing, or of writing and movies? How are these lags built into the prejudices of specific generations and specific social classes in each culture? What consequences might the study of such lags have for our ideas of what is good or bad in cultural change involving the media of mass communication? To throw more light on the Hovland-Janis-Kelley study—what kind of experience with media of communication constitutes an exposure to "opinion," and what kind constitutes an exposure to "Opinion"? It should be noted that this theme does not exhaust the anthropological variety of the *Explorations* papers; it does serve, however, as an illustration of the general interest in communication that is found in most of them.

In *Explorations* the comparative prestige of the various media is analyzed with a hypothesis in mind. Some members of the University of Toronto seminar that produced these studies suspect that print "pulls rank" on film largely because

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print is older; and that analogous biases about the comparative value of this medium or that run through whole cultural configurations. The conviction of some people that FM radio is *their* medium while AM radio is the *other* man's medium is paralleled by the belief of a Bantu tribesman that his word for a yam is better than his wife's. By such approaches these essays contribute to our view of the way in which an individual learns to incorporate intimate information systems with the remote information systems in his own culture.

The theme emerges in the essay by Dorothy Lee dealing with a Canadian Indian's perception of himself. He belongs to a tribe in which arms are labeled not as right arms and left arms, but as north arms and south arms or east arms and west arms. Thus his language, itself a communication system with a more remote focus than the nervous system that makes him aware of his own arms, constructs his self-perception in a unique way. It is only a step from such an observation to the formulation of the hypothesis that the "selves" of people who have television sets from early childhood must necessarily be different from the selves of those who do not have them. True enough, as the Hovland-Janis-Kelley studies show, the difficulty of isolating units of observation in such a field may be greater than in linguistics. Nevertheless this makes a relevant point. The opinions that Hovland, Janis and Kelley studied were regarded by the investigators as being analogous to arms that can only be "right" or "left" (that is "opinions"), but they were possibly regarded by some of the people who gave them as being "east" or "west" (that is, "Opinions").

By this time a reader familiar with the problems of research in social science will have smelled a disagreement between Kantian anthropologists and Pavlovian psychologists. It may sound as though the decision has been made in favor of Kant's "synthetic unity of perception" and against Pavlov's "reactivity." If it were so simple—which it is not—it would be an inconclusive debate.

Explorations has quite as much trouble in escaping from Kant's subjective categories as *Communication and Persuasion* has in transcending Pavlov's salivating dog. While Kant's subjective approach has become a useful program for research in human perception, it is still metaphysical. Sometimes the investigator forgets this. The cultural anthropologist is often in danger of transferring the locus of Kant's mental categories from the mind of man to the "mind" of an entire culture. The poverty of context for the information unit in communication studies like that of Hovland, Janis and Kelley is sometimes corrected in anthropology by an oversupply of context provided by master variables such as "world view" and "ethos." This probably means that, along their current routes of development, communication studies need to be brought philosophically up to date. That they present such a challenge to some observers could be taken as a sign of their variety and vitality.

Short Reviews

A HISTORY OF MECHANICAL INVENTIONS, by Abbott Payson Usher. Harvard University Press ($9.00). Usher's esteemed history, published in 1929, long out of print and almost as hard to find in libraries as in bookstores, is now reissued in a revised and enlarged edition. Material has been added on the early history of clocks, on textile techniques in Syria and China at the beginning of the Christian Era, and on internal-combustion engines and gas turbines; minor improvements and corrections have been made throughout the text. The most substantial change consists of four new introductory chapters—80-odd pages—dealing with the relation between technology and economic forces, the complex nature of social evolution, the dependence of technical advances upon concepts derived from philosophy and science as distinct from those derived from current production methods, and "the emergence of novelty in thought and action." These chapters are disappointing. They are excessively abstract, heavy with the cultural anthropologist's lingo and not startlingly original. It does not help one understand how inventions are made to be told familiar anecdotes about James Watt, Lord Rutherford and Thomas Edison, anecdotes describing the circumstances but not the thought processes leading to the invention of the steam engine, the theory of atomic structure, the electric light filament; and it is not reassuring to find the author seriously quoting Arthur Koestler's account of what went on in Archimedes' head when he discovered the funny business about King Hiero's crown. *A History of Invention* is still one of the best books of its kind, but you can skip the first four chapters.

ATOMS IN THE FAMILY: MY LIFE WITH ENRICO FERMI, by Laura Fermi. The University of Chicago Press ($4.00). These are the congenial and ironic remi-

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☐ **THE GYROSCOPE APPLIED** *by K. I. T. Richardson.* A book, *The Gyroscope and Its Applications,* was published in 1946 when secrecy restrictions prevented reference to many interesting achievements and possibilities. Since then considerable technical advances have been made and the secrecy restrictions have been relaxed to some extent, although they still apply in many instances. The present book therefore, based on that published in 1946, has been almost entirely rewritten describing much that is new but at the same time incorporating most of the information given in the first version, although this is presented in a different manner and in some cases from a different viewpoint. $15.00

☐ **THE ELEMENTS OF CHROMATOGRAPHY** *by T. I. Williams.* Although less than a decade has passed since the appearance of *An Introduction to Chromatography,* so much new work has been published that a completely new book, rather than a revised edition of the old one, seemed called for. In particular, paper partition chromatography has developed enormously since 1946, and ion-exchange chromatography, which proved so spectacularly successful in Manhattan Project, had then scarcely been described at all. Both these methods have received due attention here. $4.75

☐ **FLIGHT HANDBOOK.** The fundamental theory of aerodynamics is simply explained, and the design principles of each class of aircraft, from balloons to missiles, are lucidly described. Engineering principles in piston engines, gas turbines, ramjets, pulse-jets and rockets are discussed, and the theory of aerial navigation is also covered.

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niscences of the wife of the late physicist. Mrs. Fermi's story begins with her first meeting with her husband in Italy in 1924, when she was 16 and he was 22, "a promising physicist," already teaching at a university and soon to be known among his friends as "the Pope" because of his serene sense of infallibility. Episodically and informally she then describes almost 30 years of courtship, marriage, social and scientific life in Rome, the work which gained Fermi the Nobel prize, his migration with his family to the U. S. from Fascist Italy (whose anti-Semitic decrees in 1938 began to affect the status of his wife), his researches on the atomic bomb in New York, Chicago and Los Alamos. Among the most interesting chapters of the book are those which deal with the prewar experiments of Fermi and his associates on radioactivity and nuclear target shooting, conducted in a small laboratory with simple apparatus and the use of a Roman senator's fountain as a neutron moderator. Besides her gift for scientific explanation, Mrs. Fermi has a nice, deflating sense of humor. The anecdotes have a certain sameness of gentle malice and understatement, but several of them are pure delight. This one is typical. One day in the spring of 1940 the Fermis drove to Washington for a meeting of the Physical Society. They were accompanied by an old friend, the Italian physicist Franco Rasetti: "We had driven some time when Enrico, who never missed a chance to show me his proficiency in Americanism, announced:

" 'In a short while we'll cross the Mason-Dixon Line.'

" 'Mason-Dixon? What's that?' I asked.

" 'Fantastic! You don't know . . . ,' Rasetti started.

" 'It's the line that divides the North from the South,' Enrico explained.

" 'What sort of line? An imaginary line? A physical line?' I asked.

" 'It's formed by two rivers, the Mason and the Dixon,' Rasetti stated with his usual assurance.

" 'Rivers! You are entirely wrong!' Enrico sneered. 'Mason and Dixon were two American Senators, one from the North, the other from the South.'

"They bet one dollar. It turned out that Charles Mason and Jeremiah Dixon were English astronomers. But Enrico, never a good loser, claimed the dollar.

" 'Because,' he said, 'it is conceivable that English astronomers should become American Senators; but rivers . . . never.' "

FROM FISH TO PHILOSOPHER, by Homer W. Smith. Little, Brown and Company ($4.00). Homer Smith is a physiologist known for his important contributions to knowledge of the kidney. In this book he shows how this marvelous organ, which he characterizes as "the major foundation of our physiological freedom," has by its functional architecture and adaptation to changes in environment permitted fish to invade the land and ultimately to give rise to man. The kidney keeps the internal environment in a balanced state, which is the essential condition for the emergence of consciousness; the kidney makes urine and also transcendentalism. Smith rides his theme hard, but this is a first-class book of popular science—admirably written, provocative, of compelling interest.

HIGHWAY ENGINEERING, by Laurence I. Hewes and Clarkson H. Oglesby. John Wiley & Sons, Inc. ($8.00). A road is a lot more than a road, as this 600-page monograph plainly shows. Highway engineering is of course concerned with the different kinds of roads and how they are built, a subject which ranges from the grubbing of sites to the higher mathematics of concrete. But construction and maintenance, however complex and ramified, are only a part of modern highway practice, which embraces such matters as urban planning, highway economics, the making of surveys and plans, legal questions of rights of way, the rapidly evolving theory of highway design, the study of drainage, problems of roadside development. The student and the specialist will find this book a thorough and able exposition of every department of an important branch of modern technology.

GEORGE DAVIDSON: PIONEER WEST COAST SCIENTIST, by Oscar Lewis. University of California Press ($3.50). George Davidson was born in England in 1825, emigrated with his parents to the U. S. when he was seven, entered the U. S. Coast Survey in 1845 as clerk to Superintendent Alexander Bache, served for 45 years in charting the Pacific coastline from Mexico to Alaska, engaged in various astronomical studies, eclipse expeditions, geodetic surveys and geographical reconnaissances, established the first astronomical observatory on the West Coast and interested James Lick in putting up the money for the Lick Observatory, became professor of geodesy and astronomy and later professor of geography at the University of California, and devoted himself with immense energy to his researches and writings and to the scientific and scholarly life of California almost until the day of his death

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W. W. Lindsay, Jr., Electronics Committee Chairman (left), Sherwood C. Frey, Navy Studies Department Manager (seated), and R. P. Buschmann, Company Studies Department Manager (right), examine relationships between plane and radar performance.

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at age 86 in 1911. Oscar Lewis, known for his contributions to California history, has written an able and readable and not too long biography of this almost forgotten and unjustly neglected scientist. The volume itself, with its plates, photographs and maps, is an exceptionally handsome example of bookmaking.

THE AGE OF MOUNTAINEERING, by James Ramsey Ullman. J. B. Lippincott Company ($6.00). The first great date in the history of mountaineering is 1786, the year Mont Blanc was conquered. Men had of course climbed before. In 1492 an intrepid fellow named Antoine de Ville pulled himself to the top of Mont Aiguille, a "steep and formidable" rock tower in the Dauphiné; in 1500 Leonardo da Vinci clambered about on the southern slopes of the Pennines "in the interest of meteorological investigation." But mountaineering as a sport, a challenge, a dedicated way of life, a divine madness to which few are wholly immune, came into its own when the Swiss Horace Bénédict de Saussure decided that, since Mont Blanc was there, he must get to the top. "It became for me a kind of illness," he wrote. "I could not even look upon the mountain, which is visible from so many points round about, without being seized with an aching of desire." He did not succeed, though his determination and planning led to the conquest of the highest of the Alps after several attempts. But it is not necessary to succeed to be a great mountaineer. One of the immortals is George Leigh Mallory, who, on the morning of June 8, 1924, vanished on the summit ridge of Mount Everest; there are others similarly enshrined for their failures. The complete history of the struggle to reach the summits of the earth is told with incomparable enthusiasm and skill by Ullman. The first edition of his book appeared in 1941; it is here carried forward through the ascent of Chomolungma—the mountain we call Everest after the first Surveyor General of India. But in such rapid succession have the greatest peaks succumbed—Annapurna (26,493 feet), Tirich Mir (25,260) and Nanga Parbat (26,660) within three years—that the latest record is apt to be out of date before it gets into print. Indeed, a slip has been pasted in the end of this book announcing the climbing of K-2, the world's second highest mountain, on August 4, 1954. Ullman's fascinating history has many fine photographs, maps and sketches, and a set of interesting appendixes, one of which lists 100 famous mountains. Twenty-three of them, it is reassuring to learn, have not yet been climbed.

STREAMS, LAKES AND PONDS, by Robert E. Coker. The University of North Carolina Press ($6.00). Professor Coker describes the characteristics of inland surface waters, the flow, turbidity and pollution of streams, the basic nutrients in water, the lake or pond as a residence for plants and animals. His book brings together many different kinds of information which will interest the student, the conservationist, the health officer, the farmer and many others who wish to know more about life in fresh water.

ELECTROACOUSTICS, by Frederick V. Hunt. Harvard University Press and John Wiley & Sons, Inc. ($6.00). This volume in the series of Harvard monographs in applied science is extremely valuable for its excellent, attractively written section—a small book in itself—on the history of electroacoustic transducers (*i.e.*, mechanisms for converting electric energy into acoustic energy and vice versa), including the telephone, the microphone, piezoelectric and moving-conductor devices. Since the major portion of Professor Hunt's study deals with the theory of transducers and will appeal only to radio and audio engineers and specialists in related fields, it would be a service (and a considerable saving) to historians of science if the publishers found it possible to make the historical narrative separately available.

EXPLAINING THE ATOM, by Selig Hecht. The Viking Press ($3.75). By far the best popular book on atomic energy when it appeared in 1947, this lucid exposition by the late Professor Hecht has been brought up to date and expanded by Eugene Rabinowitch, photosynthesis investigator and editor of *Bulletin of the Atomic Scientists.* He has added material on the making of fission and fusion bombs, the melancholy history of attempts to achieve international control of atomic energy, the development of atomic power. Rabinowitch writes clearly and readably, without fuss or pretentiousness; his revision helps keep alive a classic of scientific simplification and constitutes a tribute to the memory of a warm and sympathetic human being who, as the book shows, felt deeply his social responsibilities as a scientist.

WORKSHOPS FOR THE WORLD, by Graham Beckel. Abelard-Schuman ($4.00). This is a narrative account of the functions of the specialized agencies of the United Nations, giving typical examples of the problems handled by each: FAO (Food and Agriculture Organiza-

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tion), ICAO (International Civil Aviation Organization), WHO (World Health Organization), UNICEF (United Nations Children's Fund), UPU (Universal Postal Union), ILO (International Labor Organization), ITU (International Telecommunication Union), UNESCO, International Bank, International Monetary Fund, WMO (World Meteorological Organization), IRO (International Refugee Organization), IMCO (Inter-Governmental Maritime Consultative Organization). It is a reminder of how much men can accomplish by working together, even in today's divided world.

Notes

THE FOUNDATIONS OF STATISTICS, by Leonard J. Savage. John Wiley & Sons, Inc. ($6.00). The author elaborates a theory of decision based on the currently ill-favored personalistic interpretation of probability: that probability judgments reflect personal conviction, and that the role of the mathematical theory "is to enable the person using it to detect inconsistencies in his own real or envisaged behavior."

VESALIUS ON THE HUMAN BRAIN, edited and translated by Charles Singer. Oxford University Press ($5.75). This is the first translation into English of Book VII of Vesalius' epoch-making *De Humani Corporis Fabrica.* Professor Singer provides valuable annotations, and the book is illustrated by the magnificent anatomical drawings of the *Fabrica* as well as by figures taken from other contemporary or earlier works.

MINERALS FOR ATOMIC ENERGY, by Robert D. Nininger. D. Van Nostrand Company, Inc. ($7.50). An official of the Atomic Energy Commission presents "a guide to exploration for uranium, thorium, and beryllium," with the help of which, and a Geiger counter (now sold, as the book indicates, by Sears, Roebuck as well as by Abercrombie & Fitch), almost anyone may be able to promote the national, and his personal, security. Photographs and maps.

DICTIONARY OF MATHEMATICAL SCIENCES, VOL. II, ENGLISH-GERMAN, by Leo Herland. Frederick Ungar Publishing Company ($4.50). This second volume completes a very useful bilingual dictionary of mathematics, mathematical logic, statistics, commercial arithmetic, physics and astronomy. Well thought out, clearly printed, skillfully cross-referenced.

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THE AMATEUR SCIENTIST

About utilizing the moon to occult the stars and increase telescope resolution

Conducted by Albert G. Ingalls

Where, precisely, am I? This is one of those easy-to-ask, impossible-to-answer questions. You must settle for an approximation. If you ask it while touring U. S. 80 from Plaster City, Calif., to Los Angeles, you may be content with the knowledge that you are less than a mile from Coyote Wells. But if you are an amateur astronomer setting up a telescope at the same site, you would prefer map information to the effect that you are at Latitude 32° 44′ 01″.29 North; Longitude 116° 45′ 24″.00 West.

Not even this seemingly precise pinpointing, however, would satisfy Colonel J. D. Abell and his associates in the Army Map Service. New methods of navigation, such as Loran, have disclosed gross errors in cartographic data. Particularly inaccurate are the positions of the oceanic islands; some important atolls in the Pacific appear to be as much as half a mile or more off their true positions on the map.

The personnel of Colonel Abell's bureau, in conjunction with the 30th Engineer Group under Colonel William C. Holley, has developed an ingenious method of surveying by astronomical occultations which promises greatly improved accuracy. They have invited amateurs—in or out of military service—to join in their fascinating research program.

"Our trouble," writes John A. O'Keefe, chief of the Research and Analysis Branch of the Army Map Service, "stems from the fact that we don't know straight up! If we had some way of pinpointing our zenith we could draw maps to any desired accuracy." In other words, if accurately known positions on the earth were correlated with one another by locating them with reference to the known positions of stars when they are at the zenith, the correlations would enable the cartographers to draw a good map of the world.

In principle the job is simple. You wait until a selected star of known position is directly overhead and clock it. Accurate timing is necessary because the relationship of the earth's surface to the sky changes continually as the earth rotates. Time signals broadcast from the U. S. Bureau of Standards' station WWV make precise clocking easy.

The usual instrument used for locating the zenith is a transit, which relies on a plumb bob or its counterpart, the bubble level. The source of error resides right here in these two gadgets, according to O'Keefe. Both the plumb bob and the bubble are thrown out of true by local irregularities in the density of the earth's crust which distort the gravitational field. Attempts have been made to correct for local deviations, but "this sort of guesswork gets you nowhere," says Floyd W. Hough, chief of the Service's Geodetic Division. "Even if you could estimate the effect of surface features accurately, you still would need information about conditions underground. Density varies there, too, and generally in the opposite direction."

The Army men decided to fix positions on the earth by timing occultations of stars by the moon as it moves across their positions in the heavens. One method of using the moon as a geodetic instrument is to photograph its position in relation to stars in the background at a given instant; it has been possible in this way to get fixes accurate to a tenth of a second of arc, which means locating positions on the earth with an accuracy within 600 feet. However, considering that this distance is more than twice the width of an aircraft runway, the desirability of still greater accuracy is obvious. The Army Map Service set out to improve on the accuracy of fixes by the moon's occultations.

The best telescopes, such as the 200-inch reflector on Palomar Mountain and the largest refractors, have a theoretical resolving power considerably better than .1 second of arc. But you cannot carry them from place to place on the earth, and furthermore their resolving power has practical limits, imposed by poor seeing conditions, distortion of the optical train by variations of temperature and so on. Above all there is diffraction, the master image-fuzzer, which arises from the wave character of light itself. Because adjacent waves interfere with one another, the light from a distant star does not cast a knife-sharp shadow when it passes the edge of the moon. Waves of starlight grazing the moon's edge interact, diverge and arrive at the earth's surface as a series of dark and light bands bordering the moon's shadow. The first band, the most pronounced, is about 40 feet wide.

The solution hit upon by O'Keefe and his associates was a new way to use a telescope which makes it capable of incredible resolution. They developed a portable rig (which amateurs can build) that plots lunar positions to within .005 second of arc as a matter of everyday field routine—resolution equivalent to that of an 800-inch telescope working under ideal conditions! It can also do a lot of other interesting things, such as measuring directly the diameters of many stars. It can split into double stars images which the big refractors show as single points of light. Some observers believe that it could even explore the atmosphere of a star layer by layer, as though it were dissecting a gaseous onion. Of greatest interest to the Army, the method measures earth distances of thousands of miles with a margin of uncertainty of no more than 150 feet!

The telescope that yields these impressive results has a physical aperture of only 12 inches. The design—a Cassegrain supported in a Springfield mounting—follows plans laid down by the late Russell W. Porter, for many years one of the world's leading amateur telescope makers. Full details of the optical parts and mounting are presented in *Amateur Telescope Making—Book Two.*

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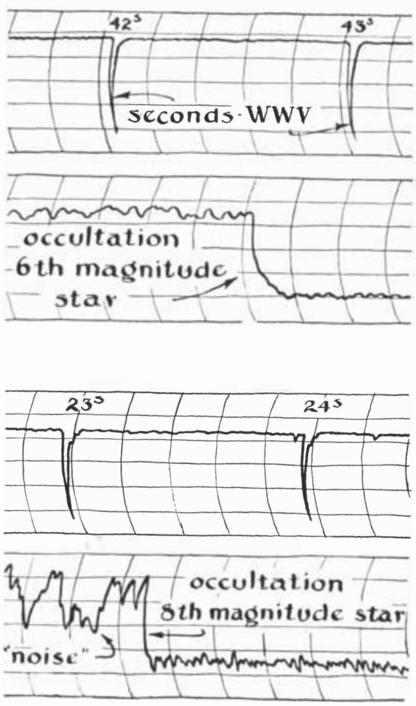
The secret of the instrument's high resolving power is in the way it is used rather than in uniqueness of optical design. The telescope is trained on a selected star lying in the moon's orbit and is guided carefully until the advancing edge of the moon overtakes and begins to cover the star. Depending on the diameter and distance of the star, it may take up to .125 of a second for the moon to cover (occult) it completely. During this interval the edge of the moon becomes, in effect, part of the telescope—like a pinhole objective with an equivalent focal length of 240,000 miles. As the edge of the moon passes across the star, the intensity of the starlight diminishes, and the differences in intensity at successive instants are measured. It is as if a 240,000-mile-long tube were equipped at the distant end with a series of slit objectives—with the moon covering one slit at a time. The resolving power depends upon the great focal length.

The tiny successive steps in the starlight's decay are detected by a photomultiplier tube and a high-speed recorder. In principle the measurement of terrestrial distances by lunar occultation resembles measuring by the solar eclipse technique. The moon's shadow races over the earth's surface at about 1,800 feet per second. Except for differences in instrumentation and the mathematical reduction of results, the eclipse of the star is essentially the same kind of event



Recordings of star occultations

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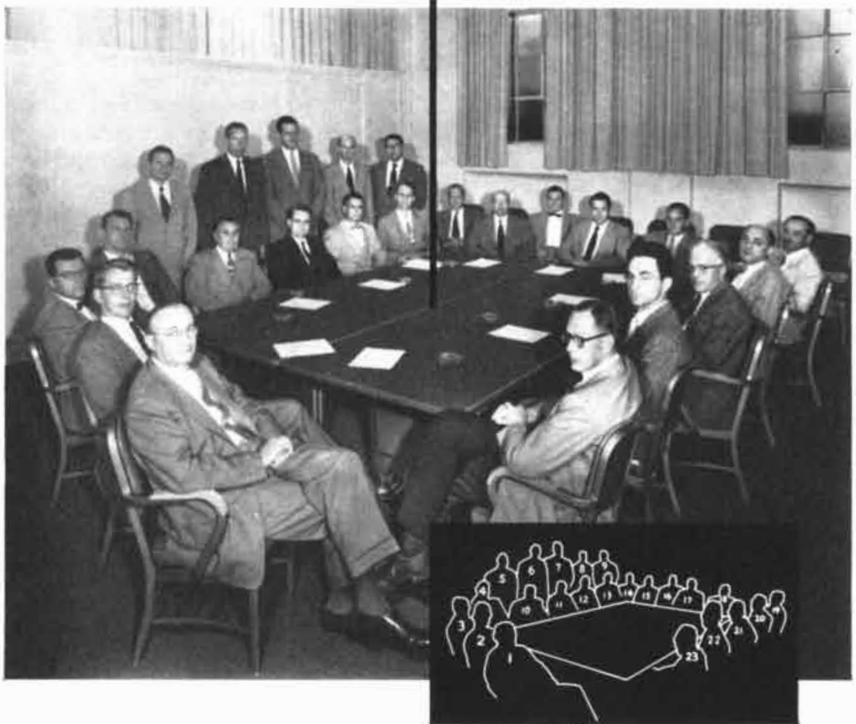

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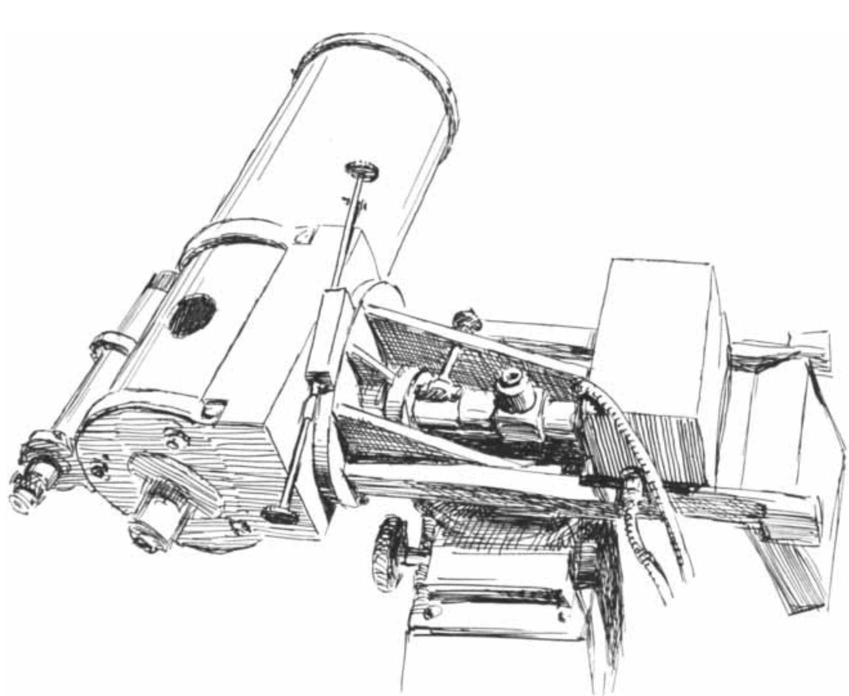
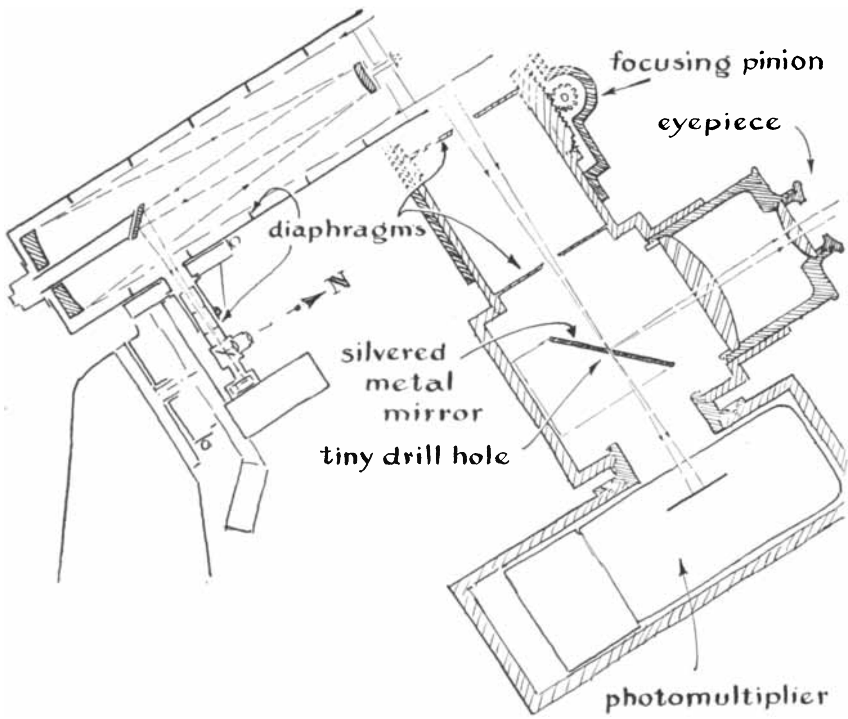
as the eclipse of the sun. The insensitivity of the eye prevents star eclipses from making newspaper headlines, but photomultiplier tubes respond to such an eclipse strongly. They also detect the fuzziness caused by diffraction at the edge of the moon's shadow. The most prominent diffraction band, as previously mentioned, is some 40 feet across—the limit to which measurements by occultation are carried. The sharpest drop in starlight registered on typical recordings spans .015 second of time. Since the moon near the meridian has an average apparent speed of about .33 of a second of angular arc per second of time, the recorded interval of .015 of a second corresponds to .005 of a second of arc. This is the instrument's effective resolving power.

Any amateur who owns a Springfield mounting equipped with a high-quality

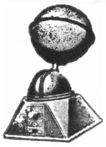


Springfield mounting equipped for photoelectric occultation work



Optical path of the system (left) *and details of the eyepiece* (right)

OPTICAL BARGAINS



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mirror of eight inches aperture or larger can convert for high resolution work at a cost which is modest in proportion to the gain in performance. What he needs is a photomultiplier tube, a power supply, an amplifier and a high-speed recorder.

The photocell costs about $150. The amplifier must be of the direct-current type with a linear response good to at least 200 pulses per second. The recorder should be a double-channel job—one pen for registering time signals and the other for starlight. The Brush Development Company of Cleveland markets a recorder of the recommended type along with a companion amplifier for about $1,000. With a little ingenuity the amateur can contrive adequate counterparts for substantially less. He also needs a filter to cut out the 400- and 600-cycle tone of WWV, so beloved of musicians. These units are available through dealers in radio equipment for about $15.

The eyepiece must be equipped with a cell for the photomultiplier tube and with a pinhole aperture for screening out unwanted moonlight. The pinhole (about .010 of an inch in diameter) is made in a metal mirror assembled in the eyepiece tube at an angle of 45 degrees, as shown in the drawing on the opposite page. A Ramsden eyepiece focuses on the pinhole. In operation the mirror is seen as a bright field with a small black speck, the pinhole, in the center. The star's image appears against the mirror as a brighter speck on the bright field. Thus it is easy to guide the image into position over the pinhole. When properly centered, some starlight strikes the edge of the pinhole, forming a small brilliant ring surrounding a jet-black speck. The ring aids in subsequent guiding.

Occultation observing has attracted a substantial following among amateurs in recent years. In the U. S. their interest in the work has been stimulated by the Occultation Section of the American Association of Variable Star Observers, whose offices are at 4 Brattle Street, Cambridge 38, Mass. Their world-wide observations, made by eye and timed by chronograph, are forwarded to Flora M. McBain at Greenwich, England. She supervises the mathematical reductions. The results of occultation observations have been used to establish irregularities in the rotation of the earth and to improve the tabulations of the moon's orbit.

Dirk Brouwer of the Yale University Observatory, who has made an exhaustive interpretation of the observations collected during the past century, sees an opportunity in the new photoelectric

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"When will Daddy come?"

Sul Ja wants her daddy. Every day she looks for him. Every day she asks her mother, "When will Daddy come?" Sul Ja is only four years old. How can her mother explain why Daddy doesn't come—that he still is a prisoner of the Communists in North Korea, that he may even be dead?

Sul Ja's mother doesn't say these things. Like Sul Ja, she hopes that her husband *will* come back some day. In the meantime she struggles desperately to keep her little family together. In war-torn Seoul, where thousands of refugees strive to rebuild their lives, the young mother runs a roadside stand —and makes $10 a month! This does little more than pay the rent, let alone meet the needs of a growing child like Sul Ja. With Korea's bitter winter here, her plight is still more precarious.

HOW YOU CAN HELP SUL JA

You can't bring Sul Ja's father home, but you *can* help her, and thousands of youngsters like her. Through Save the Children Federation, you can send warm clothing, shoes, bedding, school supplies—and even candy—to a child in Korea or in Austria, Finland, France, Western Germany, Greece, Italy or Yugoslavia. You will get a case history of "your" child, a photograph, and a progress report. You can write to "your" little boy or girl and the family, and receive letters in return, so that your material aid becomes part of a larger gift of understanding and friendship. An SCF Sponsorship is only $120 a year, $10 a month. The cost is so small—the good so great.

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SA-6

technique for the group to make an impressive addition to its already substantial scientific contribution. The photoelectric cell betters the response time of the eye (estimated at about .1 second of arc) by 100-fold or more and eliminates human variables. Thus it makes possible far higher accuracy in timing occultations. Moreover, the high-resolution aspect of the technique opens a whole new and relatively unexplored field for original work by amateurs. As Professor Brouwer points out, star occultations, like solar eclipses, can be observed only in certain regions at particular times. A world-wide network of amateur observatories equipped for high resolution work could cover many more star occultations in any year than are accessible to the great telescopes of Southern California.

One serious drawback that prevents utilizing the full potential of the increased accuracy at present is the irregularity of the moon's surface. If these irregularities are not allowed for in the calculations, the resulting position of the moon will frequently be off by several tenths of a second of arc. And if the star happens to be occulted at a point on the moon's limb where a high peak or low valley is located, the result may be off in extreme cases by two seconds of arc. A new study of the irregularities of the moon's surface by C. B. Watts at the United States Naval Observatory in Washington, expected to be completed soon, should make it possible to correct for the deviations with an accuracy matching the sensitivity of the photoelectric technique.

The drawing on page 97 shows a pair of typical curves, recording the occultations of a sixth magnitude star and an eighth magnitude one. Note the jaggedness of the fainter star's curve. This is due to "noise," a term borrowed from radio and telephone engineering to describe random fluctuations in the output current of an amplifying device. The output of noise increases when the volume or "gain" control of the amplifier is turned up to compensate for a weak input signal. Noise originating in the photomultiplier (the principal source) can be reduced by chilling the tube with dry ice. The sharp drop in each curve marks the interval of occultation. Its steepness is determined principally by the diffraction pattern. In the case of some big stars, such as Antares, the effect of size can be seen in a flattening of the curve.

When a double-star system is occulted, the curve drops steeply for a time, indicating occultation of the first

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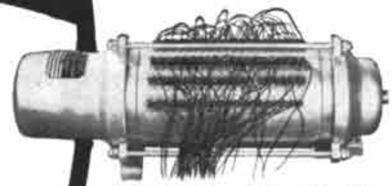

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star, then levels off, and falls steeply again when the companion is occulted. The duration of the flat portion of the curve is the measure of the pair's separation. Some curves of Antares and other large stars show bends and twists which seem to come from bright and dark parts of the star's disk as well as from the stellar atmosphere. The proper interpretation of these records, however, is still considered an open question by some astronomers—another indication of the opportunity the technique presents to an amateur who enjoys original work.

"There is far better than an even chance that we shall stumble onto much that we didn't expect," writes O'Keefe. "We are examining stellar disks with greater resolving power than ever before. We shall certainly find a lot of close, fast binary stars. Perhaps we shall also find stars with extended atmospheres and all that. In occultations of very bright stars we are in a position to detect very faint, close companions. I really do not see how anyone getting into this sport can miss hooking some information of value, and he might catch a really big fish."

Incidentally, if a college man with a background in astronomy faces induction into the armed forces and the idea of occultation work appeals to him, he would be well advised to communicate with the Army Map Service in advance. The bureau is on the lookout for likely candidates.

In many respects photoelectric occultation seems almost too good to be true. Neither poor seeing nor diffraction within the instrument has the slightest effect on the high resolving power of the method, and it is as precise when the moon occults a star low in the sky as overhead. The reasons will be discussed in these pages in a future issue along with other theoretical aspects of the phenomenon, if a significant number of readers express an active interest in the subject.

"The whole thing," writes O'Keefe, "no doubt gives the impression that a rabbit is being produced from a hat. It appears most surprising that such a powerful method for detailed examination of the sky should have gone unexplored for so long. This, of course, we enjoy. Our group did not invent the technique: It was suggested by K. Schwarzschild in Germany and A. E. Whitford in the U. S. It has not been exploited before because people simply could not believe that it works. But if I can get people to disbelieve thoroughly in something which is done before their eyes, then I have at least entertained them—and myself."

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