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October 1957

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Established 1845 SCIENTIFIC AMERICAN October, 1957 Volume 197 Number 4

ARTICLES

DEPARTMENTS

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THE COVER

The photograph on the cover shows a small section of a Sumerian tablet (*see page 74*) in the University Museum of the University of Pennsylvania. Found at Nippur, the tablet is the oldest known pharmacopoeia.

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ND FACTS

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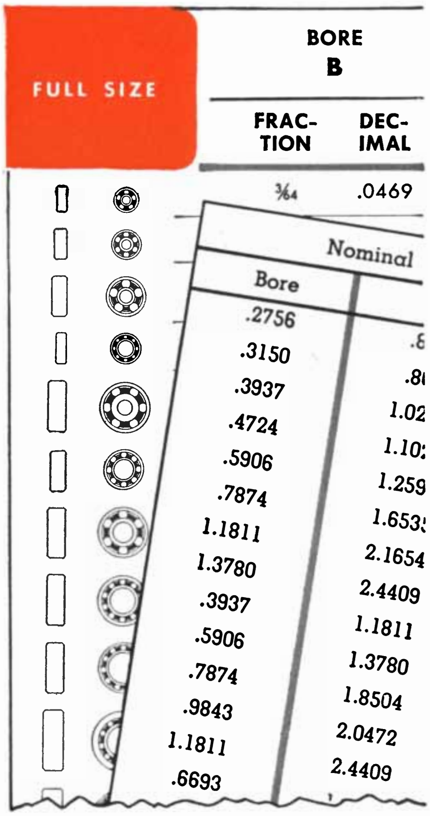

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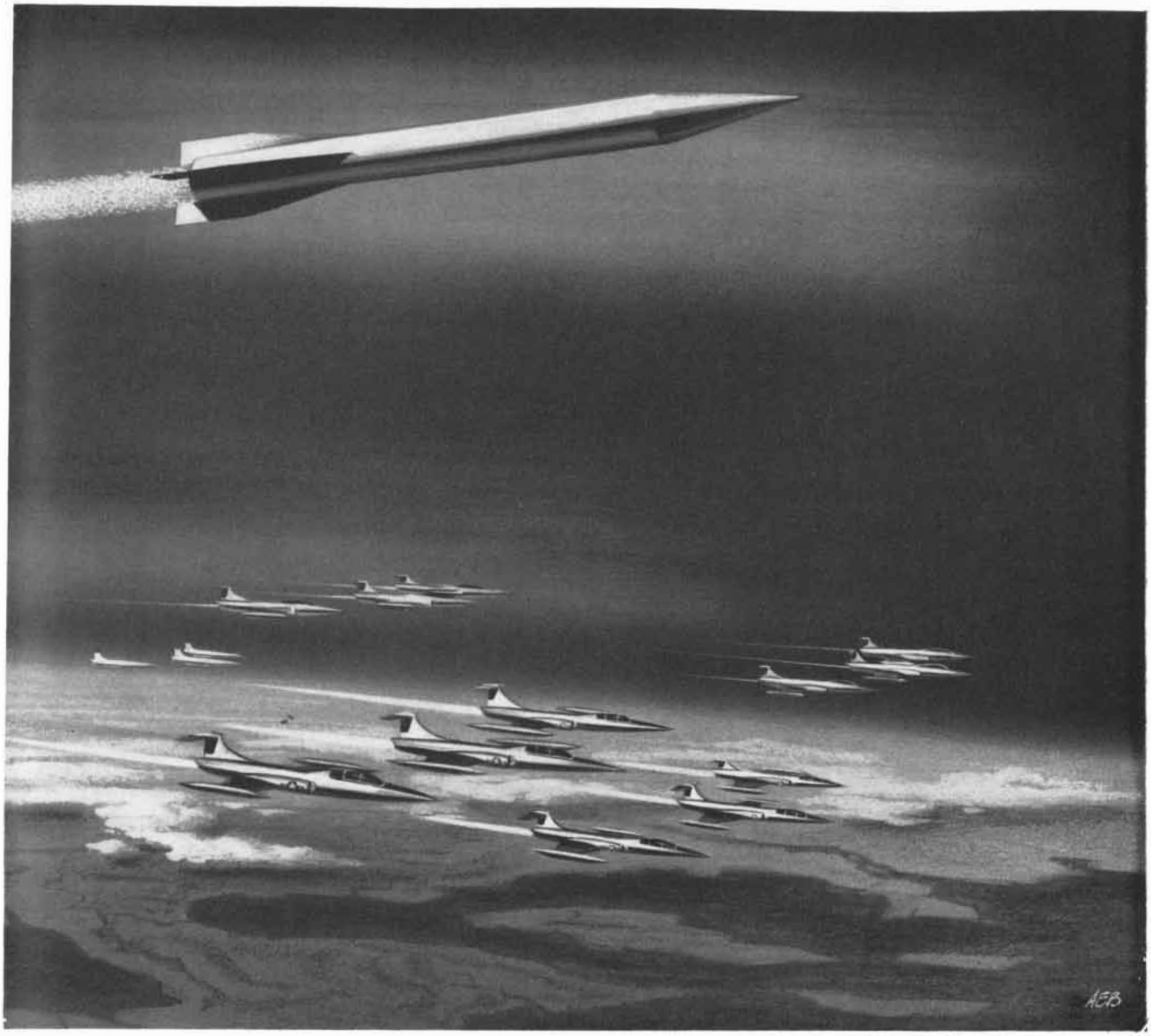

LETTERS

Sirs:

I enjoyed the excellent article "The Ear," in your August issue, by Georg von Békésy.

In his article under the heading "Operations for Deafness," Dr. Békésy speaks of two types of operations designed to cure otosclerotic deafness. The first operation (stapes mobilization) consists of loosening the rigid stapes and thus restoring the normally functioning lever action of the ossicular chain. The second operation (fenestration) consists of drilling a hole in the bony wall of the internal ear.

Stapes mobilization was tried from 1876 to 1900 abroad and in this country, but at the turn of the century was abandoned, not to be heard of again until 1952 when it was rediscovered in the U. S. Improved technique, better lighting, magnification and antibiotics have now made this operation a successful and practical one in the hands of skilled ear surgeons all over the world.

Dr. Békésy was told, he says, that the operation was successful in 30 per cent of the cases. But it is interesting to analyze this figure. Firstly, it is a statistic from the first report of 211 cases, grouping the most suitable with the least suitable cases, using the first experimental methods of five years ago. In these five years, improvements and evolutionary developments in the technique have greatly increased the percentage of success. At the Sixth International Congress of Otolaryngology held in Washington, D. C., May 6–10, 1957, ear surgeons from this country and many foreign countries, employing our technique and some modifications, reported as high as 70 per cent success.

Dr. Békésy seems not too enthusiastic about the stapes operation because "the surgeon cannot get a clear look at the scene of the operation and must apply the pushing force to the stapes at random." This is contrary to the experience of ear surgeons who use the loupe and operating microscope (10 to 40 magnification) and do get an excellent view of the operative site. The degree and direction of the force upon the stapes to move it is always dictated by the structural and pathological changes which are visible. Since these changes vary in each individual, the force upon the stapes is different. But in each instance the degree and direction of the force is precise and not "at random."

Dr. Békésy states that the mobilization causes the bone which holds the stapes rigid to break, and the breaking of bone cannot be standardized or made precise. This is true, since nature lays down this pathological bone differently in every individual. No two stapes in this disease are ever identical. However, since hearing has been restored in thousands of cases, and the improvement maintained for more than five years, one must conclude that the broken bone has remained broken and has thus provided an adequate pathway for the entrance of sound to the internal ear, a circumstance seldom provided by nature.

In conclusion, it has amply been proven that the percentage of success of the more major fenestration nov-ovalis operation is the same in ears in which the simpler stapes mobilization has failed as it is in virgin ears, and stapes mobilization can succeed in unsuccessfully nov-ovalis–fenestrated ears. The two operations are complementary. By doing the simpler mobilization operation first we lose nothing of the potential of the older technique and the patient may gain substantially from the new. Ear surgeons all over the world have adopted this view.

SAMUEL ROSEN, M.D.

New York, N.Y.

Sirs:

I am grateful to Dr. Rosen for his comments about my article.

I should like to elucidate a point about the "randomness" of the attack in the

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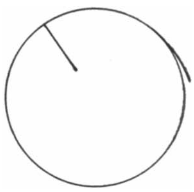

stapes mobilization. Most surgeons who perform this operation have a preferred direction and point of attack for the force they apply when they begin to break loose the stapes footplate. If the first attack is not successful, they then try another direction and continue to move from one place to another. If it were not for these random attempts, it would not happen that a patient might become stone deaf after an unsuccessful mobilization or might suffer injury to the facial nerve. Often it is not the lack of light or magnification but the curvature and narrowness of the auditory canal that make it impossible to inspect around the entire edge of the stapes footplate and locate the place and size of the bony growth on the edge. This is why it is not yet possible to develop general mechanical principles for mobilization. The operation remains in the hands of most surgeons empirical, and its success depends heavily on the surgeon's skill.

I agree with Dr. Rosen that stapes mobilization and the fenestration operation are to some degree complementary. I do not know any theoretical reason why fenestration should not be performed after an unsuccessful mobilization. Oddly enough, however, very few patients have undergone fenestration of an unsuccessfully mobilized ear. Why? I think it is partly because the laboratory surgeon, like most hospital surgeons, does not like to operate in a cavity in which a colleague has already worked. In a standard surgical technique, deeper and deeper layers are exposed in a timed sequence of steps, by proceeding from one anatomical landmark to another. Every surgeon has some landmarks of his own, and if they are destroyed he may get lost in the human temporal bone and waste time in getting reoriented. A surgeon trains himself over many years to face the pathology produced by nature, but the pathology produced by an earlier operation may be too much for him. Since the patient seldom goes back to the surgeon with whom he had no success, a possible solution would be a one-stage operation in which the mobilization would first be tried, and if it was unsuccessful the surgeon would proceed immediately to a fenestration. If this were done, only those surgeons would mobilize who could also perform a fenestration.

I gave the figure 30 per cent for successful cases of mobilization after having discussed the question with several surgeons. Dr. Rosen is correct in stating that figures are reported as high as 70 per cent. On the other hand, relatively high percentages may be obtained in the

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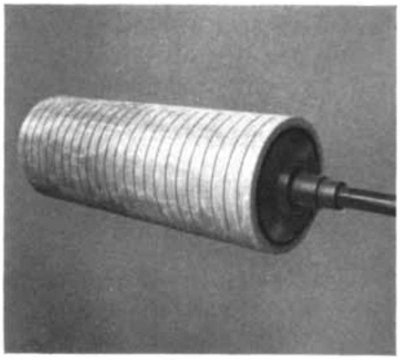

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following way. Quite early it had become obvious that in early stages of otosclerosis mobilization is easy. The physical reasons for this are clear. At the beginning of the disease, the bony bridge across the elastic band on the edge of the stapes footplate is small and it can be broken without too much force. In these cases the mobility of the footplate may be a third or a fourth of the normal (hearing loss 10 or 12 decibels). If the mobilization is successful, of course, the hearing improves at best only 10 to 12 db. In the usual otosclerotic patient, however, the mobility may be one hundredth or one thousandth of normal (hearing loss 40 to 60 db.). In these cases the bony growth is so extended that mobilization is more difficult to achieve. It is obvious that by mobilizing only very early cases the percentage of successes can be very much increased. But the improvement in hearing is so small that there is a legitimate question whether, in these cases, the operation is necessary.

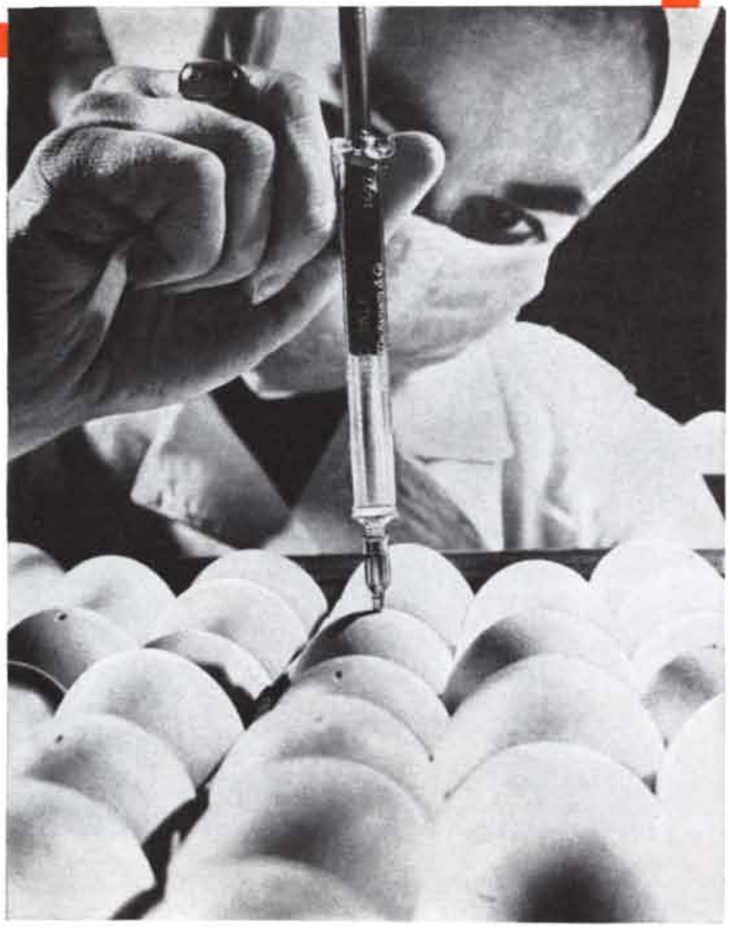
It has also been suggested that in those cases in which it is not possible to mobilize the stapes footplate a hole may be pierced through the footplate. It is well known that if the diagnosis of otosclerosis was correct, the opening immediately improves the hearing. But it is not known how, in the weeks after the operation, the inner ear will stand such an open wound. Many cases may develop secondary inflammation of the inner ear, and nerve deafness may result. This procedure is definitely not mobilization, and in my opinion a patient should be asked for his permission before this type of surgery is undertaken. It is a short-cut form of fenestration, and the improvement of hearing cannot be claimed for mobilization. I would like to point out further that a patient counts any surgery successful only if, as a consequence of the operation, he does not have to wear a hearing aid. Using the patient's criterion, the mobilization is hardly successful in 30 per cent of patients.

Surgery is a difficult field and as it grows many new and different points of view must be evaluated. I do not want to discourage new approaches to alleviating otosclerosis, but I am not convinced that the early literature on otosclerosis provides a goldmine of surgical procedures.

Georg von Békésy

Psycho-Acoustic Laboratory
Harvard University
Cambridge, Mass.

Life on the Chemical Newsfront



THE THREAT OF ASIATIC FLU VIRUS spurred a "crash" program at Lederle Laboratories in which the entire virus section was turned to producing preventive vaccine. First step is the inoculation of chick embryo with the virus strain. The harvested virus is subsequently concentrated and purified, then inactivated by formalin so that it is safe for human use and will still protect against influenza. Cyanamid's virus research center is one of the world's largest and most fully equipped, and conducts a continuing program to combat these ultramicroscopic killers. (Lederle Laboratories Division)

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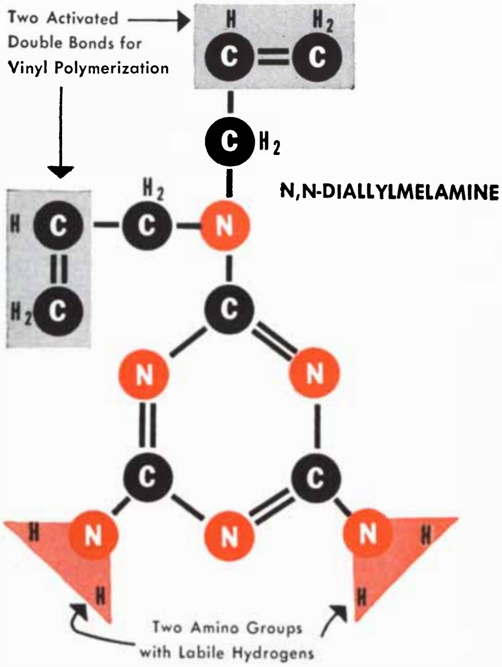

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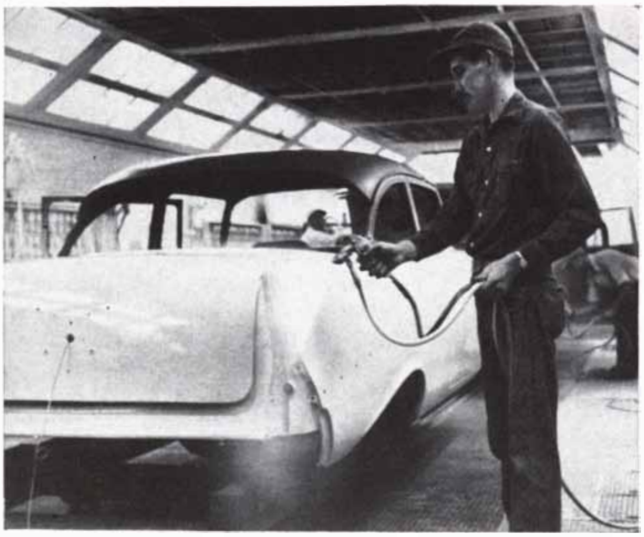

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SCIENTIFIC AMERICAN

OCTOBER, 1907: "It always affords the SCIENTIFIC AMERICAN very real pleasure to record the final success of an inventor who has shown the intelligence and indomitable perseverance which have characterized Mr. Marconi in his six years' struggle to achieve the seemingly impossible, and establish a system of wireless transatlantic telegraphy between the old and the new world. It is certain that among the many names which will always be honorably associated with the development of wireless telegraphy, that of the young Anglo-Italian will ever hold the place of honor. We say this with full knowledge of the fact that the foundation of his accomplishment was laid over 30 years ago, when Clerk Maxwell, in an address to the Royal Society, defined the character of ether waves and predicted the possibility of wireless telegraphy by means of electro-magnetic waves. Nor are we forgetful of the fact that in 1887 Prof. Hertz, by the announcement of his discoveries, earned the right to give his name to the etheric waves which Marconi and his contemporaries have turned to such good account. During the past four years the inventor has been devoting himself with unrelenting energy to the perfecting of his apparatus. The power of the plants on both sides of the Atlantic has been greatly increased. In a few days' time the system is to be opened for regular commercial dispatches, and there is a general belief that at last Marconi has triumphed over all difficulties and has seen the successful completion of his life work."

"The success of the *Lusitania* in steadily breaking all transatlantic records stands for something more than the achievement of an individual steamship company, commendable though that is, and for something more than the success of one of the two great maritime nations contending for supremacy on the high seas. The significance of the fine performance of this ship lies in the fact that it marks the successful accomplishment of a supreme effort in the development

Shown at Bell Laboratories, Murray Hill, N. J., are, left to right, F. J. Herr, S. T. Brewer, L. R. Snoke, E. E. Zajac and F. W. Kinsman.

They're wiring the seas for sound

These five Bell Labs scientists and engineers may never "go down to the sea in ships." Yet, they're part of one of the most exciting sea adventures of modern times. Along with many other specialists, they are developing the deep-sea telephone cable systems of the future.

Here's how they join many phases of communications science and engineering—to bring people who are oceans apart within speaking distance.

F. J. Herr, M.S., Stevens Institute, is concerned with systems design and analysis. He studies the feasibility of new approaches and carries out analysis programs to select optimum parameters for a proposed system design.

S. T. Brewer, M.S. in E.E., Purdue, communications and electronics engineer, explores new designs for sea-bottom amplifiers needed to step up power of hundreds of simultaneous telephone conversations.

L. R. Snoke, B.S. in Forestry, Penn State, is the team biologist. He investigates the resistance of materials to chemical and microbiological attack in sea water. Materials are evaluated both in the laboratory and in the ocean.

E. E. Zajac, Ph.D. in Engineering Mechanics, Stanford, is a mathematician. He studies the kinematics of cable laying and recovery. Cable's dynamic characteristics, ship's motion, the mountains and valleys in the ocean bottom—all must be taken into account.

F. W. Kinsman, Ph.D. in Engineering, Cornell, solves the shipboard problems of storage, handling and "overboarding" of cable. New machinery for laying cable is being developed.

Deep-sea cables once were limited to transmitting telegraph signals. Bell Labs research gave the long underseas cable a voice. New research and development at the Labs will make this voice even more useful.

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"Dr. Frederick A. Cook is at present at Etah, Peary's base in North Greenland, and proposes to make a winter dash for the Pole. This expedition is in marked contrast to many that have set out for the same objective. Dr. Cook is attended by only one man, a cook, and his expedition is said to be an afterthought, he having resolved on making the attempt while on a pleasure cruise in the North. Capt. Bartlett, the sailing master of the craft which conveyed Dr. Cook to Etah, says that a fine lot of dogs are available. To reach the Pole and return in safety, Dr. Cook must cover about one thousand miles—a dangerous trip in the winter season."

OCTOBER, 1857: "By the latest accounts from England, it is reported that the directors of the Atlantic Telegraph Company have come to the conclusion to delay the attempt to re-lay the cable until next summer. This decision, in our opinion, amounts to a confession that the failure of the undertaking was more complete than has been reported, and there is some disagreeable fact connected with it, not yet given to the public; it has also the appearance of an attempt to delay the enterprise indefinitely. We insist, however, that they are bound, in honor, by the means placed at their service, by what has been done, *Avco today*

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and by what has failed to be done, to lay that submarine cable safely through the Atlantic, whether or not a single message should ever pass from shore to shore through it."

"It is said that the number of locomotives running in the U. S. at the present time is estimated to exceed 9,000. The proportion of engines to length of road will average one to every three miles; for, while some of the Western roads have but one to every five or six miles, many others, like the Erie, New York Central, Baltimore and Ohio, &c., have one for nearly every two miles."

"Some experiments of an interesting character have been made in Paris, with a view to testing the value of different diving machines and appliances. Four kinds of diving apparatus were tried—those of Messrs. Siebe, Heinke, Cabirol and Ernous. All of these are constructed in nearly the same manner, being composed of a water-proof dress, terminated at the upper part by a cuirass of metal, to which, when on the body of the diver, is screwed a helmet of the same metal, having affixed to it a tube for giving air, the supply of which is kept up by means of an air pump and a valve for letting off the breath of the diver. One of the experiments tried with Siebe's apparatus proved that the diver can, of his own free will, come to the surface by removing a part of the weight which keeps him under water. The four divers descended at the same time. One of them remained under water 40 minutes consecutively, and the others a somewhat shorter period of time, picking up, during the submersion, several small pieces of metal which had been thrown down."

"The misunderstanding between the Russian government and Col. Colt, in regard to the delivery of a large quantity of Minié rifles, has been determined by the referees against the latter. So far as we know, it is the first case in which any government ever consented to refer a private claim to arbitrators. Under our government, meritorious claimants oftentimes suffer great injustice for want of a simple and fair mode of proceeding like this."

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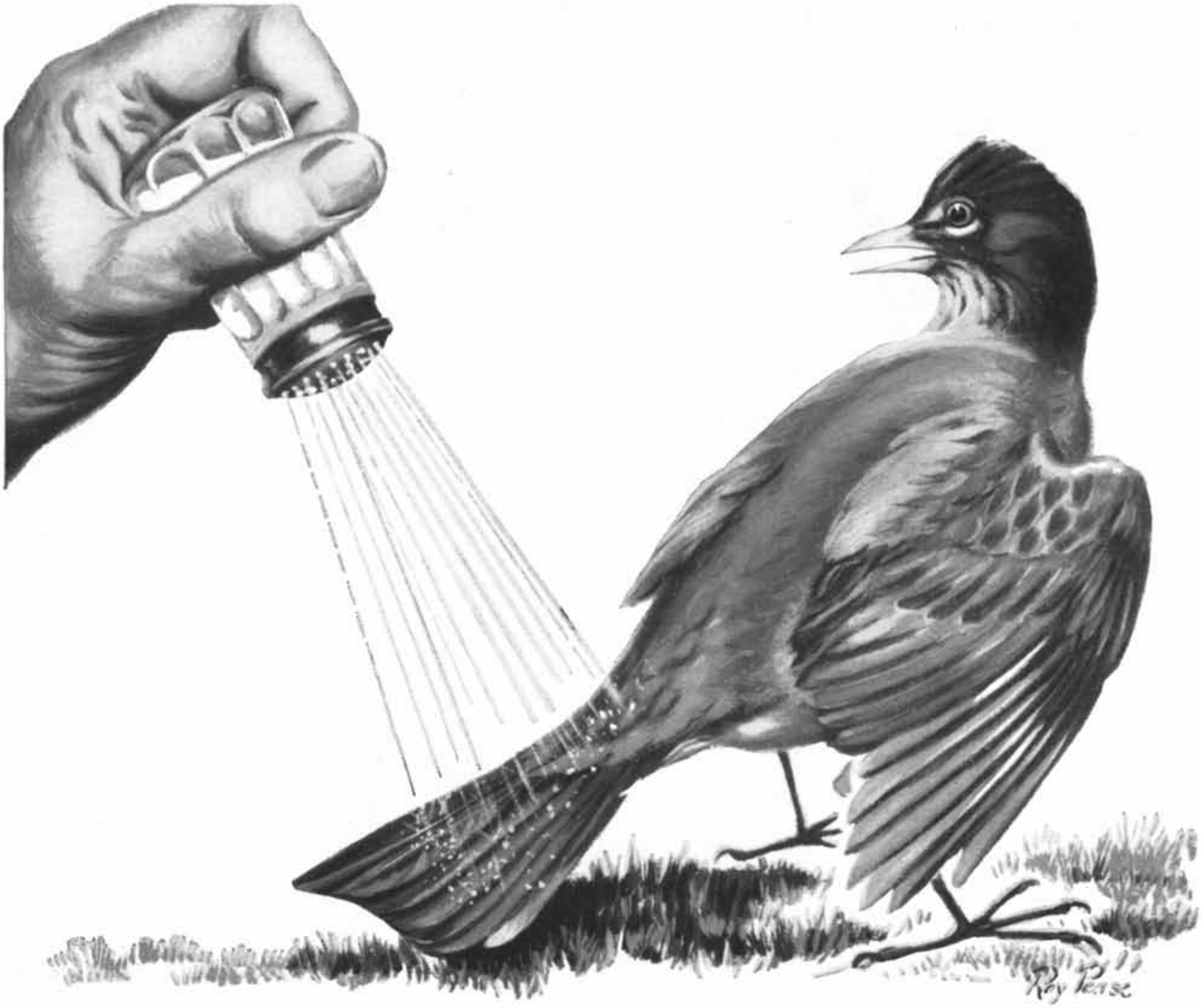

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THE AUTHORS

MORTON GRODZINS ("Metropolitan Segregation") is a political scientist who has written several notable books on the social basis of political activity. Among these are *Americans Betrayed* (about the displaced Nisei Japanese of World War II) and *The Loyal and the Disloyal.* Born in Chicago, he graduated from the University of Louisville in 1940, after having served that institution for two years as its director of public relations. He received a Ph.D. from the University of California in 1945, then went to the University of Chicago, where he has been at various times dean of the social sciences, editor of the University of Chicago Press and adviser to the Chancellor. He is now chairman of the Department of Political Science. Grodzins is using Chicago and its suburbs as a base for studying the intimate structure of the U. S. Federal system, which he describes as "not a three-layer cake of government but a marble cake or what the British call a rainbow cake: *i.e,* all 'levels' of government share important decisions in all major activities of government." His article stems from an investigation he made for the Special Studies Project of the Rockefeller Brothers Fund.

A. H. WOODCOCK ("Salt and Rain") is an oceanographer whose career has taken several unusual turns. Born in Georgia in 1905, he thought his life's ambition fulfilled when he completed two years of agricultural training at the state college and became a farmer. As luck would have it, his first job was with a yacht-fancying orchardist, and in the slack season he found himself cruising off the New England coast. Finding the sea-going life congenial, he switched to a full-time job as sailor-technician aboard the *Atlantis,* a research vessel of the Woods Hole Oceanographic Institution. At sea Woodcock began making scientific observations of his own (in fact, his recent studies in cloud physics were inspired by his early attempt to explain the soaring of sea birds). In 1942 he became a research associate of the Institution, and four years later he was appointed oceanographer.

N. TINBERGEN ("Defense by Color") does his research at the University of Oxford, where he is well known both as an expert on the innate behavior of animals and as a popular lecturer. A

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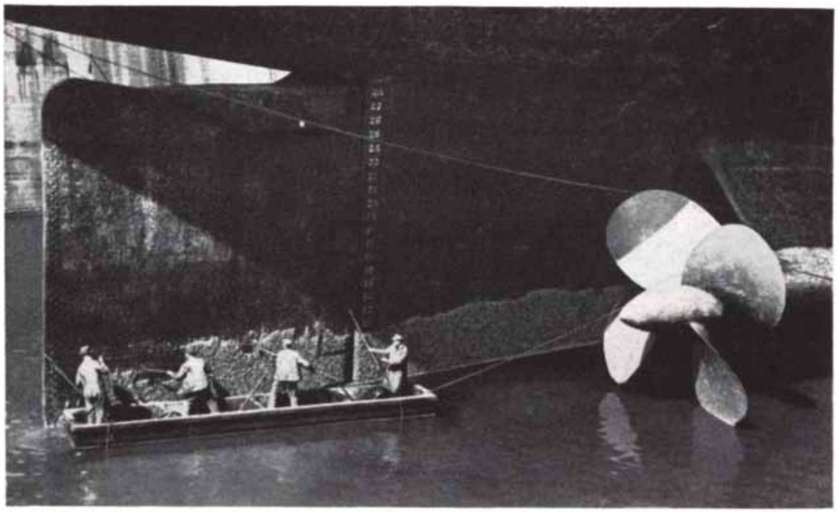

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native of the Netherlands, he received his doctorate from the University of Leiden in 1932, later studied and taught at the University of Vienna, Yale University and Columbia University. Tinbergen is the author of *The Herring Gull's World*. His two previous articles for SCIENTIFIC AMERICAN were "The Curious Behavior of the Stickleback" (December, 1952) and "The Courtship of Animals" (November, 1954).

SAMUEL NOAH KRAMER ("The Sumerians") has devoted his life to studying, copying and translating cuneiform tablets—especially those few among them which preserve the epic poems and other literary texts of ancient Sumer. He was born in Russia in 1897 and brought by his parents to Philadelphia in 1906. There he went to normal school and was a teacher in public and private schools for 10 years, meanwhile earning a B.S. from Temple University and a Ph.D. from the University of Pennsylvania. At Pennsylvania he studied the languages of ancient Mesopotamia, and after a year on expedition in Iraq, he joined the Assyrian Dictionary Staff at the Oriental Institute of the University of Chicago. A long series of grants enabled him to puzzle out hundreds of tablets preserved in U. S. and Turkish museums, and to renew the excavation of tablets at Nippur after a lapse of 50 years. He is now Clark Research Professor of Assyriology at the University of Pennsylvania and curator of the tablet collections in the University Museum.

WINSTON H. BOSTICK ("Plasmoids") is professor of physics and head of the physics department at Stevens Institute of Technology. There he manufactures and studies plasmoids by the technique which he developed over the past three years at the Livermore Radiation Laboratory of the Atomic Energy Commission. Bostick was trained at the University of Chicago, where he acquired a B.S. in 1938 (along with a varsity letter in swimming), and a Ph.D. under Arthur H. Compton in 1941. During World War II he worked at the Radiation Laboratory of the Massachusetts Institute of Technology. In 1948 he went to Tufts University, where his work in the well-known "pinch" effect led him to Livermore. In spare time Bostick plays chamber music on the violin or viola.

S. J. SINGER ("The Specificity of Antibodies") is associate professor of physical chemistry at Yale University. He was born in New York, graduated from Columbia University and received

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his doctorate in 1947 from the Polytechnic Institute of Brooklyn, where he studied the properties of synthetic polymers. From this subject it was but a short step to the polymers of biology, with which he has since been concerned. For four years Singer was a postdoctoral fellow under Linus Pauling at the California Institute of Technology. With Pauling and Harvey A. Itano, he was a codiscoverer of the abnormal hemoglobin found in victims of sickle cell anemia. He has taught at Yale since 1951.

THEODORE H. INGALLS ("Congenital Deformities") is an epidemiologist at the School of Public Health of Harvard University. He was born in Utica, N.Y., graduated from Hamilton College, and received his M.D. from Harvard in 1933. Since then his career has centered at Harvard and the hospitals of Boston. After completing his internship at Peter Bent Brigham Hospital, he was a research fellow in pediatrics for five years. Then he became an instructor in clinical pathology at Harvard Medical School. Wartime service with the Army Medical Corps led him to an interest in preventive medicine, and thus to the Harvard School of Public Health, with which he has been connected since 1951 (he is now an associate professor). This is his third article for SCIENTIFIC AMERICAN; the others were "Mongolism" (February, 1952) and "The Strange Case of the Blind Babies" (December, 1955).

J. M. BARRY ("The Synthesis of Milk") is a lecturer in biochemistry in the agriculture department of the University of Oxford. An Oxford graduate, he did research there for his M.A. in 1946 in the laboratory of Sir Robert Robinson, and also rowed in the annual boat race between Oxford and Cambridge. Since Oxford offered no course in biochemistry at that time, Barry then betook himself to the University of Cambridge for a year. (He later returned to Oxford for his doctorate.) While working at the National Institute for Research in Dairying he became curious about the chemistry of milk production. From 1948 to 1951 Barry, as a postdoctoral fellow at the University of Chicago, investigated the formation of milk proteins. Recently he has returned to the U. S.: "Last year I married an Oxford English graduate and left Oxford and milk secretion for a year's leave at the McCollum-Pratt Institute of the Johns Hopkins University, where I have been trying to find some facts about how bacteria make proteins."

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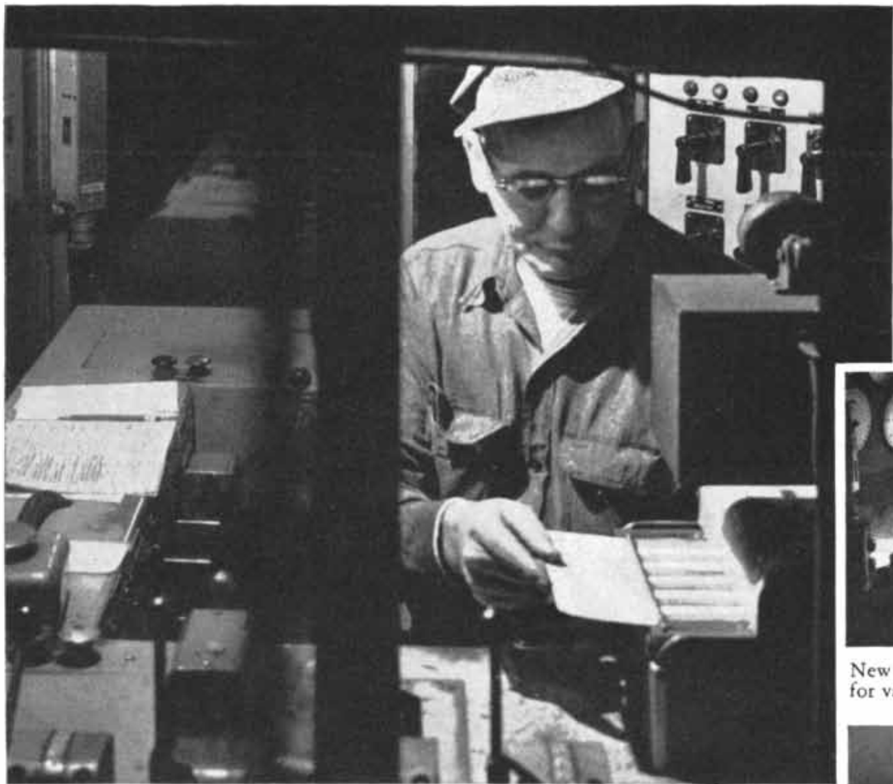

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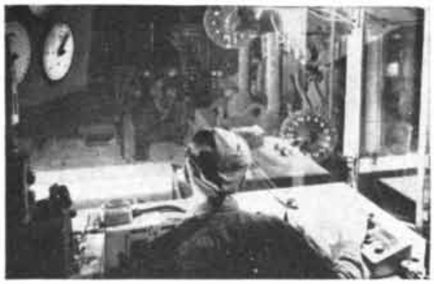

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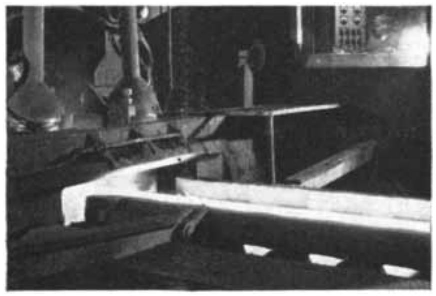

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There are many facets to the art of making adhesives. One of them is as simple and basic as the size of the batch you mix. An adhesive made in an experimental laboratory usually has different properties when it's produced on a large scale. Achieving laboratory quality in production quantities takes skill not found in any formula.

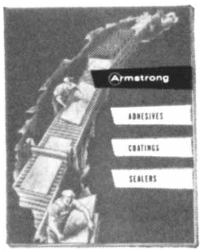
Another thing an adhesive formula doesn't tell you is the order in which ingredients should be mixed. For example, Armstrong chemists know that certain adhesives can be made far stronger by doing just two things: by combining the raw materials in a particular order; and by a delicate adjustment in their proportion.

Advanced processing techniques can also be used to extend the natural limits of some raw materials. As an illustration of this, Armstrong research chemists were recently given the problem of building more "muscle" into an already successful rubber-base adhesive.

The immediate answer seemed to be vulcanization, since it's well known that this process strengthens rubber. There was a catch here, though. Fully vulcanized rubber can't be dissolved in the solvents normally used in making adhesives. A partially vulcanized rubber could be dissolved all right, but vulcanization is a process that's hard to stop at exactly the same point every time. It would be practically impossible, therefore, to keep the quality of the adhesive uniform from batch to batch.

Armstrong chemists solved the problem by combining two rubbers that are cured with different agents. Then they treated the blend so that only one rubber cured—and its strength reinforced the uncured rubber. The result: an adhesive that was plastic and workable —and had far greater strength than its predecessor.

Making new and better adhesives is a year-round job at Armstrong. Because of this, we've been able to help a lot of fabricators find better ways to join things. For helpful information on how you can use 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, 8210 Inland Road, Lancaster, Pennsylvania.



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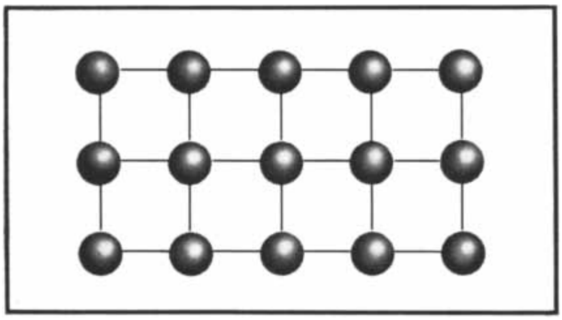
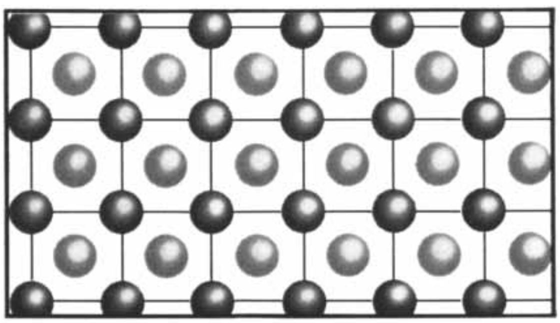


Fully cured rubber, on the other hand, is elastic. Because of its tightly linked molecules, it will return to its original shape after being stretched. But a fully cured rubber can't be dissolved in the solvents used to make an adhesive.



A combination of these cured and uncured rubbers does the trick. The particles of the cured rubber lend strength and elasticity to the uncured rubber. These blended rubbers can be dissolved to make a high-strength adhesive.


Boyle

Established 1845 SCIENTIFIC AMERICAN October, 1957 Volume 197 Number 4

Metropolitan Segregation

As Negroes move in from the South and whites move out to the suburbs a new pattern of segregation emerges in the big cities of the U. S., bringing with it significant economic, social and political problems

by Morton Grodzins

The white and non-white citizens of the U. S. are being sorted out in a new pattern of segregation. In each of the major urban centers the story is the same: the better-off white families are moving out of the central cities into the suburbs; the ranks of the poor who remain are being swelled by Negroes from the South. This trend threatens to transform the cities into slums, largely inhabited by Negroes, ringed about with predominantly white suburbs. The "racial problem" of the U. S., still festering in the rural South, will become equally, perhaps most acutely, a problem of the urban North.

The trend is most pronounced in the 14 largest metropolitan areas, those with more than one million population, where nearly one third of all U. S. citizens reside. These cities have long attracted Negroes from the South. For several decades their Negro population has been increasing much faster than their white. The decade of war and full employment between 1940 and 1950 saw the most rapid growth. While the total white population within these 14 cities rose only 4 per cent, the Negro population of the same cities leaped upward 68 per cent. Negro migration to the cities has since continued at a high, but probably less extreme, rate. A special inter-decennial census for Los Angeles shows that its non-white population increased 45 per cent between 1950 and 1956, as compared with a 10 per cent gain in the white population.

As late as 1950 non-whites constituted only a minor fraction of the total population in most of the central cities of the 14 largest metropolitan areas [*see charts on the next two pages*]. But the Negro migration, the comparatively greater rate of natural increase among non-whites and the exodus of whites to the suburbs will dramatically raise the proportion of non-whites in central cities. In Los Angeles non-whites have moved up from 6.5 per cent of the population in 1940 to nearly 14 per cent in 1956. In Chicago, according to a careful estimate by Otis Dudley Duncan and Beverly Duncan of the University of Chicago, Negroes now comprise 19 per cent of the total, compared with 8 per cent in 1940. The city is expected to be one third Negro by 1970. New York City officials forecast that in 1970 Negroes and Puerto Ricans will constitute 45 per cent of the population of Manhattan and nearly one third that of the entire city. Washington, D.C., may already have an actual Negro majority.

Estimates of future population trends must take into account some reurbanization of white suburbanites, as the proportion of older people increases and the suburbs become less attractive to those whose children have grown up and left home. Even making allowance for shifts of this sort, all evidence makes it highly probable that within 30 years Negroes will constitute from 25 to 50 per cent of the total population in at least 10 of the 14 largest central cities.

The suburbs of the metropolitan areas exhibit quite different population trends. Negroes made up only 4 per cent of their populations in 1940 and no more than 5 per cent in 1950. The only notable recent Negro suburban population growth has taken place in industrial fringe cities such as Gary, Ind., and in segregated Negro dormitory communities such as Robbins, Ill.

The sheer cost of suburban housing excludes Negroes from many suburban areas. Furthermore, the social satisfactions of slum or near-slum existence for a homogeneous population have been insufficiently studied, and it may very well be true that many Negro urban dwellers would not easily exchange current big-city life for even reasonably priced suburban homes. The crucial fact, however, is that Negroes presently do not have any free choice in the matter. They are excluded from suburbia by a wide variety of devices.

Social antagonism alone has been highly effective. In addition, the suburban towns have employed restrictive zoning, subdivision and building regulations to keep Negroes out. Some, for example, have set a minimum of two or more acres for a house site, or required expensive street improvements, and have enforced these regulations against "undesirable" developments but waived them for "desirable" ones. A builder in a Philadelphia suburb recently told an interviewer that he would like to sell houses to Negroes, but the town officials would ruin him. He explained: "The building inspectors would have me moving pipes three eighths of an inch every afternoon in every one of the places I was building—and moving a pipe three eighths of an inch is mighty expensive if you have to do it in concrete!"

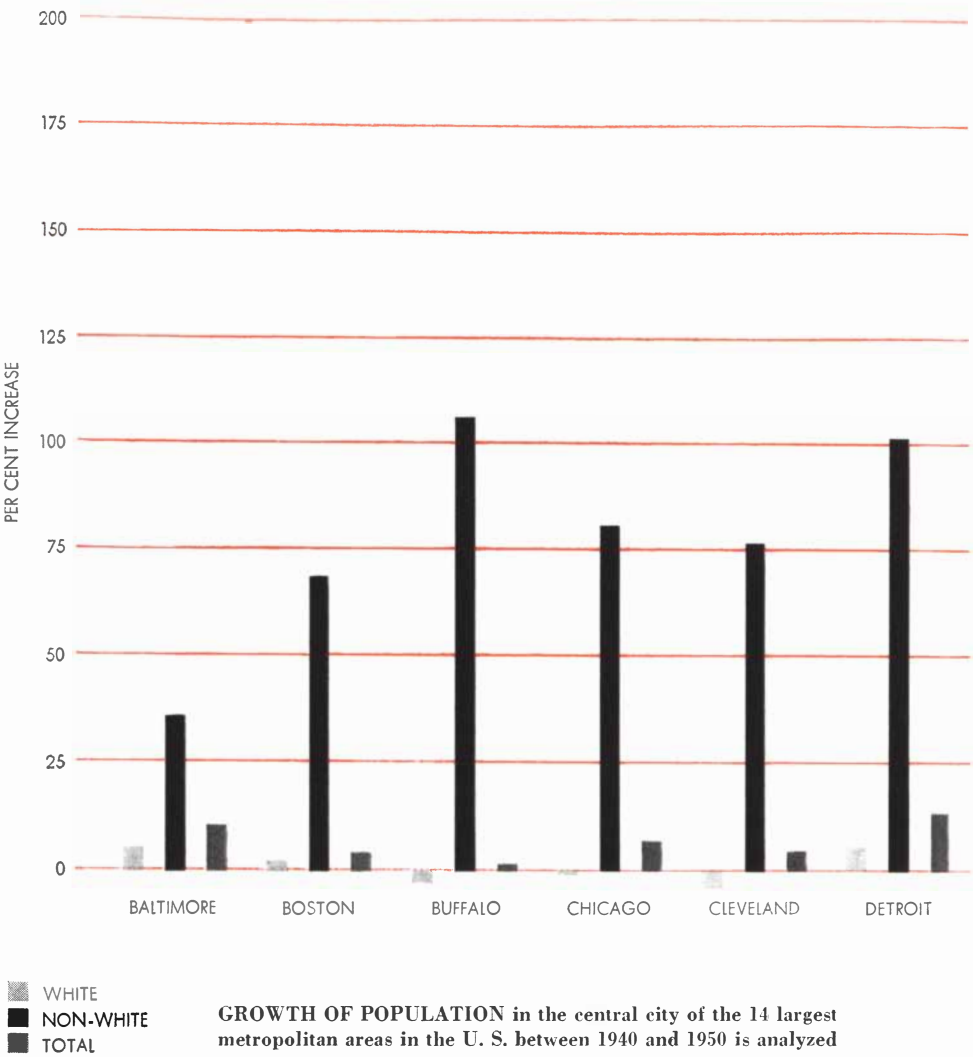
When barriers of this sort fail, suburban whites have been known to resort to violence against Negro property and persons. As this is written, 350 residents of Levittown, Pa., are demonstrating in the street before a home acquired by a Negro family.

Within the central cities, to which Negroes are thus consigned, they are further confined to virtual ghettos. Every city has its "black belt" or series of "black areas." In Chicago 79 per cent of all Negroes in 1950 lived in areas in which at least 75 per cent of the residents were Negroes [*see maps on pages 36 and 37*]. On the other hand, 84 per cent of the non-Negroes resided in areas in which fewer than 1 per cent of the residents were Negro; the figure would be even more disparate if Negro servants "living in" were not counted. Chicago is an extreme case, but all cities follow this pattern.

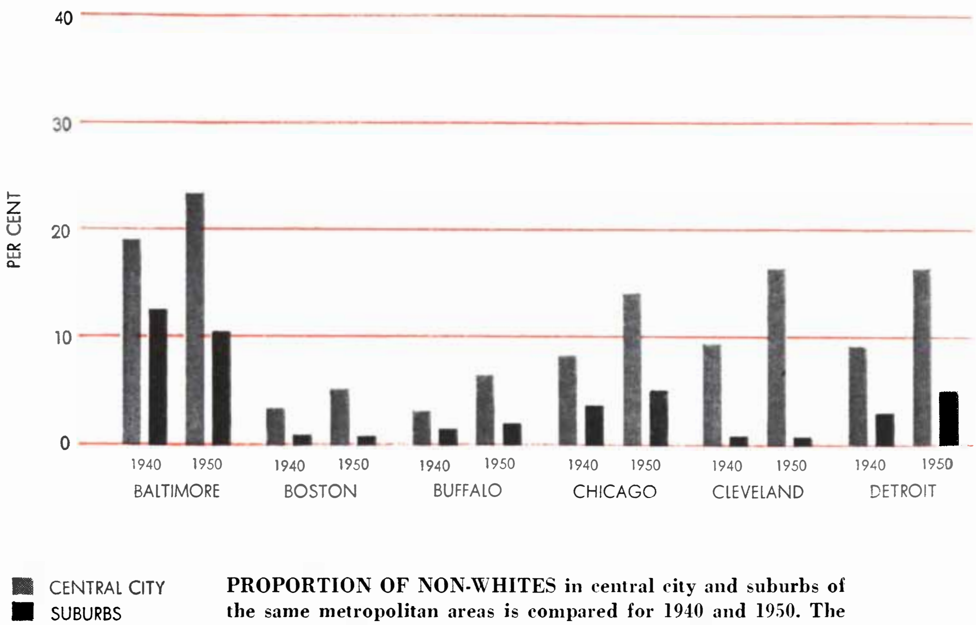
The initial Negro settlements are almost invariably near the center of the city. As the Negro population grows, the black belt tends to expand from the center block by block and neighborhood by neighborhood, sometimes radially and sometimes in concentric circles. Once a neighborhood begins to swing from white to colored occupancy, the change is rarely arrested or reversed. The Duncans found in Chicago not a single instance between 1940 and 1950 of a neighborhood "with mixed population (25 to 75 per cent non-white) in which succession from white to Negro occupancy was arrested."

This process of "tipping" proceeds more rapidly in some neighborhoods than in others. White residents who will tolerate a few Negroes as neighbors, either willingly or unwillingly, begin to move out when the proportion of Negroes in the neighborhood or apartment building passes a certain critical point. This "tip point" varies from city to city and from neighborhood to neighborhood. But for the vast majority of white Americans a tip point exists. Once it is exceeded, they will no longer stay among Negro neighbors.

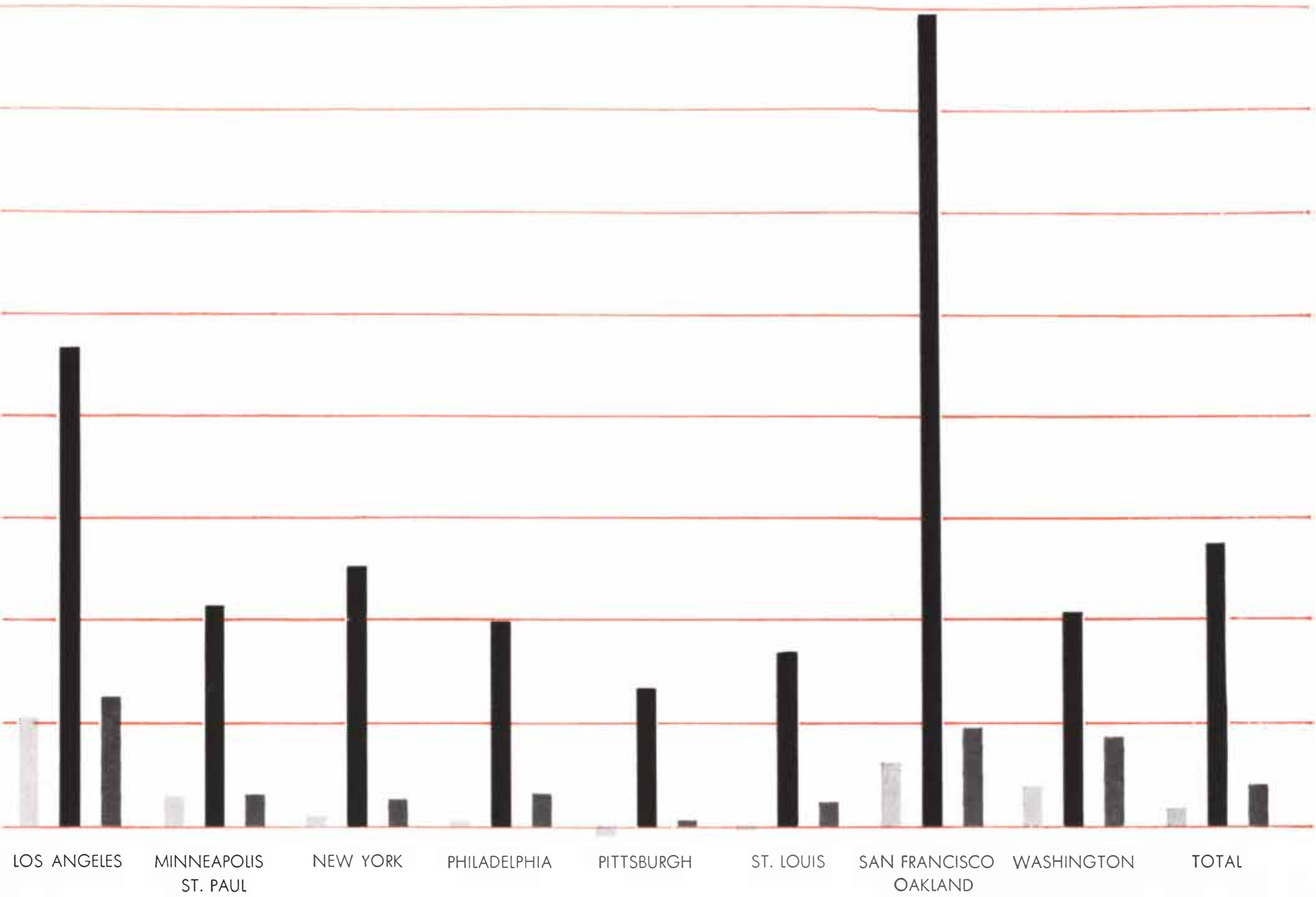
The process is not the simple one of "flight" that is a part of the real estate agent's mythology of changing neighborhoods. Negroes do not necessarily "downgrade" a neighborhood, or "push" whites out. When vacancies in a white neighborhood become available, the first Negroes to take advantage of them are usually similar to their white neighbors



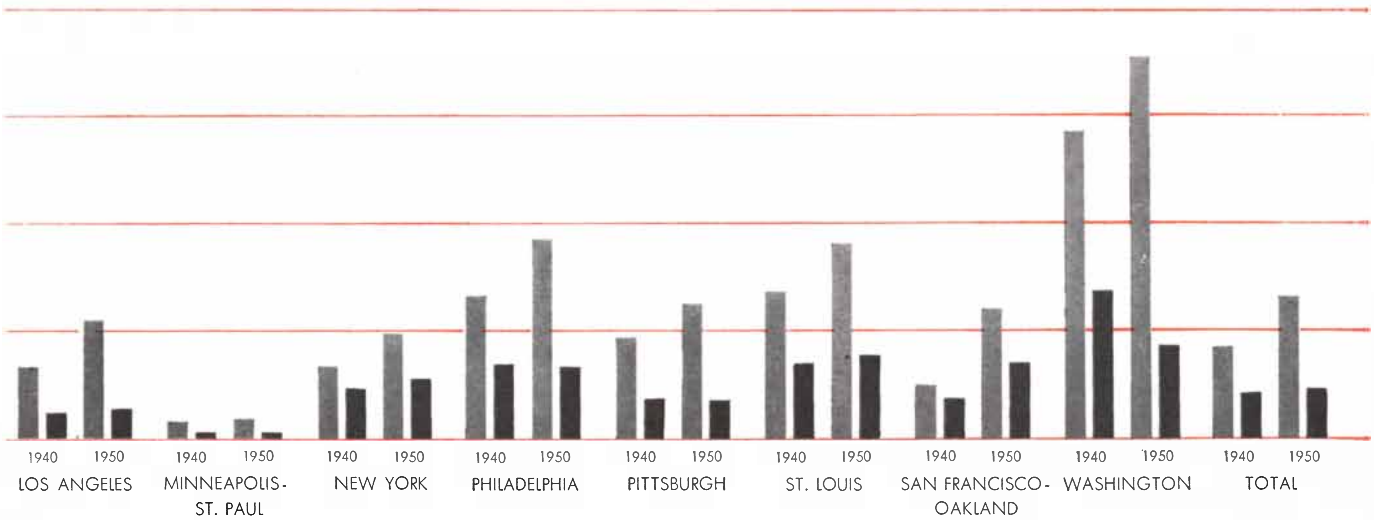
GROWTH OF POPULATION in the central city of the 14 largest metropolitan areas in the U. S. between 1940 and 1950 is analyzed



PROPORTION OF NON-WHITES in central city and suburbs of the same metropolitan areas is compared for 1940 and 1950. The



in this chart. The light gray bars indicate the increase in per cent of the white population; the black bars, the increase in the non-white population; the dark gray bars, the increase in the total population. The chart is based on information in the 1950 Census.



light gray bars indicate per cent of non-whites in the central city; the dark gray bars, per cent of non-whites in the suburbs. In many cases the proportion of non-whites in the suburbs decreased between 1940 and 1950. This chart is also based on the 1950 Census.

in income, employment, educational attainment, habits and manners. Yet whatever the social qualifications of the new Negro neighbors, when their numbers increase, whites leave. The "piling up" process—gross overcrowding of dwellings and areas—occurs only after the transition from complete white to complete Negro occupancy has taken place.

Many people for many purposes have explored how the tip point operates. Real estate operators, seeking the higher revenues that come with Negro overcrowding, talk freely among themselves about "tipping a building" or "tipping a neighborhood." Quakers in the Philadelphia suburbs of Concord Park and Greenbelt Knoll have given heed to the tip point in their efforts to build interracial communities. They have concluded that this goal can be achieved only if the proportion of Negroes is controlled: "Early in our sales program we found that white buyers would not buy without assurance that Negroes would be in a minority." The only interracial communities in the U. S., with the exception of a few abject slums, are those where limits exist upon the influx of non-whites.

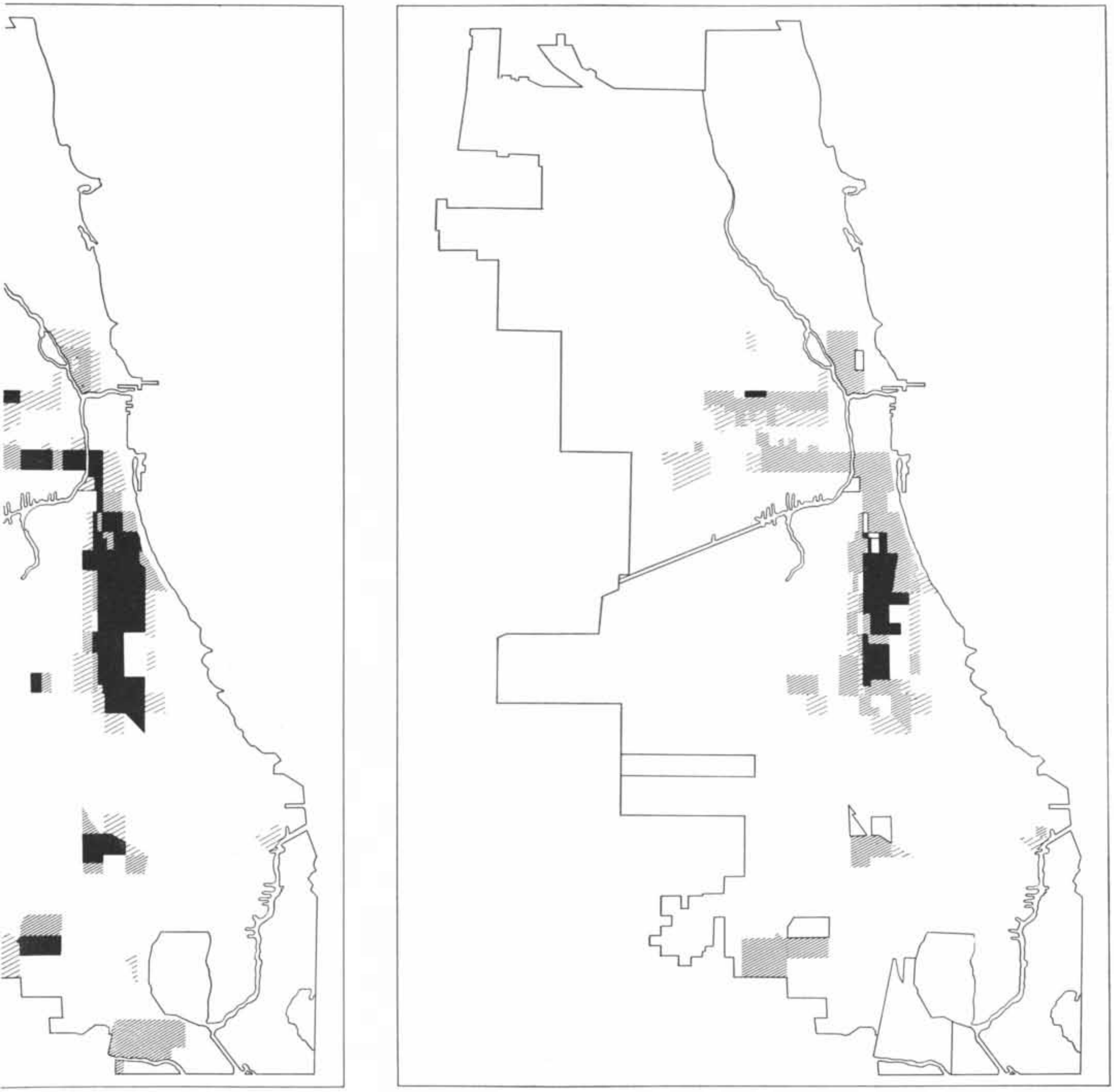
Education and community organization can raise the tip point, but they have not yet prevented tipping in the end. Sooner or later, as the increasing

PROPORTION OF NEGROES in areas of Chicago is mapped for 1920 (*left*) and 1950 (*right*). The proportion is given in per cent as indicated by the key at the lower left. These maps are based on *The Negro*

Negro population of the big cities makes its demand for additional housing effective, the apartment house, the block and the neighborhood are tipped and incorporated in the black belt. If Negroes were permitted to distribute themselves throughout the city on the basis of income, fewer areas would be tipped, but the restriction process confines them to particular areas.

The general picture for the future is thus clear enough: large segregated minorities, even majorities, of Negroes in the central cities; large majorities of whites, with scattered Negro enclaves, in their suburbs.

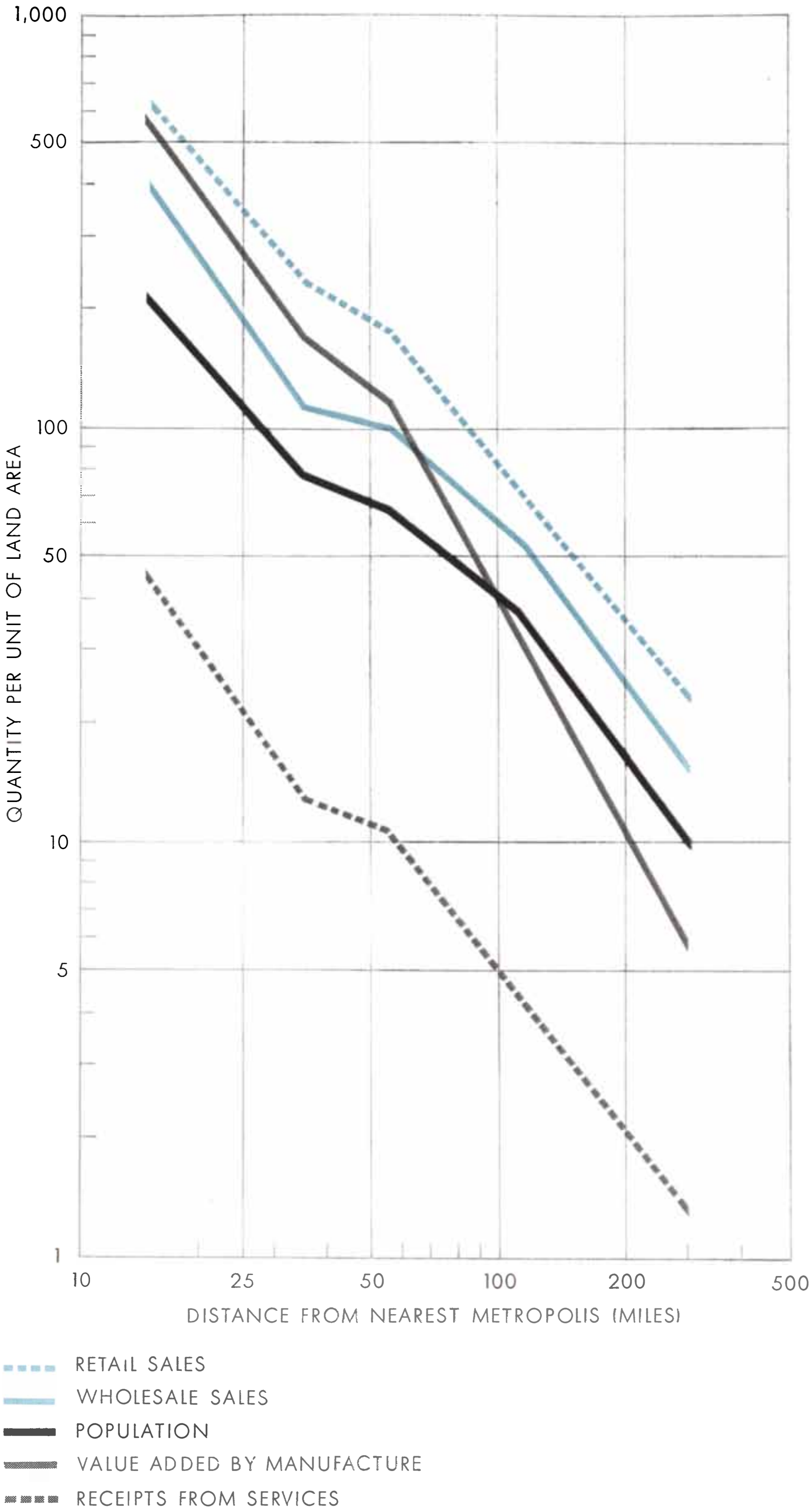
Some of the social consequences of the urban-suburban racial and class schism are already apparent; others can be predicted. Within the central cities the first result is the spreading of the slums. The Negro population always increases faster than the living space available to it. The new areas that open up to Negro residence become grossly overcrowded by conversion of one-family houses to multiple dwellings and the squeezing of two or more Negro families into apartments previously occupied by a single white one. Though complete statistical evidence is lacking, it is likely that Negroes pay substantially more rent for given accommodations than whites,



PILING UP
CONSOLIDATION
INVASION

Population of Chicago, by Otis Dudley Duncan and Beverly Duncan.

CREATION OF SLUMS is suggested in this map for 1950. "Piling up" of Negro population occurs in areas almost entirely Negro.



IMPORTANCE OF CITIES to the national economy, whatever the change in their population structure, is reflected in this chart based on 1940 Census figures for 67 metropolitan communities. The curve for population indicates the number of people per square mile. The curves for retail sales, wholesale sales, value added by manufacture and receipts from services indicate dollar value per 1/100 square mile of hinterland area. The chart was originally plotted in *The Structure of the Metropolitan Community*, by Donald J. Bogue.

and the higher rent itself makes for higher density. Housing occupied by Negroes is always more crowded, more dilapidated and more lacking in amenities such as private baths than housing occupied by whites with equivalent incomes.

Income factors alone account in significant part for the slum conditions in which urban Negroes live. Negroes are heavily over-represented in low-income jobs, in menial service, in unskilled and semiskilled factory labor and in "dirty work" generally. In this respect they are not unlike some earlier immigrants to our cities: the Irish and the Poles, for example, also settled mainly in slums. Aside from low income, movement into the unaccustomed city environment tends to break down whatever stability of attitude and habit the Negro brings with him from the rural South. Family disorganization among Negro city dwellers is high, as measured by such indices as broken marriages, families headed by females, and unrelated individuals living in the same household. How does a mother keep her teen-aged son off the streets if an entire family must eat, sleep and live in a single room? What opportunity for quiet or security is there in a tightly packed, restless neighborhood? The slum encourages rowdiness, casual and competitive sexuality, a readiness for combat; disease and crime rates soar.

The boundaries of the black belt are often sharply defined by the racial antagonisms of its surrounding neighborhoods. These are usually inhabited by low-income groups whose condition borders on that of the Negroes themselves. Some of these neighbors are also recent immigrants to the city: Southern "poor whites" in Chicago, Puerto Ricans in New York. Others are old residents at the lower end of the income scale, people who, like the Negroes themselves, do not find success in life or life itself easy. Between these groups and the Negroes tensions run high. Studies have shown that the greatest animosity is found on the edge of the expanding Negro district, where whites live in fear of "invasion." A young white resident of one of those neighborhoods recently beat a Negro to death with a hammer. "I just wanted to get one of them," he explained. "Which one didn't matter." With the exodus of middle and upper classes to the suburbs, the white population of the city is made up in larger part of low-income groups, who generally exhibit more racial prejudice. In consequence, racial passions are on the rise and find less community restraint.

Within the black belts hundreds of

ALTERED CHARACTER of the Harlem area of New York City is demonstrated by these two photographs. The photograph at top shows residences at the southwest corner of Lenox Avenue and 131st Street in 1910. The photograph at bottom shows corner today.

thousands of Negroes live, eat, shop, work, play and die in a completely Negro world with little or no contact with other people. For large numbers of them, segregation is more complete than it ever was for Negro rural residents in the South. This is true even in the city school systems. If segregation is measured by the standard of the number of students who attend all-Negro schools, then it is undoubtedly true that more Negro students are segregated in the schools of New York City and Chicago than in some Southern states.

This picture of segregated Negro slums needs some qualification. Here and there churches have successfully established interracial congregations. On a few blocks in urban America Negroes and whites have demonstrated that they can live together as neighbors. Labor unions, though traditionally anti-Negro, have in some places accepted Negroes as full partners in leadership as well as membership. There have also been advances within the Negro community itself. Although a casual observer of the black belt sees only slums, the fact is that there are oases, usually areas of newest acquisition, inhabited by better-off Negroes. As the Negro community grows in size, satisfactory career lines, economic security and the home and community life that accompany these developments become possible.

Segregation bestows some advantages on part of the Negro community, providing protected markets for professionals and businessmen and protected constituencies for political and church leaders. But those who profit from segregation also suffer from it. Like other well-off Negroes they feel the pinpricks along with the sledges of discrimination.

The larger evidence is not that of integration nor intracommunity social gains. Rather it is in the direction of more uncompromising segregation and larger Negro slums.

These population shifts bring with them profound economic consequences. Of first importance is a decline of parts of the central cities' business activity and associated property values. In almost every city the big downtown department stores are losing trade to the suburban shopping centers. Retail sales in the central business district of Chicago fell 5 per cent between 1948 and 1954 while sales in the suburbs increased 53 per cent. The downtown stores, with non-white and low-income customers more and more predominant in their clientele, tend to concentrate on cheap merchandise. "'Borax' for downtown, Herman Miller for the suburbs" is a slogan of the furniture business. The decline of the central-city department store is accompanied by a general deterioration of the downtown area. There are some striking exceptions, most notably in mid-town Manhattan. But in most cities—Chicago, Boston, Los Angeles are good examples—the main streets become infested with "sucker joints" for tourists: all-night jewelry auctions, bargain linens and cheap neckties, hamburger stands and bars with jazz bands. The slums, in other words, are spreading to the central business districts.

A further, though more problematic development, is the movement to the suburbs of banks, corporation offices, law firms and the businesses that service them. The need for close contact and communication that caused them to cluster in the city may be relieved by the teletype machine, facsimile and closed-circuit television. Even the downtown hotel is likely to give way to the suburban motel, except for the convention trade, an incidental further boost to the honky-tonk transformation of the downtown business areas. On the other hand, the cities have maintained their preponderance in manufacturing. The relative immobility of heavy industry has the result of fixing the laboring and semiskilled groups, including large numbers of Negroes, within the central cities. To rebuild the loss of tax revenues resulting from decline of their downtown and residential areas, some cities are engaged in campaigns to attract new manufacturing enterprises. The success of such efforts will, of course, accentuate the evolution of the central cities into lower-class ethnic islands.

Whatever the melancholy resemblance between the older segregation patterns of the rural South and the newer ones of the urban North, there is one important difference: the Negroes of the North can vote. What will happen

DEPARTMENT STORES EXTEND THEIR OPERATIONS to the suburbs because of the changing character of their metropolitan surroundings. At left is a photograph of Broadway when the councils of some cities, and their representations in state legislatures, become predominantly Negro?

The most likely political development is the organization of Negroes for ends conceived narrowly to the advantage of the Negro community. Such political effort might aim to destroy zoning and building restrictions for the immediate purpose of enlarging opportunities for desperately needed Negro housing against stubborn social pressures. If successful, the outcome might merely extend the Negro ghetto and cause a further departure of white populations to the suburbs. Yet the short-run political appeal of this action cannot be denied. What the Negroes seek for themselves in Chicago in 1975 or 1985 might not be any more selfishly conceived than what Irish-dominated city councils in Boston and New York have sought in the past.

At the very least, these cities that become politically dominated by Negroes will find it more difficult to bring about the urban-suburban cooperation so badly needed in so many fields. They will find greatly exacerbated what is already keenly felt in a majority of states: the conflict between the great urban center and the rural "downstate" or "upstate" areas. Similar effects will follow in the national Congress, once a number of large cities are largely represented by Negro congressmen. The pitting of whites against Negroes, of white policies against Negro policies, does not await actual Negro urban domination. The cry has already been raised in state legislatures. The conflict can only grow more acute as race and class become increasingly coterminous with local government boundaries.

In the long run it is highly unlikely that the white population will, without resistance, allow Negroes to become dominant in the cities. The cultural and economic stakes are too high. One countermeasure will surely present itself to the suburbanites: to annex the suburbs, with their predominantly white populations, to the cities. This will be a historic reversal of the traditional suburban antipathy to annexation. But from the point of view of the suburbanite he will be annexing the city to the suburbs.

The use of annexation to curb Negro political power is already under way. It was an explicit argument used in the large-scale suburban annexation to Nashville in 1951. And other recent annexations, largely confined to the South, have been designed for the same end. The more familiar practice of gerrymandering is also already widely employed to reduce Negro representation in legislative bodies of city, state and nation.

The political forecast is a new round of repression aimed at Negroes. For this one, they will be better armed—in effective numbers, economic strength, political sophistication, and allies in the white population.

and Third Street in downtown Los Angeles. In the middle distance is a department store called "The Broadway." Farther down the street is another store called "May Co." At right is a photograph of new branches of these stores in a suburban shopping center.

SALT AND RAIN

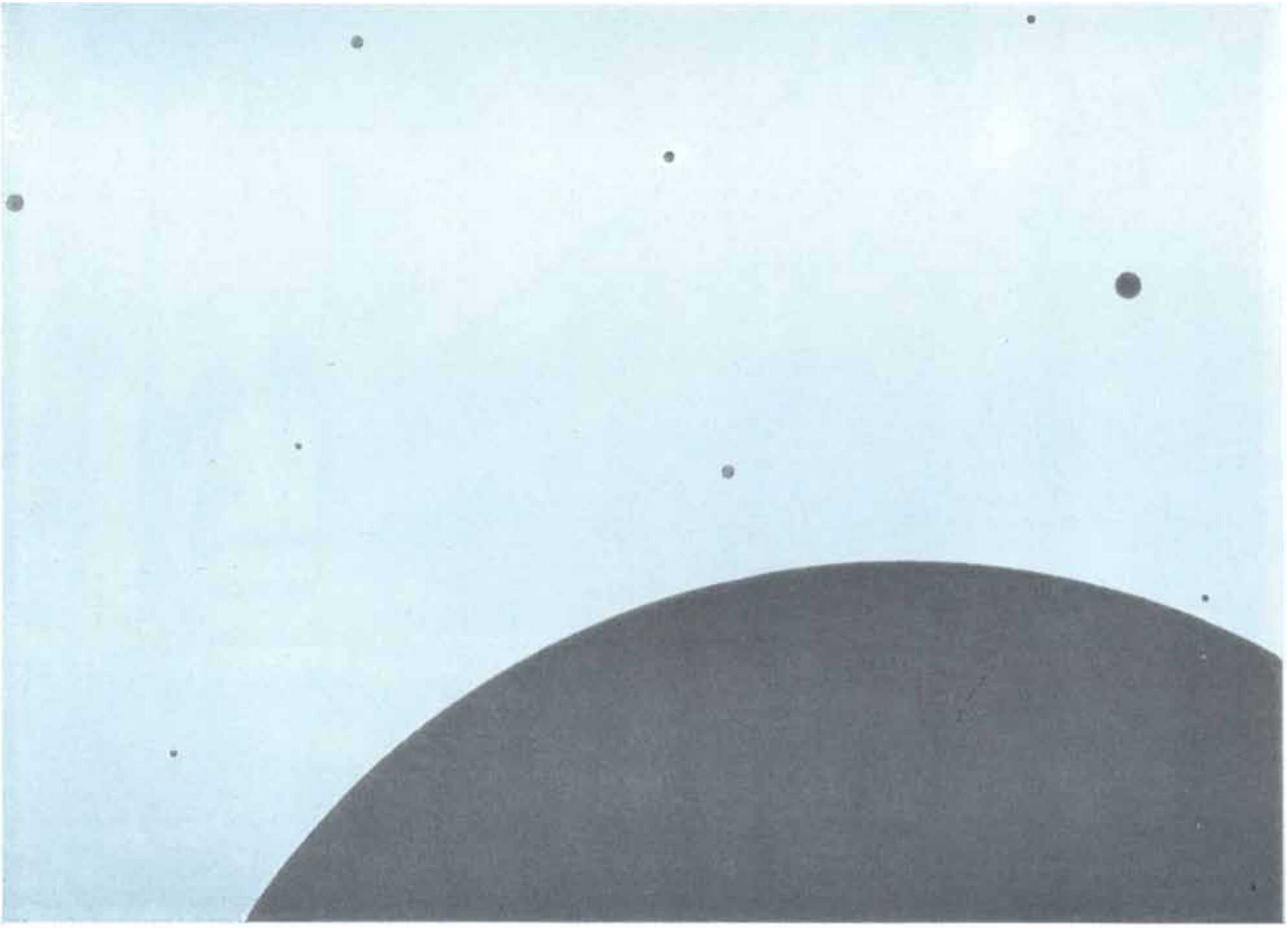
What makes the tiny water droplets of a cloud grow into the large drops of rain? Some recent studies indicate that particles of salt from the sea may play a key role in the process over both sea and land

by A. H. Woodcock

When you stand at the rail of a ship on a bright sunny day with a fresh wind blowing and watch the sparkling whitecaps dancing on the sea, rain is likely to be one of the farthest subjects from your mind. But those whitecaps have begun to interest meteorologists intensely. There is reason to suspect that they are responsible, in an unexpected way, for much of the rainfall that nourishes life on the earth. We have arrived at this suspicion through laboratory studies of the bubbles that form their spray.

The chain of reasoning starts from one of the key questions of meteorology: What makes clouds turn into rain? More specifically, the question is: How do the tiny droplets of a cloud coalesce into water drops big enough to fall as rain?

If cloud droplets themselves could fall to the ground, our planet would have fewer water problems. As everyone knows, a cloud at ground level (*i.e.*, fog)



CLOUD DROPLETS AND RAINDROP are enlarged some 100 diameters in this schematic comparison. The cloud droplets (*dots*) are about .001 inch in diameter; the raindrop (*arc*), about .1 inch. One raindrop consists of a million to eight million cloud droplets.

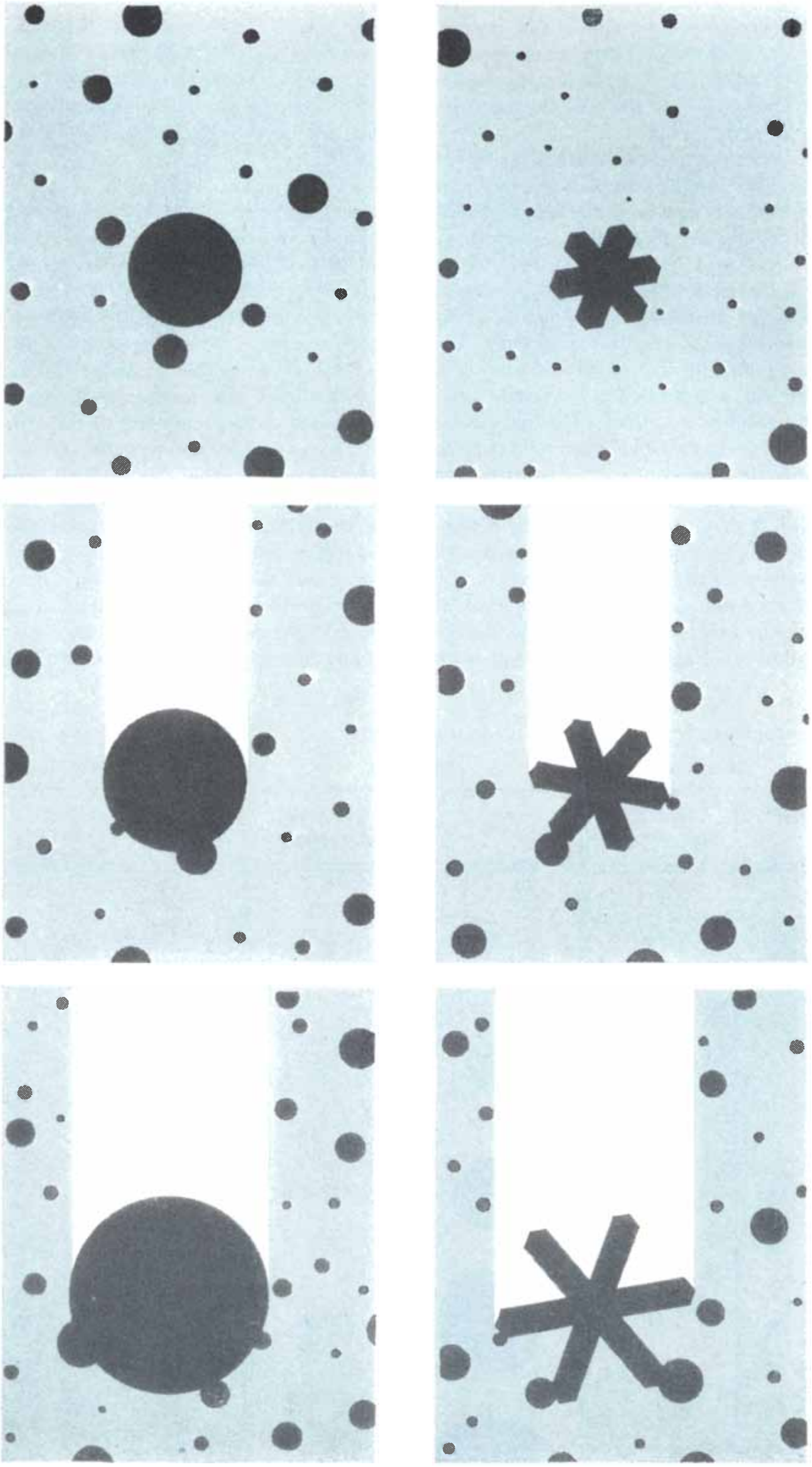
deposits moisture on leaves, twigs and other surfaces. The grass grows greener and longer under the drip zone of a tree or bush, and even under a telephone line. (This observation has led one cloud physicist to propose that water might be trapped for reservoirs by stringing wires on mountains frequently shrouded in cloud.) But over most of the earth clouds usually float high in the air. Their droplets fall so slowly that they evaporate long before they might reach the ground. To come down as rain the droplets in a cloud must grow to drops that fall at least 20 times faster. The problem that has occupied cloud physicists is to learn just how and under what conditions droplets grow into raindrops.

Let us see what gives rise to the cloud droplets themselves. The beam of a searchlight pointed upward at night shows that even apparently clear air is actually a "soup" of particles. The air may contain anywhere from 10,000 to 100,000 particles per cubic inch. When the relative humidity is high, water vapor condenses on many particles and begins to form droplets; this accounts for the haziness of the air on a muggy day and for the poor visibility you may have noticed while flying in an airplane below a cloud. Actual cloud materializes when the humidity reaches a certain critical value which turns most of the dust particles into water droplets.

Under the right conditions the cloud droplets will combine rapidly into raindrops; a concentration of 10,000 cloud droplets per cubic inch yields one raindrop per 10 cubic inches. There are two general theories about how this takes place.

One is the ice-crystal theory, originally developed by Tor Bergeron of Sweden and Walter Findeisen of Germany. In the cold upper regions of a high cloud the droplets are supercooled. If ice crystals are present, they evaporate the droplets and then absorb the vapor, much as crystals of calcium chloride and other drying agents absorb moisture. The ice crystals, feeding on the cloud droplets, may grow to large size and fall as snow or melt to rain.

This process is the basis of artificial rainmaking by means of dry ice and other crystals. The exciting experiments and discoveries of Irving Langmuir, Vincent J. Schaefer and Bernard Vonnegut in the laboratories of the General Electric Company led to the first clear-cut information on how nature makes rain [see "Cloud Seeding," by Bernard Vonnegut; Scientific American, January,



TWO PROCESSES by which cloud droplets grow into raindrops or snow are outlined. In the first picture of the sequence at left droplets of various sizes have formed by condensing on nuclei such as smoke or salt particles. The largest nuclei form the largest droplets. In the second and third pictures a large droplet grows by collision with small droplets until it is heavy enough to fall to the ground. In the first picture of the sequence at right a snow crystal forms when a droplet freezes or when a freezing nucleus is present. The droplets in the vicinity of the crystal tend to evaporate, providing water vapor for the crystal to grow. In the second and third pictures the crystal has grown large enough to fall and to grow by coalescence with the droplets. It may melt into a raindrop or reach the ground as snow.

1952]. But it soon became evident that the ice-crystal process is not the only way. Rain can fall from warm clouds as well as cold. How is it generated in clouds that lack ice crystals and supercooled droplets?

We must find some other mechanism that can combine droplets into big drops, and this brings us to the second theory. It suggests that large particles in clouds grow into raindrops by sweeping up the smaller droplets. The particles of dust or dustlike material in our atmosphere have a great range of sizes: if we magnified them so that the smallest were the size of a BB pellet, the largest would be as big as a bathtub. The big particles form comparatively large cloud droplets, and these of course fall faster than the small ones. As they move through the cloud, they pick up the smaller droplets in their path, just as a rolling drop of mercury gathers up any mercury drops it encounters. Thus the larger dust nuclei in a cloud can grow to the size of a raindrop. Each big droplet has plenty of smaller ones to feed on, because BB-sized nuclei outnumber the bathtub-sized ones about 100,000 to 1. A cloud will produce rain, according to this theory, when it contains sufficient moisture and a suitable number of giant nuclei.

It may be that some rains are triggered by ice crystals, some by giant nuclei and some by both combined. Very probably both processes play a part in many rains. We are therefore led to the interesting question: What are the giant nuclei and where do they come from? This question gave rise to the researches I mentioned at the beginning of the article. My associates and I at the Woods Hole Oceanographic Institution, and other groups in the U. S., Sweden and Australia, have been investigating the possibility that the rain-generating giant nuclei are salt particles from the sea.

The problem is being explored along several lines, with the objects of determining how much salt is taken up from the sea by winds, how much is carried inland over the continents, what the sizes of the salt particles are, whether they serve as nuclei for raindrops, how salty inland rains are, and so on.

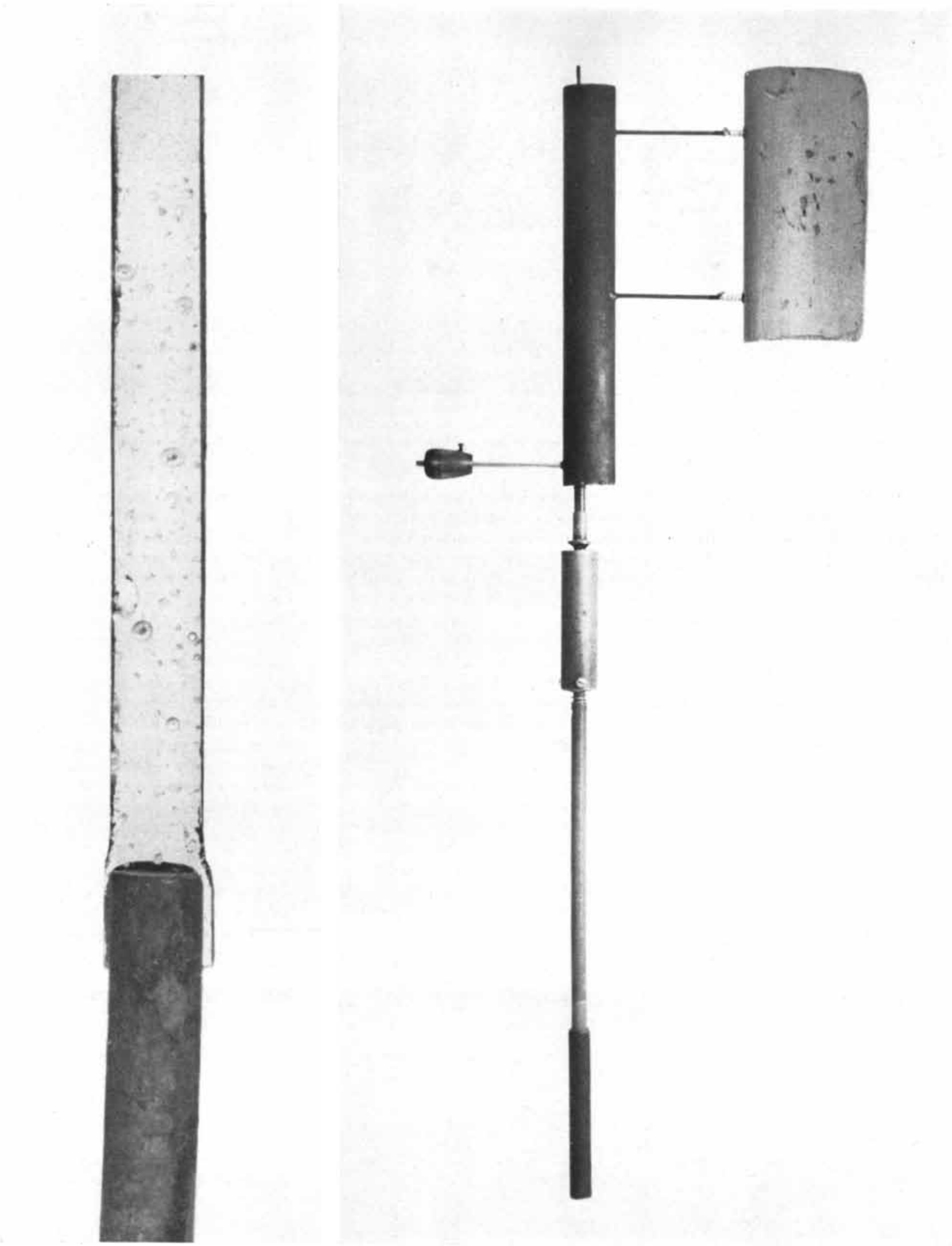
First, there can be no doubt that winds blowing over the oceans pick up a substantial load of salt particles. Ordinary sea winds carry from 10 to 100 pounds of sea salt per cubic mile of air; storm winds may bear as much as 1,000 pounds or more per cubic mile. Secondly, it is equally plain that the winds transport a great deal of salt from the sea over land. The corrosion of steel towers testifies to the saltiness of our inland atmosphere. A gentle, invisible rain of salt falls constantly on the land. We can taste the salt on pine needles, and in the early morning light we see the salt particles glittering like jewels on spider webs. Systematic surveys have verified that salt particles, large and small, are spread through the atmosphere, from the ground up to high altitudes. Cloud-physics groups at the University of Chicago, at the University of Stockholm and in Australia have found them over much of the interior of the U. S., Sweden and Australia.

Next, there is statistical evidence of a relationship between the amount of salt carried inland from the sea and the amount of salt in our rainfall. This is based on measurements of the average salt content of sea air, the amount of sea air blown in over our coastlines in a year, the country's total yearly rainfall and the average saltiness of the rain (as sampled by C. Junge at 60 stations distributed throughout the U. S.). It turns out that the actual "salt-fall" in rain (3.8 pounds per acre per year) is remarkably close to the theoretical total deposit of salt (4.8 pounds per acre) that would be expected from the calculation of the salt load brought in over our shores by the winds.

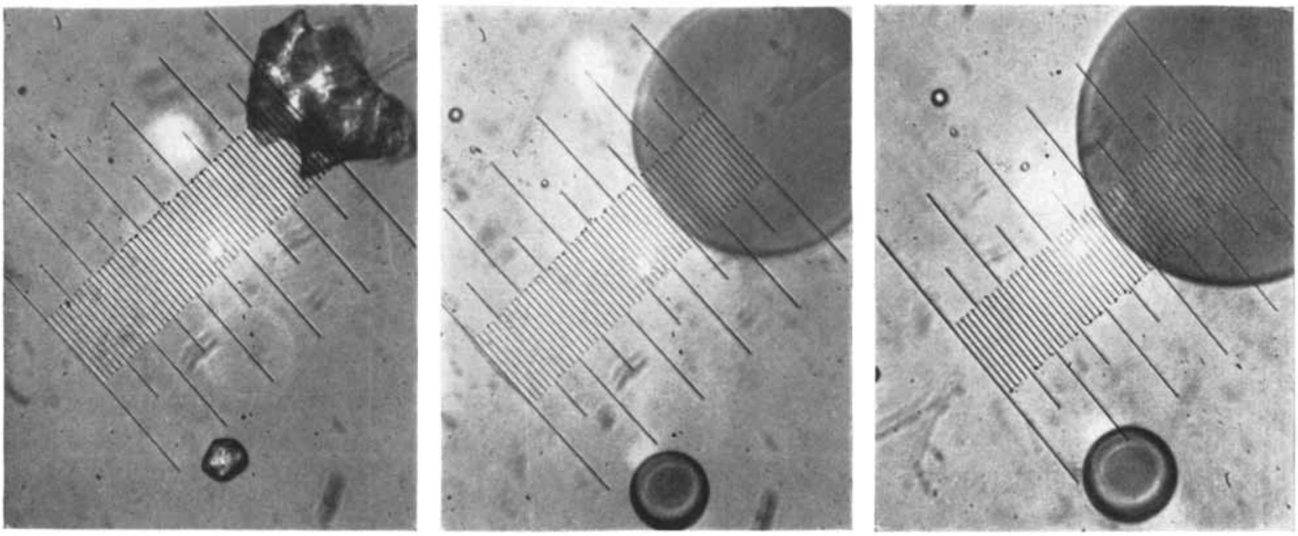
Let us look at the salt particles in some detail. We have collected them in the air on glass slides held out of an airplane: the slides soon become fogged with salt crystals or droplets. Although the particles are tiny (some amounting to as little as a millionth of a millionth of an ounce), we can weigh them by an indirect method which entails exposing them to moisture. Salt greedily takes up water from the air, as anyone who has dealt with a salt shaker on a humid morning is well aware. A salt crystal kept in damp air collects enough water to dissolve completely into a droplet. The amount of water it will collect depends

SALT PARTICLE SIZE (TIMES 100)		RAINDROP SIZE (TIMES 10)		APPROXIMATE NUMBER PER CUBIC YARD OF AIR
	DIAMETER (MILLIMETERS)		DIAMETER (MILLIMETERS)	
	.44		5.8	3,000
	.66		8.7	1,000
	.96		12.4	400
	1.41		18.7	100
	2.06		26.8	1

SIZE OF RAINDROPS is directly related to the size of the salt particles on which they condense. This relationship was observed in photographs such as those on pages 46 and 47.



SALT WAS SAMPLED by Woodcock with glass slides such as the one at left. The slides were held out of airplanes at various altitudes by means of the apparatus at right. The slide can be seen projecting from the top of the apparatus. Below the slide is a housing in which it is enclosed until it is ready for exposure. To the right of the housing is a wooden airfoil which keeps the slide pointed forward. When the apparatus is held out of an airplane, the slide is brought out of the housing by pushing the handle at bottom. After a prescribed interval, the slide is moved back into the housing, the apparatus brought back into the airplane and the slide dismounted.



SALT PARTICLES grow into droplets in these two sequences of three photomicrographs each. The photomicrographs were made by placing slides bearing salt particles in a chamber in which the humidity could be controlled. The salt particles in the sequence

on its weight [*see illustrations on pages 46 and 47*]. Thus we can calculate the weight of a salt particle from the size of the droplet it forms in air of a given relative humidity.

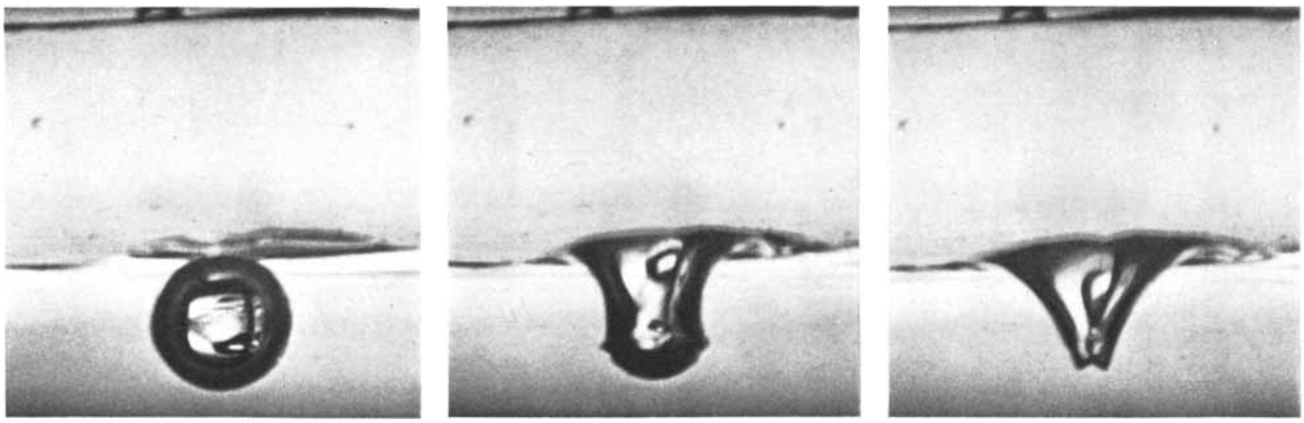
By "reading" the weights of sea-salt particles in this way we have been able not only to measure the salt load of the air at various locations and altitudes but also to relate the particles to raindrops. We have learned, for one thing, that there is a direct parallel between the sizes of salt particles in the air and the sizes of raindrops [*see chart on page 44*]. Rain usually has a salt concentration of about one part per million by weight. Assuming that this ratio holds in the individual drops, we can compute the size of raindrop that a salt particle of a given size should form. The larger the particle, the larger the raindrop, of course. Analysis of ocean rain with the help of a raindrop "spectrograph," an instrument developed by Australian workers to sort out the drops according to size, has shown that the larger drops do indeed contain more salt than the small ones.

All of this certainly seems to indicate that salt particles act as nuclei to produce raindrops and precipitation. The idea gains further support from a finding that the number of drops per unit volume in rain over the sea is about the same as the number of salt particles in ocean air.

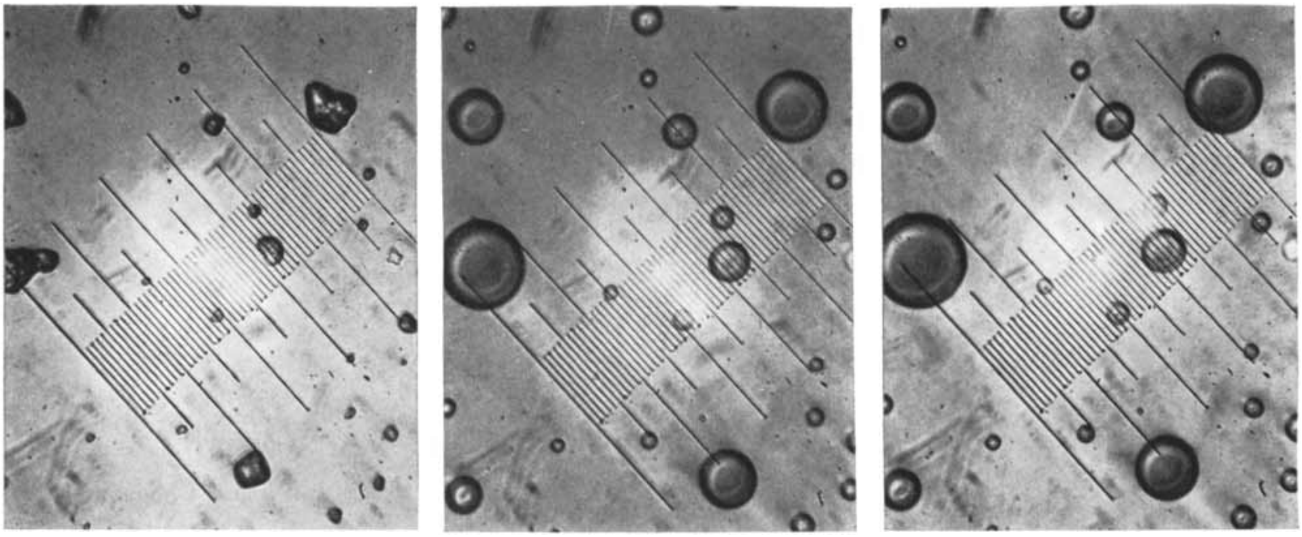
We come now to the question of how salt particles get into the air from sea water. A natural place to look for the mechanism is in whitecaps or surf. Their bursting bubbles are known to shoot small droplets into the air. Members of our laboratory have examined the process by high-speed photography and other studies and learned some important facts.

When a bubble in the froth of a whitecap bursts, it shoots into the air a jet which breaks into many droplets. The starting speed of these droplets ranges from 10 to 80 miles per hour. Because of the air resistance, the droplets rise no higher than eight inches from the surface. But this gives time enough for the water to evaporate and leave tiny salt particles floating in the air, where they can be swept up by the wind. The bubbles range from microscopic size up to about one tenth of an inch in diameter. Small bubbles vastly outnumber the larger ones, which accounts for the fact that small salt particles are so much more numerous than large ones in the air.

The discovery that salt particles fired into the air by bubbles on the sea surface may be largely responsible for our



BURSTING BUBBLE fires droplets of water into the air in this sequence of six high-speed photographs made at the Woods Hole Oceanographic Institution. This is the main mechanism by which salt particles rise from the surface of the sea. In the first photo-



at left were obtained from concentrated sea water; the particles in the sequence at right, from droplets in the air at an altitude of 2,000 feet. In the first photograph of each sequence the relative humidity is 32 per cent; in the second, 84 per cent; in the third, 96 per cent.

rain presents a number of exciting questions for study. Among other things, we would like to know a good deal more about what factors control the formation of bubbles on the surface of the sea. Besides the winds that kick up whitecaps, other important factors seem to be the fall of raindrops and the melting of snowflakes, both of which processes produce bubbles. Since these three phenomena (wind, rain and snow) are so variable, air masses arriving over land from the sea must vary a great deal in salt load. Does saltier air produce more rain? The answers to such questions may bring us closer to being able to control rainfall than we have been up to now.

Basic research often yields by-products which are just as interesting as the main question being pursued. It was so in our studies. Studying the droplets shot from the sea surface, we discovered that they were electrified. In some manner not yet understood, the bubble-bursting mechanism separates charges, so that most of the ejected droplets are positively charged. Duncan C. Blanchard of our laboratory measured their charges by suspending them in an electric field (the technique originated by the Nobel prize physicist Robert A. Millikan). On the basis of his measurements he calculated that the charged droplets ejected from the oceans may account for a major part of the electrification of the atmosphere.

Another unexpected and important discovery, made in our laboratory by Charles H. Keith, was that droplets ejected from a water surface covered with organic matter come out coated with this material. Since the seas in many parts of the world have organic films floating on their surface, this finding suggests that the oceans may supply a substantial part of the food of plants. It has been known that airborne droplets sometimes contain small sea organisms and parts of plankton. The notorious "red tide" along our Gulf seacoast, an occasional phenomenon produced by great swarms of reddish plankton, sends up airborne droplets containing a substance very irritating to mucous membranes, as shore dwellers and fishermen have discovered to their distress.

Looking at those innocent whitecaps on the sea, one would hardly imagine that they are important causes of our planet's rain, the electrification of our atmosphere and the distribution of plant nutrients from the sea to the land. Whether they turn out in the end to be more or less important than we now think them, they have led us into an eye-opening new field of research.

graph the bubble is intact. In the second the bubble breaks through the surface. In the third it becomes almost conical. In the fourth a tiny jet of water begins to form. In the fifth a droplet breaks away from the jet. In the sixth another droplet begins to form.

PEPPERED MOTH (*Biston betularia*) is almost invisible against the varicolored background of a mossy tree trunk. The reader will find the moth just above and to the right of the center of this photograph. This kind of camouflage is called disruptive coloration.

Defense by Color

It is generally assumed that the coloration of some animals is for the purpose of deceiving predators. Is this assumption true? An account of some experimental efforts to answer the question

by N. Tinbergen

Animals with the gift of "camouflage" have been a beguiling subject of debate ever since Charles Darwin's time. Is their coloring actually a disguise to deceive their enemies, or is it just an accident of nature? Anyone who has watched a flounder change color to match its background, or seen a "twig" suddenly start crawling along a branch, is not likely to be in much doubt about the answer. But it can be argued that this evidence is entirely subjective and circumstantial. After all, we see these animals with human eyes, and we cannot be sure that their predators see them exactly as we do; in fact, we know that the vision of many animals is quite different from ours. Furthermore, if we accept the idea of protective coloration, it is not easy to understand how the processes of evolution could have produced the exquisitely precise patterns of mimicry that some of these animals display.

The 19th-century naturalists looked for answers to these questions in the field; nowadays zoologists prefer to investigate them in the laboratory. This article is an account of experiments which have cleared up some of the questions and brought to light many fascinating new facts.

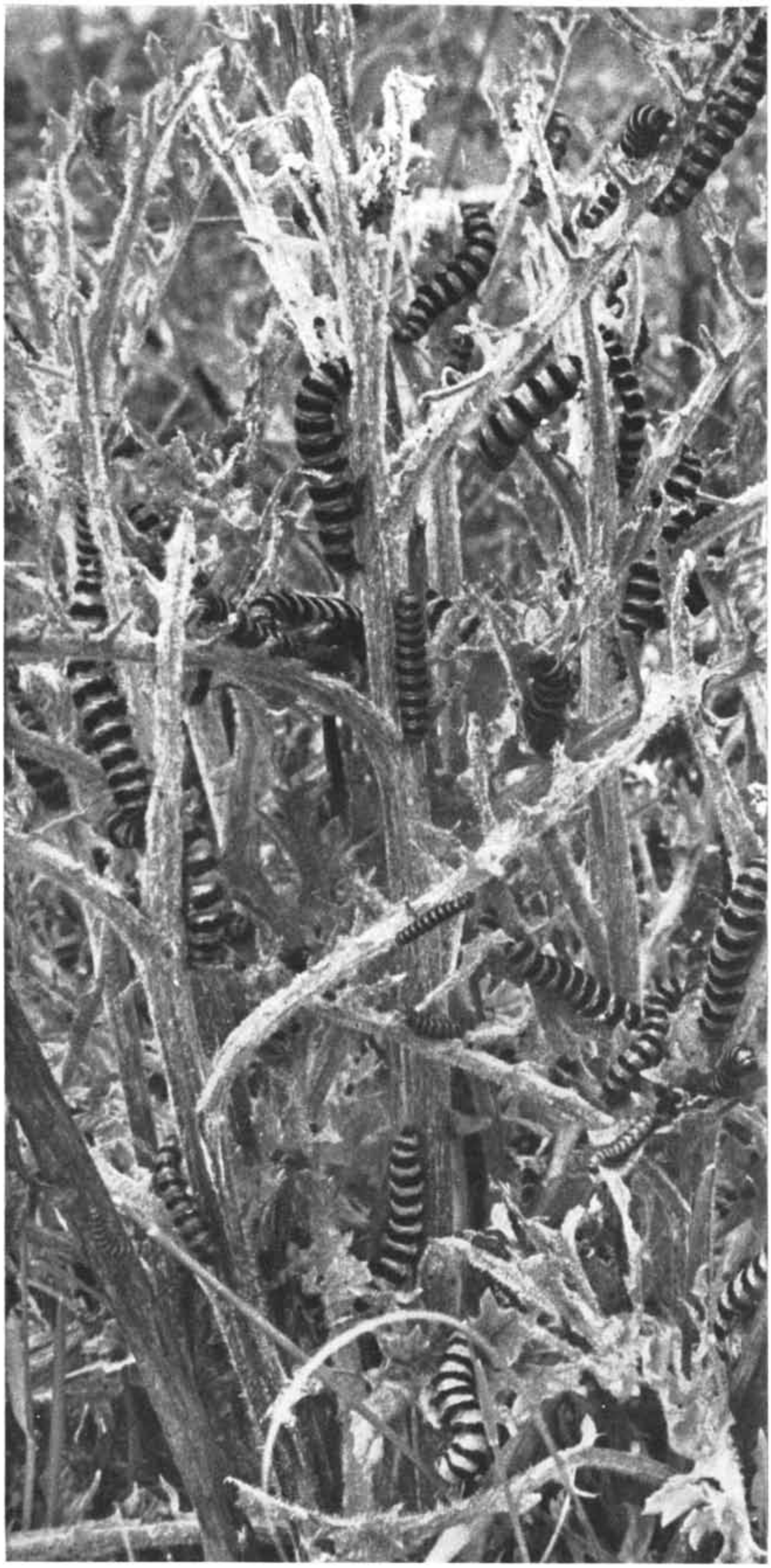
The English zoologist Hugh B. Cott, in his classic work called *Adaptive Coloration in Animals*, has described a number of ways in which color patterns can serve as defense. There are animals whose coloring gives concealment, by matching the background of their usual environment; there are evil-tasting animals whose coloring is bright and conspicuous, as if to advertise their distastefulness; there are animals that mimic these species, so that, although they are not distasteful themselves, predators avoid them; there are insects that display glaring "eye spots" which are thought to scare predators away; there are other insects with small eyelike spots on their wing tips which are believed to deceive predators into striking there instead of at the head.

Some of this may sound fanciful, but experiments have shown that the facts are stranger than fancy. Let us take the camouflage experiments first.

A classic series of experiments was performed by the late F. B. Sumner at the Scripps Institution of Oceanography [see "How Animals Change Color," by Lorus J. and Margery J. Milne; Scientific American, March, 1952]. He tested, among other things, the effectiveness of adaptive coloring in protecting fish against a predator. As subjects he used minnows of the genus called *Gambusia*, which turn dark when kept in a black tank and bleach out when kept in a white tank. Sumner put a large number of bleached and dark fish in a white tank and introduced a penguin to feed on them. Since the fish change color only slowly, the dark fish remained considerably more conspicuous in this tank than the bleached ones. The upshot of the experiment was that the penguin did in fact catch many more of the dark fish; conversely, in a dark tank the bleached fish suffered the heavier losses. Tests with other predators—herons and fish that prey on Gambusia—gave the same result.

Many other experiments have con-

LARVA OF THE PUSS MOTH (*Dicranura vinula*) illustrates the stratagem of countershading. The larva usually hangs upside down from a branch or twig; in that position its shading makes it appear flat. In this position the shading makes the larva conspicuous.

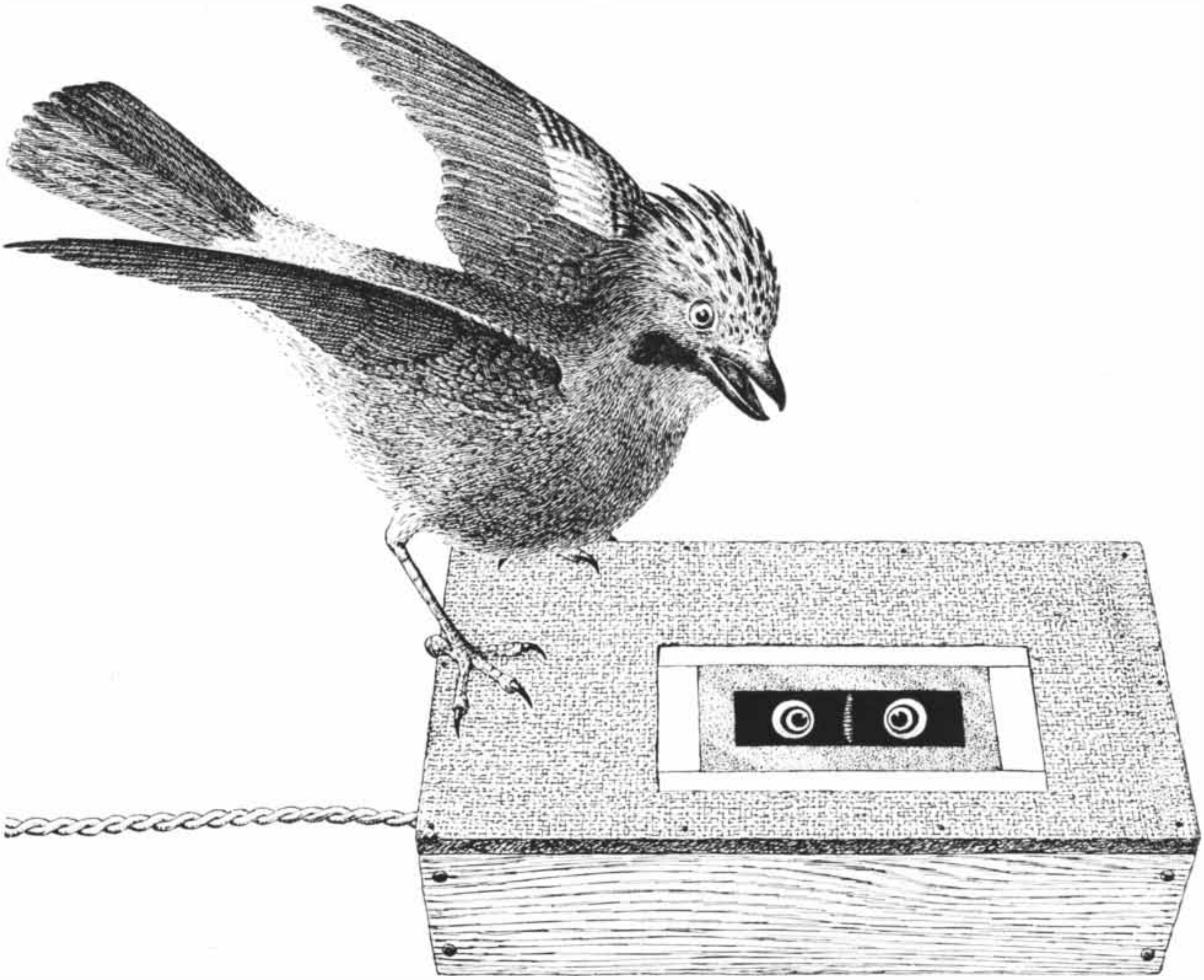


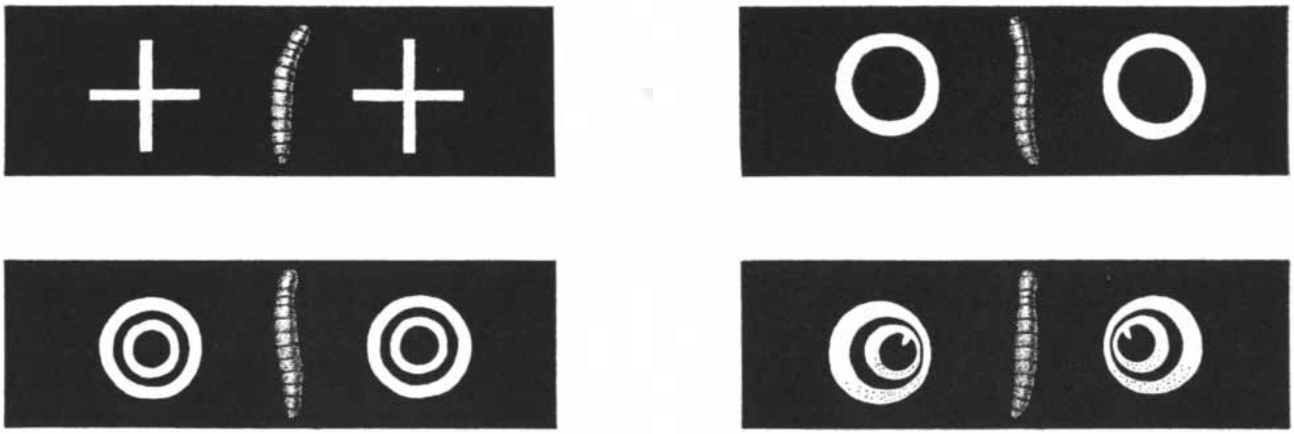
CONSPICUOUS CATERPILLARS advertise their distastefulness with yellow and black stripes. Birds that have tasted the cinnabar-moth larvae shown in this photograph learn to avoid them, and cease to prey upon other larvae which have a similar warning pattern.

firmed that camouflaged individuals come off far better against their predators than more conspicuous ones. Some of the camouflage patterns are quite remarkable: certain caterpillars look exactly like a twig [*see photograph on page 54*]; there is a peppered moth which matches tree bark almost perfectly [*see page 48*], and so on. One of the effective camouflage devices is countershading—a transition from a dark shade on the upper side of the animal to a lighter shade on the underside, which counteracts natural shading and makes the creature look like a flat spot instead of three-dimensional, at least to human eyes [*see photograph on the preceding page*].

Leen de Ruiter, one of my co-workers in the department of zoology at the University of Oxford, has demonstrated that countershading protects caterpillars against birds. He had to use killed caterpillars to eliminate the possibility of their giving themselves away by moving. (In nature all camouflaged animals freeze as soon as they spot a predator, and some of them hold a stationary position all day.) De Ruiter mounted countershaded caterpillars on twigs, half of them dark side up, the other half, light side up. He then distributed these objects in a naturally planted aviary occupied by European jays. The birds ate many more of the inverted (light-side-up) caterpillars than of the others. De Ruiter was able to prove that the loss of countershading was responsible for their readier detection. By tests with models he established further that shading creates an illusion of three-dimensionality for birds, as it does for us in a painting.

De Ruiter next tested the birds on caterpillars that resemble twigs. The very first experiment yielded a result almost too good to be true. Over the floor of the aviary he scattered some birch twigs and caterpillars of a species that looks like these twigs. When jays were admitted to the cage, they began to hop about looking for food. For the first 20 minutes or so they ignored the twigs and the motionless caterpillars. Then one of the birds happened to step on a caterpillar, and this made the animal wriggle. The jay snapped it up and immediately began to pick up, indiscriminately, other caterpillars and twigs as well! Clearly the bird confused twigs with caterpillars, and *vice versa*. Much the same thing happened in repetitions of the test with other jays and with chaffinches. When caterpillars outnumbered twigs, the birds took the disappointments in stride





EFFECTIVENESS OF FRIGHTENING PATTERNS at bottom was tested by flashing a light in the box at top just as a bird approached a mealworm, so that the patterns appeared suddenly on either side of the worm. The birds were frightened most by the eye spots at lower right, which closely resemble the "warning spots" on the wings of certain moths (*see photographs on next two pages*).

EYED HAWK MOTH (*Smerinthus ocellata*) **in the photographs on these two pages shows how a species with eye spots on its wings uses them to frighten birds. In its usual position** (*photograph at left*) **the moth's eye spots are concealed. It will remain in this**

and went on hunting for caterpillars. But if they picked up more twigs than caterpillars, they became discouraged and gave up searching. This suggests that in nature it is important for stick caterpillars not to become as numerous as their inedible models.

The tests illustrated another interesting point. The detection of the first caterpillar apparently affected the bird's nervous system in some way: in anthropomorphic language, it suddenly began to "expect" stick caterpillars. This phenomenon of developing a "set" for a particular stimulus—a searching image of a specific prey—has been observed in many animals. The German physiologist Erich von Holst has noted similar effects at lower integration levels of the nervous system, and he has proposed a theory to explain such "stimulus expectation."

Consider now the opposite of camouflage—the showy coloring that announces distastefulness. A good example is the caterpillar stage of the European cinnabar moth. This larva is boldly colored with yellow and black stripes, and its characteristic swarms on ragwort can be seen a long way off [*see photograph on page 50*]. Birds and other caterpillar-eaters sometimes try the creature, but after one taste they let it strictly alone. The German zoologist Wilhelm Windecker made a systematic analysis to find out what part of the cinnabar caterpillar was distasteful to birds, offering them various portions of its body in a mixture with mealworms. He found that the unpalatable part was the caterpillar's hairs.

Windecker also discovered that once a bird has tasted this unpleasantness, it will avoid all animals colored like the cinnabar caterpillar. Other experimenters have demonstrated the same phenomenon. For example, Georg Mostler of Germany found that a bird will not attack wasps after one or two disagreeable experiences with them; furthermore, it will not even take certain flies with the same yellow and black pattern as wasps, although it has previously eaten these flies with relish. The memory of a bird for unpleasant experiences is very good indeed; one of Mostler's birds refused wasps eight months after its last encounter with one. Another experimenter who has looked into the matter of color-pattern conditioning is Hans Mühlmann of Germany. He painted red rings around mealworms, dipped them in a distasteful substance and then offered them to his birds. The birds thereafter shied away from mealworms with red wings or any roughly similar markings.

Possibly the strangest form of visual armor is the frightening "eye spots" possessed by certain moths and butterflies. These species have no bad taste or other weapon: their only defense is a pair of big, bold eyelike markings on their underwings which they display suddenly when touched by a predator [*see photograph on next page*]. My colleague A. D. Blest proved that this bluff scares birds off. He presented peacock butterflies, a species that has these markings, to his birds. When the butterflies, on being pecked, displayed their eye

position until it is touched or pecked at by a bird. When this happens it will display its eye spots (*photograph at right*). The spots are called false warning colors because they are capable of frightening a bird even though the moth poses no real threat.

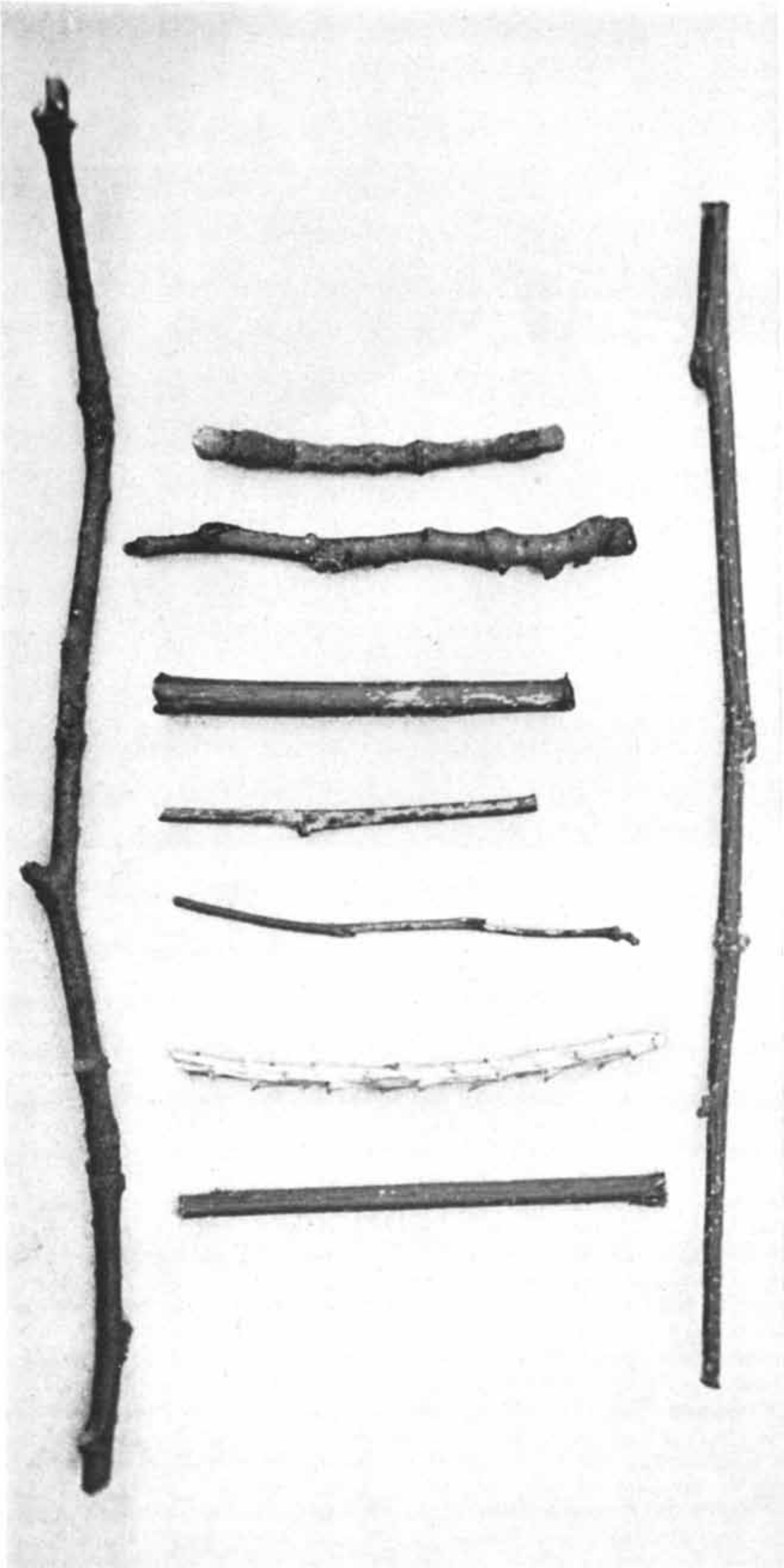
spots, the birds jumped back. Sometimes the birds tried again later and ate the butterflies, but in most cases they let the creatures alone. Testing the birds on peacock butterflies whose eye spots had been rubbed off, Blest found them much less inhibited about attacking these.

He went on to compare the effects of various patterns. For these experiments he constructed a simple box with slides bearing patterns—a pair of crosses, a pair of rings, etc. The pattern was displayed by switching on a light in the box [*see illustrations on page 51*]. Blest laid a mealworm on top of the box to attract the bird and switched on the display suddenly just as the bird pecked. Its frightening effect was measured by how frequently it put birds to flight. Each pattern evoked very consistent responses from the various birds tested, some of which had been raised in cages, others caught in the wild. The birds were somewhat troubled by a pair of crosses or parallel bars; a pair of single rings was more frightening; double rings still more frightening; and the pattern that drove the birds off most effectively was a pair of eyelike designs exactly like the eye spots on insects' wings.

Finally, Blest tested the theory that small spots on the extremities of some insects serve as deceptions to deflect predators from a vulnerable part of the animal. Using mealworms for his experiments, he painted a small spot on either the head or tail end. The birds then usually picked up the end that had the spot, whether it was at the head or the tail, although they normally show a slight bias for the head end. The experiments gave support to the idea that the natural spots found on the wing tips of insects may serve as deceptive targets for birds.

We have overwhelming evidence, then, that the protective colors and markings of animals cannot be mere accidents. An enormous number of animal forms have patterns of the kinds I have been discussing. Moreover, the behavior of the animal is generally calculated to make the most of its deceptive markings. For instance, a countershaded animal always keeps its dark side up: indeed, there is a fish (*Synodontis batensoda*) whose bottom side is darker than its top, and this fish habitually swims upside down! Countershaded animals vary considerably in the mechanisms responsible for their color scheme (in some it is due to the skin, in others to the skin and blood, etc.), and they differ in the method of determining which side is up (some responding to light, others to gravity), but in every case the net result is the same: all of them keep the darker side turned up. This can only mean that the phenomenon is a true adaptation.

If protective coloration is not an accident but an adaptive product of evolution, how does the crude process of natural selection produce the highly special and intricate patterns that these animals display? In the case of the insects we have been considering, birds must act as the selectors. Now birds are notoriously undiscriminating in some ways: for instance, a male robin will posture at the sight of a dummy made



MIMICRY OF A TWIG (*second from top*) by a caterpillar (*at top*) is shown in this photograph. The mimicked twig came from the species of birch that this caterpillar normally inhabits. The rest of the twigs came from other trees. In experiments predatory birds confused the caterpillars only with twigs from the caterpillars' host trees.

of red feathers, as if it were a rival male robin. What reason is there to suppose, then, that birds can act as fine-grain selectors, destroying, say, caterpillars that differ slightly from twigs, so that only the very "best" stick insects survive? De Ruiter's and Blest's experiments give direct information on this point.

De Ruiter strewed various kinds of twigs in a cage, along with caterpillars that mimicked one of the twig types. He found that birds confused a caterpillar only with a twig that it resembled closely. For instance, when a bird discovered the caterpillar resembling a birch twig (by accidentally stepping on it), the bird proceeded to pick up birch twigs but not other kinds. This discrimination suggests that a bird is capable of distinguishing between a twig and a caterpillar that does not quite match the twig.

Blest's experiments with the various patterns on his slides likewise demonstrated that birds have fairly good powers of discrimination. His birds were markedly less frightened by a double-ring pattern than by a drawing which included shading and a highlight so that it looked more like an eye.

The same set of experiments suggests an answer to another key question about the evolution of protective patterns: How did such adaptations start? It is quite unlikely that mutation suddenly produced a butterfly with spots on its wings that looked like eyes. The eye spots must have evolved from much cruder beginnings. Let us imagine some ancient ancestor of this butterfly which had only a weak tendency to fly. When pecked by a bird, it merely flapped its wings. This would be a poor defense against the bird, but if a mutant of the butterfly turned up with spots on its wings, the deterrent would be stronger. As Blest's experiments showed, even a pair of crosses suddenly displayed to a bird has a slightly frightening effect upon it. So wing spots which appeared suddenly when a butterfly spread its wings would give it a slightly improved chance of survival; in the course of time evolution would favor the descendants whose spots came more and more to resemble an eye. Thus the insect, armed only with this phony but effective threat, would remain a viable species in spite of its stationary habits.

Of course we have no direct proof of such a theory, but we can at least say that the results of the experiments performed so far are consistent with it. Indeed, it is hard to think of any other reasonable explanation of the experimental findings and the amazingly artful color defenses of these animals in nature.

Kodak reports on:

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Two new aerial films

In an economy based squarely and frankly on planned technological obsolescence, it has been almost embarrassing that for many years the aerial mappers' *Kodak Super-XX Aerographic Film* has stayed virtually unchanged. When a company makes a product on which a whole craft bases itself, strong pressures are felt from the customers themselves to leave well enough alone. Eventually, though, comes time to uncork the achievements of research and see what happens.

So: In an airplane we identically mount two identical, simultaneously actuated cameras with identical lenses and take them up to 20,000 feet on a good day. One contains *Kodak Super-XX Film* and the other the new *Kodak Plus-X Aerecon Film*. We do some photography, give both films the same processing in *Kodak Developer D-19*, and put a magnifier to the negatives. Railroad ties are not resolved on the Super-XX, and they *are* resolved on the Plus-X Aerecon.

Plus-X Aerecon is designed for high-altitude work. It is about a third of a stop slower than *Super-XX*. Its spectral sensitivity goes out to 710 $m\mu$ in the near-infrared. Its acutance—a measure of the sharpness with which it can reproduce the edge of an object—is very much higher than that of *Super-XX*. Furthermore, its acutance remains high at the high densities. On a resolving power test object of 1000:1 contrast, *Plus-X* gives an advantage over *Super-XX* in the ratio of 9:8, but when the contrast drops to 2:1 the resolving power advantage of *Plus-X*, instead of vanishing, rises to 3:2. Our research men find this astonishing. (They will be glad to talk with you and load you up with reprints of papers that distinguish in extremely precise language between resolving power, acutance, granularity, and graininess, which are all very different concepts.)

The new *Kodak Tri-X Aerecon Film* also goes out to 710 $m\mu$ and has twice the speed of *Super-XX*. We have long made "Tri-X" aerial film of this speed in order to extend the length of the shooting day and, in high latitudes, of the shooting season; to say nothing of the shooting night for nocturnal aerial photographers, who can work longer hours when their load capacity of light-bombs goes farther.

Now we have succeeded in putting this high speed into an emulsion of higher acutance which, in hot countries, can be processed as hot as 90 F.

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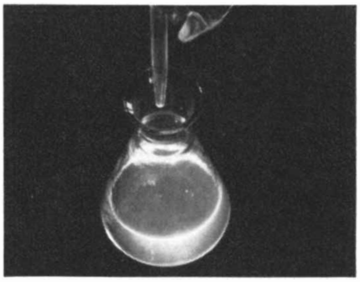
There are direct-reading pH meters and there are 57 different *Eastman pH Indicators* that work by simple color change. (We own a great many meters and sell a lot of indicators.) If none of our indicators gives a color you can see through the material being measured, you might consider one of the 23 *Eastman Fluorescent Indicators* and an ultraviolet lamp. They change fluorescence with pH. They also lend† a Mephistophelean air to your work.



Our newest compound with this property, trans-*o-Hydroxycinnamic Acid* (Eastman 7398, long known as coumaric acid) is for titrating weak acid against strong base. It is said to take on a green fluorescence in passing from pH 7.2 to 9.0, to detect mercurous ions amidst mercuric ions, and to inhibit zygote germination in the green alga *Chlamydomonas eugametus*.

† *For an 11" x $15\frac{1}{2}$" chart of the indicators or a copy of List No. 40 of some 3600 other highly available* Eastman Organic Chemicals, *write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company). If anybody wants to give* us *a procedural abstract of the mercurous ion determination from the Polish journal that published it, we'll distribute it to other interested parties.*

A hobby for clear nights

The following proposal offers little prospect for fame, advancement, or even succor to suffering humanity. All it offers is a chance to add a few grains to the mortar in the edifice of science. Here and there are a few happy people who enjoy that sort of thing.

Why not celebrate the International Geophysical Year by gathering some data for the IGY Auroral Data Center, Rockefeller Hall, Cornell University, Ithaca, N. Y. (or, if you are Canadian, for the IGY Auroral Centre, National Research Council, Ottawa)? Write them for instructions.

The sun is now at the stormy stage of its cycle. It sends forth bursts of electrons and ions which set the night sky ablaze with the rayed arcs, homogeneous arcs, pulsating arcs, pulsating spots, glows, rays, coronas, and flames of the aurora. On clear, moonless nights when the show is on, in places without overwhelming competition from smog-scattered illumination emitted by certain atmospheric gases when they are excited in glass tubes for the greater glory of hot dogs and horsepower, it is worth looking up in the sky for.

Looking is all you need do. Either the Center or the Centre supplies free report forms carrying a printed protractor for measuring angles in the sky.

Photographic records, however, are also wanted. To make them one needs a camera lens faster than *f*/4.5. (The *Cine-Kodak K-100 Cameras* of the U. S. and Canadian official observing programs have *f*/1.4 lenses.) With *Kodak Royal Pan Film* or *Kodak Tri-X Film* at *f*/3.5, reasonable exposure times for medium to bright auroras run from 18 to 60 seconds. Much faster and better for the purpose is the phenomenal new *Kodak Royal-X Pan Film*, but it must be processed according to the package directions rather than through usual commercial channels.

At Cornell, if necessary, they'll put the graduate students' wives to work reading the flood of photos and reports that ought to come in.

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

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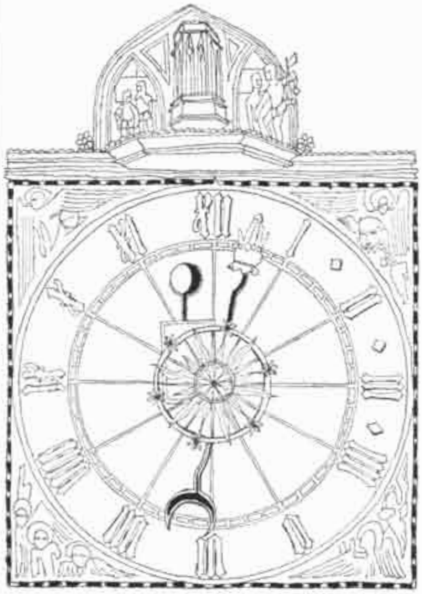
SCIENCE AND



Upturn

The half-century-long decline in study of science and mathematics in high schools was reversed last year, according to an official survey by the U. S. Office of Education. For the first time since 1910, the proportion of students taking science and mathematics courses increased.

More high schools made such instruction available. In 1956 physics and chemistry were offered by 82 per cent of the nation's high schools, against only 77 per cent in 1954; and 81 per cent gave courses in plane geometry, compared with 78 per cent in 1954. But enrollments are still far behind 1910. For example, last year 28.7 per cent of all high-school students were taking algebra; in 1910, 56.9 per cent.

Biased Neutrons

Now that physicists have discovered the first examples of asymmetrical matter [see "The Overthrow of Parity," by Philip Morrison; Scientific American, April], symmetry is beginning to collapse all along the line. They first found violations of the conservation of parity in the decay of cobalt atoms and mesons, which turned out to emit electrons mainly in one direction. Physicists of the Argonne National Laboratory now report that they have detected asymmetry in the neutron: when a neutron decays, about two times out of three it discharges the electron from its north magnetic pole.

The Argonne experimenters got their neutrons lined up parallel by putting a magnetized cobalt-iron mirror in the path of a neutron beam from a reactor: after reflection from the mirror the magnetic axes of all the neutrons were uniformly oriented with the north poles pointing upward. The direction of emission of electrons from the lined-up neutrons was then detected with counters. It developed that emission upward prevailed over emission downward in the ratio of 100 to 62. The theoreticians are now trying to figure out what this tells about the nature of neutrons.

The group reporting this work in *The Physical Review* were M. T. Burgy, R. J. Epstein, V. E. Krohn, T. B. Novey, S. Raboy, G. R. Ringo and V. L. Telegdi.

Storable Liquid Hydrogen

Liquid hydrogen evaporates rapidly even in the best-insulated container: about 20 per cent boils away in a single day. Three scientists at the National Bureau of Standards have now discovered a way to slow its evaporation.

In a hydrogen molecule the two protons may spin in the same direction or in opposite directions: the first form is called ortho, the second para. Normally hydrogen is mainly in the ortho form, but when it is liquefied at minus 423 degrees Fahrenheit, nearly all the molecules slowly change to the para form. The change releases heat, and this is the reason for liquid hydrogen's evaporation even in a sealed and cooled container.

Daniel H. Weitzel, Charles C. Van Valin and James W. Draper of the Bureau of Standards devised a treatment which quickly converts hydrogen almost completely to the para form. As soon as it is liquefied, they let it run over a bed of ferric oxide particles, which flip over some of the magnetic hydrogen atoms so that the spins of each pair are in opposite directions. The homogeneous para hydrogen then releases no appreciable heat. It can be stored for a month with only 20 per cent loss.

Revolution in Radar

A team of Columbia University physicists and engineers has extended the practical range of radar perhaps tenfold through an entirely new method of sending and receiving signals. Heretofore not

THE CITIZEN

even the most powerful radar has been able to get a distinguishable echo from an object as small as an airplane beyond a few hundred miles. The new radar will resolve such signals for much greater distances or with much less power.

The system, whose details are classified, is able to separate weak signals from background electrical "noise" and amplify them. It broadcasts a continuous stream of microwaves, instead of pulses, and analyzes the incoming signal; it identifies the steady reflection from the target and filters out the erratic noise.

John R. Dunning, dean of the Columbia School of Engineering, expects the new radar to "alter the whole concept of how we're going to communicate over long distances and in outer space." There are still, however, some engineering problems to be solved, and it may be three years before the equipment can be manufactured.

The new radar is an outgrowth of ideas on which the late Edwin H. Armstrong, pioneer in FM radio, was working before his suicide in 1954. The research was completed at Columbia's Edwin H. Armstrong Laboratory by a group headed by John H. Bose, Lawrence H. O'Neill, R. I. Bernstein and Sterling Fisher.

Uranium Plasma

A radically new and possibly cheaper way of generating electric power from nuclear fission has been suggested by S. A. Colgate and R. L. Aamodt of the University of California. They propose an ingenious scheme for converting the energy of uranium fission directly to electricity.

Their reactor would simply be a hollow cylinder, 150 feet long and 25 feet in diameter. Into one end they would pump a plasma of fissionable uranium at 6,000 degrees centigrade (that is, in the form of completely ionized gas). The cloud of uranium vapor, sufficiently concentrated to form a critical mass, would start an explosive fission chain reaction. This would shoot the gas down the length of the cylinder. It would pass through a magnetic field girdling the cylinder. Since ionized gas is an excellent conductor of electricity, its interaction with the stationary magnetic field would generate an electric current, just as in a conventional generator. When the dispersed gas collected at the other end of the cylinder, it would again be concentrated enough to constitute a critical mass, and it would now be fired back. Shuttling back and forth faster than the speed of sound, the gas would generate a continuous alternating current.

Colgate and Aamodt, outlining their proposal in *Nucleonics*, concede that it may be hard to find a suitable heat-resisting material for the walls of the reactor: their preliminary design calls for graphite. If this problem can be solved, they believe their odd reactor will work. They estimate that one such reactor would generate almost 500,000 kilowatts at an over-all efficiency of about 20 per cent—a figure that compares favorably with the efficiency of generating plants in general.

Colgate is a member of Project Sherwood, the hydrogen-fusion experimental program at Livermore, Calif. Aamodt is on the staff of the Los Alamos Scientific Laboratory.

Backward Comet

Last April astronomers were treated to a rare sight: a new comet with a tail that points toward the sun instead of away from it, as most comets' tails do. Fred L. Whipple, director of the Smithsonian Institution's Astrophysical Observatory, now believes he can explain why this freak comet, called Arend-Roland, wears its tail backward.

The pressure of the sun's light is generally assumed to push a comet's tail away from its direction. Whipple suggests that Arend-Roland is probably a newly formed comet which has never before visited the neighborhood of the sun. Still unbaked by the sun's heat, it may have a feathery mantle of icy crystals. As it approaches the sun, heat may be penetrating deeply into this mantle and vaporizing the crystals; jets of steam from the heated material would then shoot in the sun's direction, for the jets would be stronger than the pressure of the sun's light.

Early Returns from I.G.Y.

The International Geophysical Year, only three months old, has already yielded some important discoveries. As this issue of SCIENTIFIC AMERICAN went to press several had been announced.

Alfred C. B. Lovell, director of the Jodrell Bank Experimental Station in England, reported that radar stations at Jodrell Bank and at Halley Bay in Antarctica had confirmed that auroras occur simultaneously in the Northern and Southern Hemispheres.

Sydney Chapman, president of the international I.G.Y. committee, reported that streams of corpuscles from the sun come much closer to the earth's surface than had been thought. A balloon-borne Geiger counter released in Minnesota after the eruption of a gigantic solar flare detected charged particles as low as 20 miles above the ground.

Maurice J. Davidson, a Columbia University geologist, discovered a submarine mountain range 5,000 feet high on the floor of the Arctic Ocean.

But the satellite projects were not going too well. Scientists of the U.S.S.R. had not yet made laboratory models of their satellites or even decided on their size or weight. In the U. S., workers on Project Vanguard have built 20-pound models, but the propulsion problem is still so formidable that they think they may have to begin with projectiles no bigger than a softball, carrying no instruments except possibly a radio transmitter for tracking purposes.

From Babylon to Crete

Linear A has been cracked. This is the strange ancient script, found by archaeologists on the island of Crete, which has long resisted decoding [see "The Language of Homer's Heroes," by Jotham Johnson; SCIENTIFIC AMERICAN, May, 1954]. Cyrus H. Gordon of Brandeis University, a specialist in Semitic languages and culture, has now deciphered Linear A and made the surprising discovery that it is the language of the ancient Babylonians, the so-called Akkadian language [*see article beginning on page 70*].

Sixty years ago the British archaeologist Sir Arthur Evans unearthed some 2,000 baked clay tablets in the ruins of an ancient palace at Knossos on Crete. They had two kinds of script, which were given the names Linear A and Linear B. After defying linguists and cryptographers for half a century, Linear B was finally broken five years ago by a young British architect, Michael Ventris. It was identified as a pre-Homeric Greek language. Linear A remained baffling. It seemed to be an earlier version of Linear B, but the language was plainly not Greek.

Gordon studied Ventris's work and concluded that Linear A must have been

Who sets the pace in inertial navigation?

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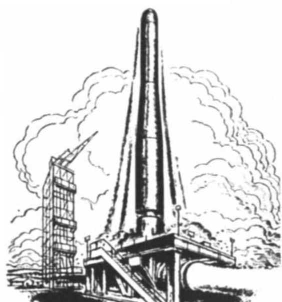

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used for a Semitic language. The first break came when he found that two frequently linked symbols, according to Ventris's pronunciation key, stood for the sounds "gab-ba." This he recognized as the word meaning "all" in Akkadian. Gordon confirmed that the language is Akkadian by working out a dozen syllables, and he is proceeding toward unraveling the Linear A writing.

Apart from the interesting discovery of this intimate connection between ancient Crete and distant Babylonia, the finding raises some puzzling questions, among them: Why did the Cretans go to the trouble of devising a new script for Akkadian to replace the cuneiform script in which it had long been written?

Controlled Mutation

A team of biologists at Columbia University has succeeded in producing synthetic genes which changed the heredity of bacteria. Stephen Zamenhof, Rosalie de Giovanni and Sheldon Greer reported their achievement at a meeting of the American Institute of Biological Sciences in Palo Alto, Calif.

They created the new genes by substituting one compound for another in nucleic acids, the genetic material. The substance they replaced is thymine. Instead of thymine they fed the bacteria a similar substance called 5-bromouracil. Apparently some of the bacteria incorporated 5-bromouracil in their genetic material, for their offspring differed drastically from the original strain. Some were giants, others dwarfs, still others grotesquely misshapen. Not all the changes were permanent, but a few have persisted through 180 generations.

Mouse-Rat

Dutch physiologists at the Netherlands national Medical Biological Laboratory have manufactured a beast with the body of a mouse, the blood of a rat and patches of mouse skin and rat skin. Their feat is reported in *Nature*.

The Dutch experimenters, and also English workers, had first produced mice which made rat blood instead of mouse blood. After exposing the mice to heavy doses of radiation which presumably destroyed their blood-cell synthesizing machinery, the experimenters planted rat bone-marrow in the mice. Many of the mice survived and thereafter had only red and white cells of the rat type in their blood.

On their rat-blooded mice the Dutch

SILICONE NEWS

DOW CORNING

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- Protect vital communications
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STRIKING STRENGTH — The Convair B58 Hustler, spectacular new addition to our air arm, delivers an extremely accurate and lethal "punch". One of the reasons for its superior fire power efficiency is Silastic,* the Dow Corning silicone rubber.

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On the civilian front, products ranging from "fry pans" to electric motors —from portable TV's to automobile transmissions — have been improved with Silastic, the silicone rubber that retains superior electrical and physical properties from —130 to over 500 F.

NEW SWITCH—Communications are vital in military operation. Stromberg-Carlson solved a major problem of reliability in field-type telephone switches by adopting coil spacers and insulators of silicone resin-bonded glass laminate. While the spacers and insulators formerly used would melt under unusual stress, the silicone-glass parts are unaffected even if trouble on the circuit should force temperatures to 680 F! Here again, as in hundreds of industrial and consumer products, Dow Corning Silicones have helped solve a major dependability problem.

READY RADAR — Strung above the Arctic Circle is a line of Distant Early Warning radar stations. In that remote, deep-freeze area, dependable and maintenance-free power is essential. That's why Western Electric Company, prime contractor for DEW Line installations, specified silicone insulated dry-type transformers to supply station power and lighting requirements.

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CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST. GOBAIN, PARIS workers grafted patches of rat skin. Ordinarily a skin graft from one animal to another will not take. But on the mice with rat blood the rat skin not only took hold but grew rat hair. Apparently these mice had lost the ability to manufacture antibodies against rat tissue. This idea is borne out by analysis of their gamma globulin (the blood fraction that contains antibodies). The mice's blood serum contains gamma globulin of the rat type.

Some of the mice with transplanted rat marrow have a mixture of mouse and rat blood. No one has yet explained how they can survive, for the two kinds of blood might be expected to induce antibodies which would make the blood cells clump and kill the animals.

Long Dreams

Nathaniel Kleitman, the eminent University of Chicago student of sleep, has killed another myth about sleep. He reports that dreams are not fleeting but have about the same pace as waking experiences.

Kleitman and an associate, William Dement, had seven men and two women sleep wearing electrodes that recorded their brain waves and eyeball movements. Five or six times a night the sleepers were awakened and asked what, if anything, they had just been dreaming. Comparing the answers with the electrical records, Kleitman and Dement were able to trace parallels between the dreams and their records. They found that during a dream the eyeballs move rapidly and brain waves take on a saw-tooth pattern quite different from the long, rolling waves of dreamless sleep. Most of the eyeball movements were up and down, but one sleeper who dreamed that he was watching two people hurl tomatoes at each other moved his eyes from side to side.

The experimenters concluded that the dreams of their subjects averaged about 20 minutes in length. The shortest was three minutes, the longest 50. Dreams tend to be longer toward morning. The experiments were described in the *Journal of Experimental Psychology.*

Lonely Eminence

Military tradition says, and most ordinary experience agrees, that a leader is most effective when he does not fraternize with his men. Fred E. Fiedler, a University of Illinois psychologist, tested this theory by long observation of

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military officers, business executives and athletic coaches. He concludes that social aloofness does indeed strengthen leadership—but not for the reason most people think.

The supposed reason is that familiarity breeds contempt. Fiedler finds, however, that the degree of familiarity of a group with its leader has little or no bearing on how well the members follow him. They get to know him well and freely discuss his weaknesses no matter how distant he is from them. The most important effect of aloofness is on the leader himself. A leader who has few personal friendships with members of his group has a clearer perception of his role and is freer to make rational decisions. Such a leader gains the greatest respect and cooperation from his followers—whether the group is a military unit, a basketball team or a business organization.

Philology by Machine

The International Business Machines Corporation and the Roman Catholic Church recently collaborated on a massive work of linguistic scholarship. They compiled a concordance (index of words and phrases) of the 13-million-word complete works of Saint Thomas Aquinas, employing a relatively simple data-processing machine of the punched-card type, which is economical enough to be used in many universities. If manually performed, this task would have required about 40 years of drudgery by 50 scholars.

The method was devised by P. Tasman of IBM in collaboration with a Jesuit priest, Father Robert Busa of the Aloisianum, an academy of Thomistic studies in Italy near Milan. After clerks had typed every phrase on cards, the machine broke them down into individual words, listed the words alphabetically and cited all their occurrences in phrases.

The project raised the intriguing possibility of using mechanized scholarship for textual analysis, according to a report in the *IBM Journal of Research and Development*. In making a concordance, the computer acquires so perfect a knowledge of the author's style that it can be used to ferret out spurious additions to the text and reconstruct brief lost passages with far greater accuracy than any human scholar. On a test run, the IBM 705 computer was able to fill in correctly gaps as long as five words which had been deliberately crossed out in a text.

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If you work with *avant-garde*, specialized engineering—for jet aircraft, rocket flight through space, or cross-country turnpike cruisers—you run smack up against a need for particular kinds of liquids for special kinds of work. You might find you need a special coolant that slows down neutrons; a hydraulic fluid with a particular viscosity range; a fire-resistant or high-temperature lubricant. Such *functional fluids* must be chemically made to meet the demands of the operation: higher temperatures, greater velocities, extreme pressures, highly critical operating environments.

In your development of new engineering design in the field of servomechanisms, aerodynamics, applied hydraulics—Monsanto can assist you greatly with the development of the kind of functional fluid your work requires—from synthetic lubricants for turbine-engine cars to operable hydraulic fluids for rockets that approach the thermal barrier.

Here are some examples of fluids now undergoing field evaluation which show how Monsanto can help meet specialized needs for "chemically tailored" lubricants:

Monsanto, to date, has developed: Fire-resistant hydraulic fluids for aviation and industrial applications including:

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Thermally stable synthetic hydraulic fluids for guided missiles and supersonic aircraft including OS-45, Type III, and OS-45, Type IV.

Monsanto is presently developing: Fire-resistant steam turbine lubricants; nuclear reactor coolants; radiation resistant hydraulic fluids and lubricants; 700° F. jet engine lubricants; synthetic automatic weapons lubricant.

Monsanto has programmed for development: "Chemically tailored" fluids for automotive use such as improved high-temperature brake fluids, superior automatic transmission fluids, synthetic lubricants for automotive gas turbine engines, and, for the aircraft field: hydraulic fluids and lubricants capable of operating in the range of 800° F.-1000° F.

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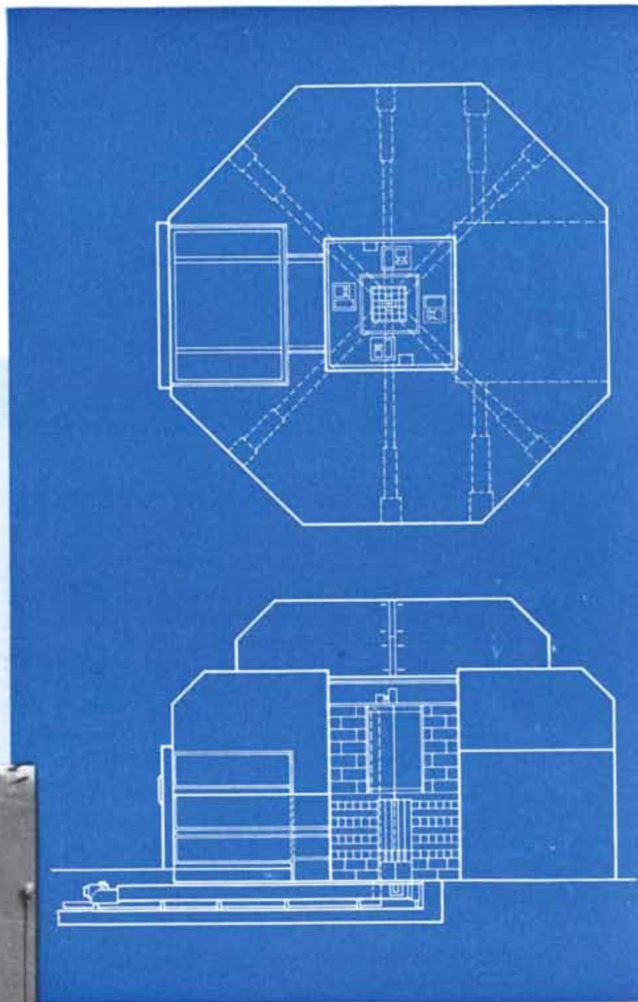
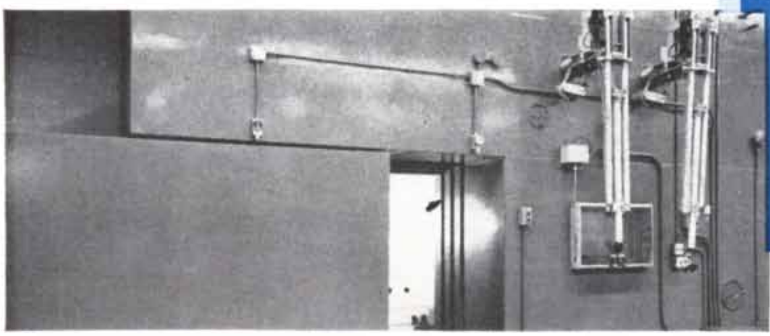


The current "need to know" phase of peace time Nuclear Energy Applications requires a versatile, practical, and economical tool for the ultimate realization of economic nuclear propulsion and locomotion as well as the multitude of radiation applications requiring experimentation and study.

The present state of the art emphasizes the need for data which determine radiation damage effects, the constant improvement in energy conversion, the manufacture and use of isotopes and the training of skilled operators and technicians.

After carefully studying the reactors available, Nucledyne undertook the design of the NTR 100. This new reactor makes possible the following specifications and realizations.



NUCLEDYNE FURNISHES THE SUPPORT FACILITIES

The above operative 100,000 curie cobalt 60 hot cell was designed and constructed by Nucledyne. This cell will provide an area 16 x 16 x 15½ to be used for dynamic testing (under a 10^6 R/HR flux) to determine the effect of radiation upon fuels, lubricants and oils.

NTR 100 Reactor

This reactor design provides a basic neutron source that can be used by both industry and training centers. The use to which this design can be put is limited only by the imagination of the user. For a minimum cost, a medium flux level of 10^{12}n/cm^2/sec. is achieved. This enables the researchers in reactor engineering, chemistry, physics, biology, and medicine to explore the peace time uses of the atom.

Because of the flux level and "customized" experimental facilities this reactor can be used in most testing situations.

Typical experiments used in reactor engineering training can be performed with ease and safety. Start up and operating procedures are those in common use on most reactors providing thorough training in reactor operation.

REACTOR CORE

The reactor core uses a standard and well proven type of fuel element; namely the MTR type fuel plates. The core is water moderated, water reflected top and bottom, and graphite reflected on the sides to achieve a high flux to power ratio by lowering the critical mass.

REACTOR SHIELD

The biological shield is barytes concrete. Experimental facilities such as water irradiation tank, thermal column, beam holes, etc. can be designed to meet individual requirements.

CONTROL ROD SYSTEM

Four symmetrically located control rods are being used. One is under servo control, one is a shim and the other two are cocked for safety rods.

SHUTDOWN MECHANISMS AND SAFETY FEATURES

The reactor core has large negative temperature and void coefficients plus two independent shutdown mechanisms. These shutdown mechanisms consist of insertion of gravity actuated rods and a moderator dump feature.

GENERAL REACTOR DESCRIPTION

Maximum Power:	100 kw
Maximum Thermal Flux:	$>10^{12}$n/cm^2/sec
Critical Mass:	2.5 kg
Type of Core:	Four side graphite reflected heterogeneous, water reflected top & bottom
Core Size:	5 element x 5 element, MTR type
Available Test Area on One Face of Graphite Reflector:	5 ft.^{2}
Graphite Thermal Column:	5ft. x 5 ft. x 6 ft. deep
Moderator & Coolant:	Water
Over-all Reactor Height:	11 ft.
Maximum Width (across corners of octagon)	18 ft.
Biological Shield:	6 ft. Barytes Concrete
Shield Over Lattice:	3.5 ft. Water and 3.75 ft. Barytes Concrete
Water Circulation Rate:	34 gpm
Storage Tank Volume:	500 gal.
Power Requirements:	50 kw, 110-V a-c, Single Phase

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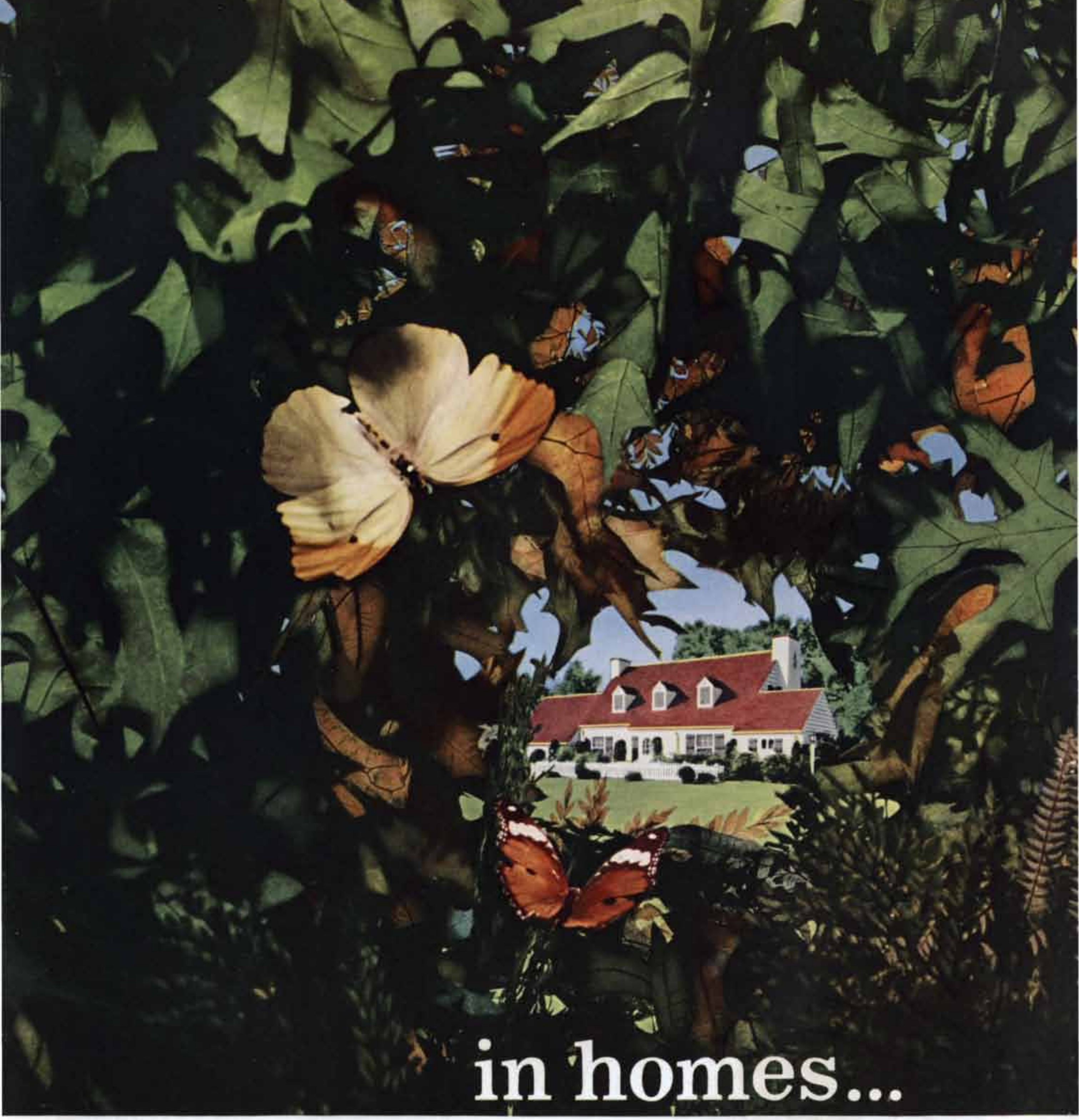

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PARTLY EXCAVATED BURIAL of a lady-in-waiting to a Sumerian royal family of 2500 B.C. was moved intact from Ur to the University Museum of the University of Pennsylvania. Amid the rich ornaments of gold may be seen the teeth of their wearer.

The Sumerians

This gifted people lived at the head of the Persian Gulf roughly between 5,000 and 3,500 years ago. Their brilliant technological and social inventions laid the foundation of modern civilization

by Samuel Noah Kramer

The Tigris-Euphrates plain is a hot, arid land. Six thousand years ago it was a wind-swept barren. It had no minerals, almost no stone, no trees, practically no building material of any kind. It has been described as a land with "the hand of God against it." Yet it was in this desolate region that man built what was probably the first high civilization. Here were born the inventions of writing, farming technology, architecture, the first codes of law, the first cities. Perhaps the very poverty of the land provided the stimulus that mothered these inventions. But the main credit must go to the people who created them—a most remarkable people called the Sumerians.

These Sumerians, as now revealed by long archaeological research, were a surprisingly modern folk. In many ways they were like the pioneers who built the U. S.—practical, ambitious, enterprising, jealous of their personal rights, technologically inventive. Having no stone or timber, they built with marsh reeds and river mud, invented the brick mold and erected cities of baked clay. They canalled the waters of the Tigris and Euphrates rivers into the arid fields and turned Sumer into a veritable Garden of Eden. To manage their irrigation systems they originated regional government, thus emerging from the petty social order of the family and village to the city-state. They created a written language and committed it to permanent clay tablets. They traded their grain surpluses to distant peoples for metals and other materials they lacked. By the third millennium B.C. the culture and civilization of Sumer, a country about the size of the state of Massachusetts, had spread its influence over the whole Middle East, from India to the Mediterranean. And there is hardly an area of our culture today—in mathematics or philosophy, literature or architecture, finance or education, law or politics, religion or folklore—that does not owe some of its origins to the Sumerians.

One might suppose that the story of the Sumerians and their accomplishments would be one of the most celebrated in history. But the astonishing fact is that until about a century ago the modern world had no idea that Sumer or its people had ever existed. For more than 2,000 years they had simply vanished from the human record. Babylonia and ancient Egypt were known to every history student, but the earlier Sumerians were buried and forgotten. Now, thanks to a century of archaeological labor and to the Sumerians' own cuneiform tablets, we have come to know them intimately—as well as or better than any other people of the early history of mankind. The story of how the lost Sumerian civilization was discovered is itself a remarkable chapter. This article will review briefly how the history of the Sumerians was resurrected and what we have learned about them.

The Cuneiform Tablets

Modern archaeologists began to dig in Mesopotamia for its ancient civilizations around a century ago. They were looking for the cities of the Assyrians and Babylonians, who of course were well known from Biblical and Greek literature. As the world knows, the diggers soon came upon incredibly rich finds. At the sites of Nineveh and other ancient Assyrian cities they unearthed many clay tablets inscribed with the wedge-shaped writing called cuneiform. This script was taken to be the invention of the Assyrians. Since the Assyrians were apparently a Semitic people, the language was assumed to be Semitic. But few clues were available for decipherment of the strange cuneiform script.

Then came a development which was to be as important a key to discovery in Mesopotamia as the famous Rosetta Stone in Egypt. In western Persia, notably on the Rock of Behistun, European scholars found some cuneiform inscriptions in three languages. They identified one of the languages as Old Persian, another as Elamite, and the third as the language of the Assyrian tablets. The way was now open to decipher the cuneiform writing—first the Old Persian, then the Assyrian, of which it was apparently a translation.

When scholars finally deciphered the "Assyrian" script, they discovered that the cuneiform writing could not have been originated by the Assyrian Semites. Its symbols, which were not alphabetic but syllabic and ideographic, apparently were derived from non-Semitic rather than Semitic words. And many of the cuneiform tablets turned out to be written in a language without any Semitic characteristics whatever. The archaeologists had to conclude, therefore, that the Assyrians had taken over the cuneiform script from a people who had lived in the region before them.

Who were this people? Jules Oppert, a leading 19th-century investigator of ancient Mesopotamia, found a clue to their name in certain inscriptions which referred to the "King of Sumer and Akkad." He concluded that Akkad was the northern part of the country (indeed, the Assyrians and Babylonians are now called Akkadians), and that Sumer was the southern part, inhabited by the people who spoke the non-Semitic language and had invented cuneiform writing.

So it was that the Sumerians were rediscovered after 2,000 years of oblivion. Oppert resurrected their name in 1869. In the following decades French, American, Anglo-American and German expeditions uncovered the buried Sumerian cities—Lagash, Nippur, Shuruppak, Kish, Ur (Ur of the Chaldees in the Bible), Erech, Asmar and so on. The excavation of ancient Sumer has proceeded almost continuously for three quarters of a century; even during World War II the Iraqi went on digging at a few sites. These historic explorations have recovered hundreds of thousands of Sumerian tablets, great temples, monuments, tombs, sculptures, paintings, tools, irrigation systems and remnants of almost every aspect of the Sumerian culture. As a result we have a fairly complete picture of what life in Sumer was like 5,000 years ago. We know something about how the Sumerians looked (from their statues); we know a good deal about their houses and palaces, their tools and weapons, their art and musical instruments, their jewels and ornaments, their skills and crafts, their industry and commerce, their *belles lettres* and government, their schools and temples, their loves and hates, their kings and history.

The Peoples of Sumer

Let us run quickly over the history. The area where the Sumerians lived is lower Mesopotamia, from Baghdad down to the Persian Gulf [*see the map at the right*]. It is reasonably certain that the Sumerians themselves were not the first settlers in this region. Just as the Indian names Mississippi, Massachusetts, etc., show that North America was inhabited before the English-speaking settlers came, so we know that the Sumerians were preceded in Mesopotamia by another people because the ancient names of the Tigris and Euphrates rivers (*Idigna* and *Buranun*), and even the names of the Sumerian cities (Nippur, Ur, Kish, etc.), are not Sumerian words. The city names must be derived from villages inhabited by the earlier people.

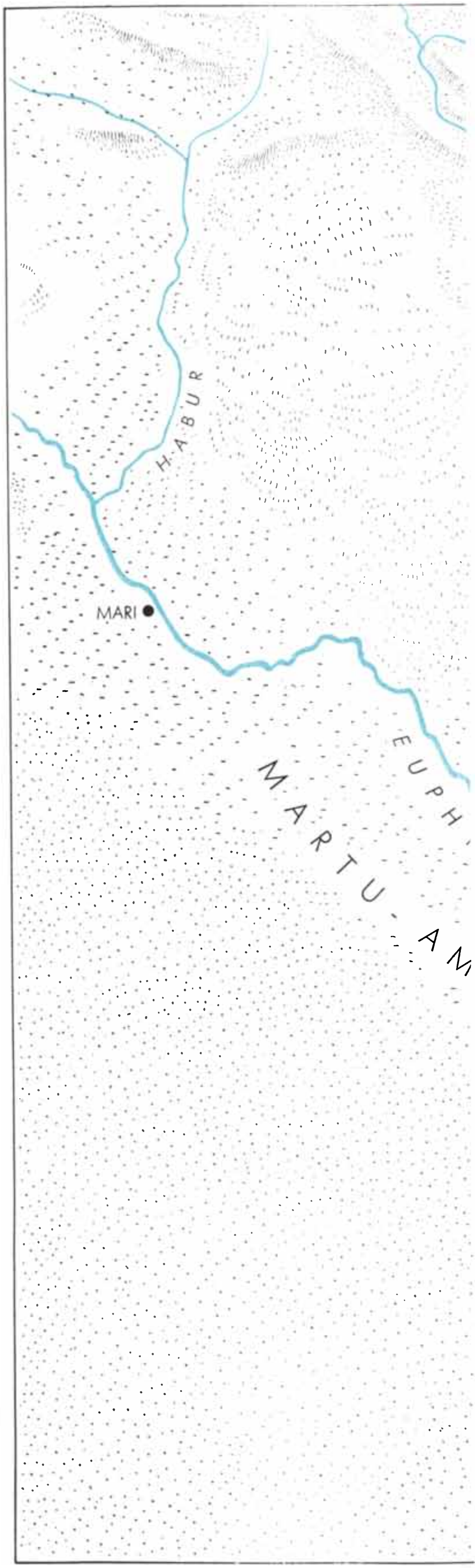
The same kind of clue—words that turn up in the Sumerian writing but are plainly not Sumerian in origin—tells us something about those first settlers in Sumer. As Benno Landsberger of the University of Chicago, one of the keenest minds in cuneiform research, has shown, among these pre-Sumerian words are those for farmer, herdsman, fisherman, plow, metal smith, carpenter, weaver, potter, mason and perhaps even merchant. It follows that the predecessors of the Sumerians must already have developed a fairly advanced civilization. This is confirmed by excavations of their stone implements and pottery.

The dates of Sumer's early history have always been surrounded with uncertainty, and they have not been satisfactorily settled by tests with the new method of radiocarbon dating. According to the best present estimates, the first settlers occupied the area some time before 4000 B.C.; new geological evidence indicates that the lower Tigris-Euphrates Valley, once covered by the Persian Gulf, became an inhabitable land well before that date. Be that as it may, it seems that the people called Sumerians did not arrive in the region until nearly 3000 B.C. Just where they came from is in doubt, but there is some reason to believe that their original home had been in the neighborhood of a city called Aratta, which may have been near the Caspian Sea: Sumerian epic poets sang glowingly of Aratta, and its people were said to speak the Sumerian language.

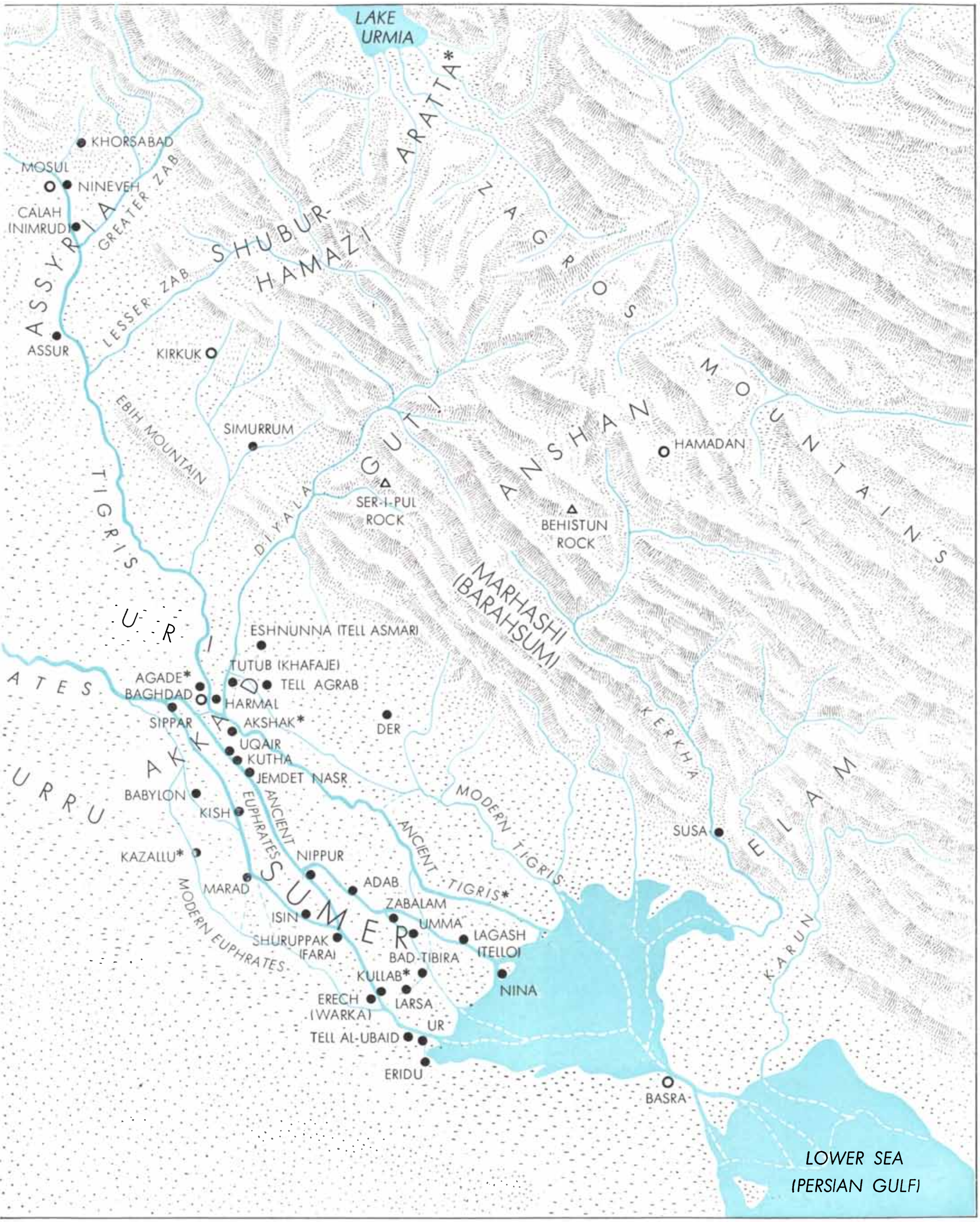
Wherever the Sumerians came from, they brought a creative spirit and an extraordinary surge of progress to the land of Sumer. Uniting with the people who already inhabited it, they developed a rich and powerful civilization. Not long after they arrived, a king called Etana became the ruler of all Sumer: he is described in Sumerian literature as "the man who stabilized all the lands," and he may therefore be the first empire builder in human history. Sumer reached its fullest flowering around 2500 B.C., when its people had developed the cuneiform symbols and thereby originated their finest gift to civilization—the gift of written communication and history. Their own history came to an end some 800 years later: about 1720 B.C. In that year Hammurabi of Babylon won control of the country, and Sumer disappeared in a Babylonian kingdom.

Life in Sumer

The Sumerians' writings and disinterred cities, as I have said, make it possible to reconstruct their life in great detail. Their civilization rested on agriculture and fishing. Among their inventions were the wagon wheel, the plow and the sailboat, but their science and engineering went far beyond these elementary tools. For irrigation the Sumerians built intricate systems of canals, dikes, weirs and reservoirs. They developed measuring and surveying instru-



SUMER and its neighbors are located on this map of the area between modern



Turkey and the Persian Gulf. Ancient cities are indicated by black dots; modern cities, by open dots. Cities and areas whose exact location is not known are marked by asterisks. In Sumerian times a large fresh-water lake lay beyond the head of the Persian Gulf.

SUMERIAN TABLETS are inscribed with cuneiform signs. At upper left is the medical tablet of which a section is shown on the cover (about 2000 B.C.). At upper right is a fragment of the epic poem "Enmerkar and the Lord of Aratta" (about 1800 B.C.). At lower left is part of the law code of Hammurabi (about 1700 B.C.). At lower right is a textile inventory (about 1950 B.C.).

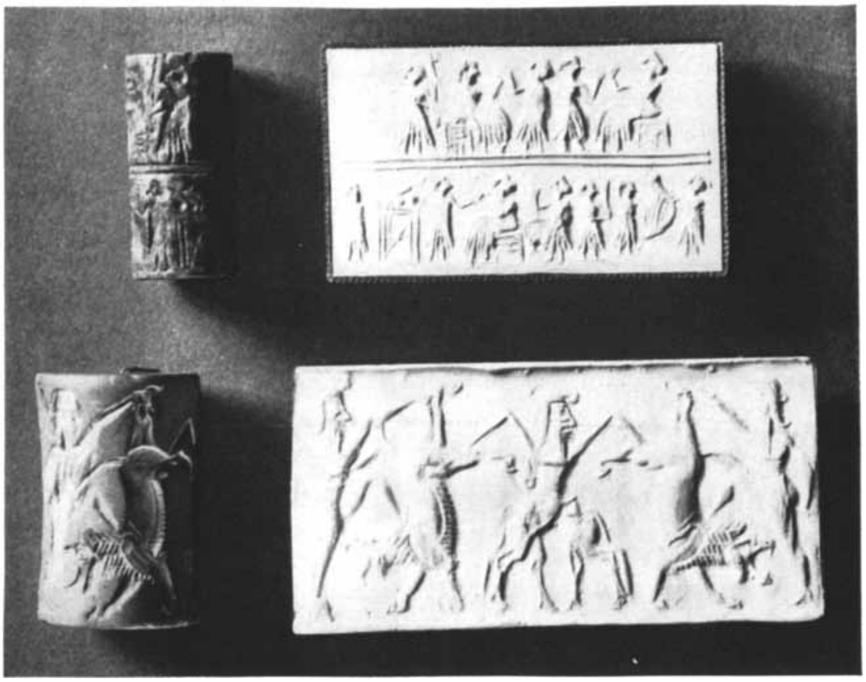
ments, and a sexagesimal number system (*i.e.*, based on the number 60) with a place notation device not unlike our decimal system. Their farming was highly sophisticated: among their tablets is a veritable farmer's almanac of instructions in agriculture.

In the crafts, the Sumerians' inventions included the potter's wheel, metal casting (of copper and bronze), riveting, soldering, engraving, cloth fulling, bleaching and dyeing. They manufactured paints, leather, cosmetics, perfumes and drugs. Prescriptions recorded on some of their tablets show that the Sumerian physician had command of a large assortment of *materia medica*, prepared from plants, animals and inorganic sources.

Although the Sumerians' economy was primarily agricultural, their life was centered mainly in the cities. Here lived many of the farmers, herdsmen and fishermen, as well as merchants, craftsmen, architects, doctors, scribes, soldiers and priests. Artisans and traveling merchants sold their products in the central town market, and were paid in kind or in money—usually silver coin in the form of a disk or ring. The dozen or so cities in Sumer probably ranged from 10,000 to 50,000 in population. Each was enclosed by a wall and surrounded with suburban villages and hamlets.

The dominant feature of every Sumerian city was a massive temple mounted on a high terrace. It usually had the form of a ziggurat, Sumer's most distinctive contribution to religious architecture. This is a pyramidal tower with a series of ascending terraces winding around the outside. To break the unattractive blankness of the temple's mud-brick walls, the Sumerian architects introduced buttresses and recesses, and they also beautified the building with columns decorated in colored mosaics. Inside the temple were rooms for the priests and a central shrine with a niche for the statue of the god. Each city in Sumer had a different tutelary god, and the Sumerians considered the city the god's property. Thus the city of Nippur, for example, belonged to Enlil, the god of the air. Nippur became Sumer's chief religious and cultural center, and Enlil was elevated to the highest rank as father of all the gods.

Originally the cities were governed by the citizens themselves, presided over by a governor of their selection. On all important decisions the citizens met in an assembly divided into two chambers —the "elders" and the "men." But for military reasons they gradually relinquished this democratic system. Each city acquired a ruler—at first elected, later hereditary—who organized its defense against the other cities and against foreign invaders. In the course of time the king rivaled the city's religious leaders in wealth and influence. The rulers of Sumer's dozen or so city-states also contended with one another for control of the whole country, and the history of Sumer is largely a record of bitter conflicts among its cities, which eventually led to its downfall.



TWO SUMERIAN CYLINDER SEALS are shown at left. Impressions were made with the seals by rolling them over wet clay. At right are two impressions made by this method.

The life of the individual citizen in a Sumerian city was remarkably free and prosperous. The poorest citizen managed to own a farm and cattle or a house and garden. To be sure, slavery was permitted, and a man could sell his children or his entire family to pay off his debts. But even slaves had certain legal rights: they could engage in business, borrow money and buy their freedom. (The average price for an adult slave was 10 shekels—less than the price of an ass.) The great majority of Sumerians were free citizens, going about their business and the pursuit of happiness with a minimum of restrictions. This did not, however, apply to children, who were under the absolute authority of their parents, could be disinherited or sold into slavery, and had to marry mates chosen by the parents. But in the normal course of events Sumerian families cherished their children and were knit closely together by love and mutual obligations. Women had many legal rights, including the right to hold property and engage in business. A man could divorce his wife on comparatively slender grounds, or, if they had no children, he was allowed to take a second wife.

Most Sumerian families lived in a one-story, mud-brick house consisting of several rooms grouped around an open court. The well-to-do had two-story houses of about a dozen rooms, plastered and whitewashed inside and out; these houses boasted servants' rooms and sometimes even a private chapel. Often the house had a mausoleum in the basement where the family buried its dead. The Sumerians believed that the souls of the dead traveled to a nether world where existence continued more or less as on earth. They therefore buried pots, tools, weapons and jewels with the dead. When a king died, the palace sometimes buried with him some of his courtiers and servants and even his chariot and animals.

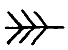
Sumerian men were often clean-shaven, but many of them wore a long beard and had long hair parted in the middle. In early times their usual dress was a flounced skirt and felt cloak; later these were replaced by a long shirt and a big fringed shawl draped over the left shoulder, leaving the right arm bare. The common dress for women was a long shawl covering the body from head to foot, except for the right shoulder. Women usually braided their hair into a heavy pigtail and wound it around the head, but on important occasions they wore elaborate headdresses consisting of ribbons, beads and pendants.

Music apparently occupied a large place in the life of the Sumerians—at home, in school and in the temple. Beautifully constructed harps and lyres were found in the royal tombs at Ur. Research has also turned up references to drums, tambourines, reed and metal pipes, and hymns written on tablets. Some of the important personages in the palaces and temples of the Sumerian cities were musicians.

The Sumerians cannot be said to have produced any great art, but they did show considerable skill in carving and sculpture. Perhaps their most original contribution to the graphic arts was the cylinder seal—a stone cylinder with a carved design which was impressed in clay by rolling the cylinder over it. These designs, or seals, appear on clay tablets, jar covers and so on. They depict scenes such as a king on the battlefield, a shepherd defending his flock from wild beasts, heraldic arrangements of animals. Eventually the Sumerians settled on one favorite seal design which became almost their trademark—a scene showing a worshipper being presented to a god by his personal good angel.

Religion

The Sumerians lived by a simple, fatalistic theology. They believed that the universe and their personal lives were ruled by living gods, invisible to mortal

EARLIEST PICTOGRAPHS (3000 B.C.)	DENOTATION OF PICTOGRAPHS	PICTOGRAPHS IN ROTATED POSITION	CUNEIFORM SIGNS CA. 1900 B.C.	BASIC LOGOGRAPHIC VALUES		ADDITIONAL LOGOGRAPHIC VALUES		SYLLABARY (PHONETIC VALUES)
				READING	MEANING	READING	MEANING	
	HEAD AND BODY OF A MAN			LÚ	MAN			
	HEAD WITH MOUTH INDICATED			KA	MOUTH	KIRI$_3$ ZÚ GÙ DUG$_4$ INIM	NOSE TEETH VOICE TO SPEAK WORD	KA ZÚ
	BOWL OF FOOD			NINDA	FOOD, BREAD	NÍG GAR	THING TO PLACE	
	MOUTH + FOOD			KÚ	TO EAT	ŠAGAR	HUNGER	
	STREAM OF WATER			A	WATER	DURU$_5$	MOIST	A
	MOUTH + WATER			NAG	TO DRINK	EMMEN	THIRST	
	FISH			KUA	FISH			KU$_6$ ḪA
	BIRD			MUŠEN	BIRD			ḪU PAG
	HEAD OF AN ASS			ANŠE	ASS			
	EAR OF BARLEY			ŠE	BARLEY			ŠE

EVOLUTION OF SUMERIAN WRITING is outlined in the chart at left. The earliest pictographs were inscribed vertically on tablets. Around 2800 B.C. the direction of this writing was changed from vertical to horizontal, with a corresponding rotation of the pictographs. The pictographs were now reduced to collections of linear strokes made by a stylus which had a triangular point. Some of these cuneiform signs are logographic, *i.e.*, each sign represents a spoken word. Some of the signs represent more than one word;

eyes. The chief gods were those of water, earth, air and heaven, named respectively Enki, Ki, Enlil and An. From a primeval sea were created the earth, the atmosphere, the gods and sky, the sun, moon, planets and stars, and finally life. There were gods in charge of the sun, moon and planets, of winds and storms, of rivers and mountains, of cities and states, of farms and irrigation ditches, of the pickax, brick mold and plow. The major gods established a set of unchangeable laws which must be obeyed willy-nilly by everything and everybody.

Thus the Sumerians were untroubled by any question of free will. Man existed to please and serve the gods, and his life followed their divine orders. Because the great gods were far away in the distant sky and had more important matters to attend to, each person appealed to a particular personal god, a "good angel," through whom he sought salvation. Not that the people neglected regular public devotions to the gods. In the Sumerian temples a court of professionals, including priests, priestesses, musicians and eunuchs, offered daily libations and sac-

CUNEIFORM SIGNS	TRANSLITERATION	TRANSLATION
	AMA-AR-GI$_4$	FREEDOM
	ARHUŠ	COMPASSION
	DINGIR	GOD, GODDESS
	DUB-SAR	SCRIBE
	É-DUB-BA	SCHOOL, ACADEMY
	HÉ-GÁL	PLENTY, PROSPERITY
	ME	DIVINE LAWS
	NAM-LÚ-LU$_7$	HUMANITY, HUMANENESS
	NAM-LUGAL	KINGSHIP
	NAM-TAR	FATE, DESTINY
	NÍG-GA	PROPERTY
	NÍG-GE-NA	TRUTH
	NÍG-SI-SÁ	JUSTICE
	SAG-GÍG	BLACK-HEADED ONES, THE SUMERIAN PEOPLE
	UKKIN	ASSEMBLY

some are syllabic, *i.e.*, they also represent syllables. The accents and subscript numbers on the modern transliteration of the cuneiform signs are used by modern scholars to distinguish between signs having the same pronunciation but different meanings. In the chart at right are 15 cuneiform words, their transliteration and their English translation.

AREA AROUND NIPPUR, one of the principal cities of Sumer (*see map on pages 72 and 73*), is covered with barren dunes today. Six thousand years ago much of the area was similarly barren. The Sumerians and their predecessors made it fertile by irrigation.

NIPPUR WAS EXCAVATED in 1951 and 1952 by a joint expedition of the University Museum of the University of Pennsylvania and the Oriental Institute of the University of Chicago. In this photograph the houses of Nippur's scribal quarter are uncovered.

rifices of animal and vegetable fats. There were also periodic feasts and celebrations, of which the most important was a royal ceremony ushering in each new year.

This ceremony is traceable to the cycle of nature in Mesopotamia. Every summer, in the hot, parched months, all vegetation died and animal life languished. In the autumn the land began to revive and bloom again. The Sumerian theology explained these events by supposing that the god of vegetation retired to the nether world in the summer and returned to the earth around the time of the new year; his sexual reunion with his wife Inanna, the goddess of love and procreation, then restored fertility to the land. To celebrate this revival and ensure fecundity, the Sumerians each year staged a marriage ceremony between their king, as the risen god, and a priestess representing the goddess Inanna. The marriage was made an occasion of prolonged festival, ritual, music and rejoicing.

The Sumerians considered themselves to be a chosen people, in more intimate contact with the gods than was the rest of mankind. Nevertheless they had a moving vision of all mankind living in peace and security, united by a universal faith and perhaps even by a universal language. Curiously, they projected this vision into the past, into a long-gone golden age, rather than into the future. As a Sumerian poet put it:

Once upon a time there was no snake,
there was no scorpion,
There was no hyena, there was no lion,
There was no wild dog, no wolf
There was no fear, no terror,
Man had no rival.

Once upon a time . . .
The whole universe, the people in unison,
To Enlil in one tongue gave praise.

To students of the ancient religions of the Near East, much of the Sumerian cosmology and theology is easily recognizable. The order of the universe's creation, the Job-like resignation of sinful and mortal man to the will of the gods, the mystic tale of the dying god and his triumphant resurrection, the Aphrodite-like goddess Inanna, the ideals of "humaneness"—these and many other features of the Sumerian creed survive without much change in the later religions of the ancient world. Indeed, the very name of the Sumerian dying god, Dumuzi, endures as Biblical Tammuz, whose descent to the nether regions was still

STATUETTES show the appearance of the Sumerians. The four statuettes at left, made about 2500 B.C., were found at Tutub (modern Khafaje). The statuette at right, made about 1850 B.C., was found at Ur. It represents Princess Enannatumma, high priestess

mourned by the women of Jerusalem in the days of the prophet Ezekiel. It is not too much to say that, with the decipherment of the Sumerian tablets, we can now trace many of the roots of man's major religious creeds back to Sumer.

Cuneiform

But the Sumerians' chief contribution to civilization was their invention of writing. Their cuneiform script is the earliest known system of writing in man's history. The cuneiform system served as the main tool of written communication throughout western Asia for some 2,000 years—long after the Sumerians themselves had disappeared. Without it, mankind's cultural progress would certainly have been much delayed.

The Sumerian script began as a set of pictographic signs devised by temple administrators and priests to keep track of the temple's resources and activities. They inscribed the signs in clay with a reed stylus, and this accounts for the curious wedge-shaped characters. In the course of the centuries Sumerian scholars developed the signs into purely phonetic symbols representing words or syllables.

More than 90 per cent of the tablets that have been excavated in Sumer are economic, legal and administrative documents, not unlike the commercial and governmental records of our own day. But some 5,000 of the finds are literary works: myths and epic tales, hymns and lamentations, proverbs, fables, essays. They qualify as man's oldest known literature—nearly 1,000 years older than the *Iliad* and the Hebrew Bible. In addition the tablets include a number of Sumerian "textbooks," listing the names of trees, birds, insects, minerals, cities, countries and so forth. There are even commemorative narratives which constitute mankind's first writing of history.

From the Sumerians' invention of writing grew the first formal system of education—another milestone in human intellectual progress. They set up "professional" schools to train scribes, secretaries and administrators; in time these vocational schools became also centers of culture where scholars, scientists and poets devoted their lives to learning and teaching.

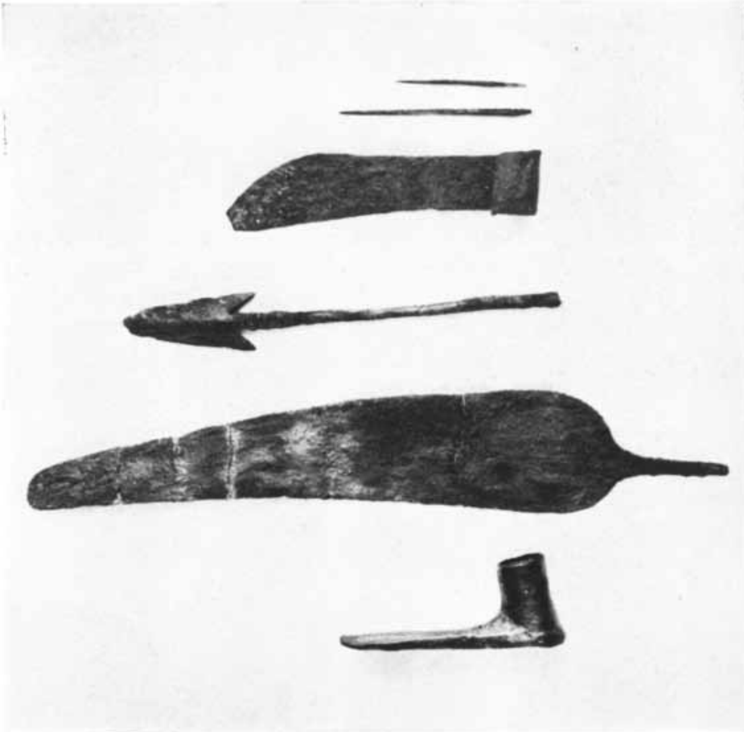
The head of the school was called "the school father"; the pupils, "school sons." Among the faculty members were "the man in charge of drawing," "the man in charge of Sumerian," "the man in charge of the whip." There was no sparing of the rod. The curriculum consisted in copying and memorizing the lists of

of the moon-god Nanna and sister of Lipit-Ishtar, king of Isin. Enannatumma presided at some of the most important reconstruction of Ur after it had been destroyed by the Elamites.

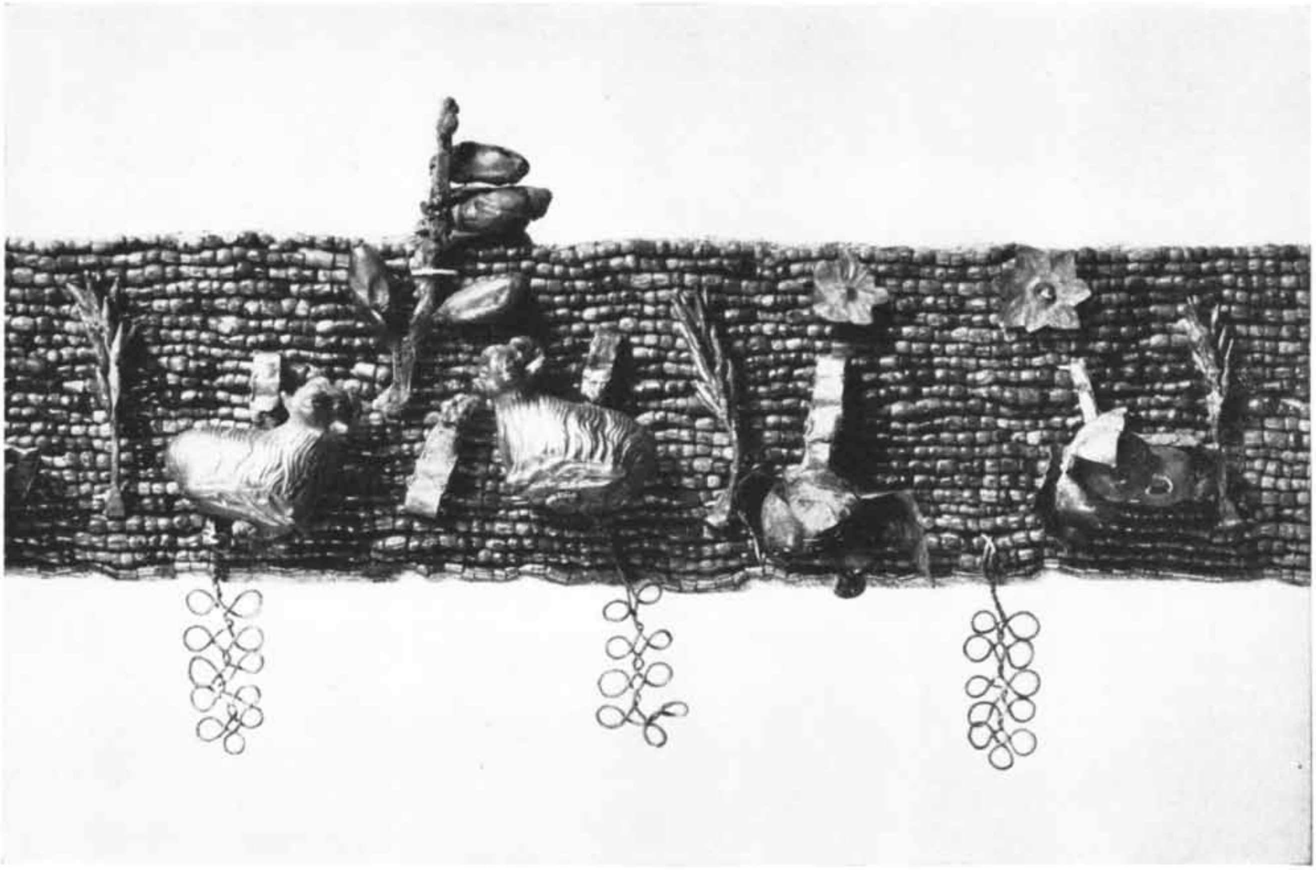
words and names on the textbook tablets, in studying and composing poetic narratives, hymns and essays and in mastering mathematical tables and problems, including tables of square and cube roots.

Teachers in ancient Sumer seem to have been treated not unlike their counterparts in the U. S. today: their salaries were low and they were looked upon with a mixture of respect and contempt. The Sumerians were an aggressive people, prizing wealth, renown and social prestige. As their tablets suggest, they were far more concerned with accounts than with academic learning.

Their restless ambition and aggressive spirit are reflected in the bitter rivalry among their cities and kings. The history of Sumer is a story of wars in which one city after another rose to ascendancy over the country. Although there are many gaps in our information, we can reconstruct the main outlines of that history from references in the tablets. The first recorded ruler of Sumer, as I have mentioned, was Etana, king of Kish. Probably not long afterward a king of Erech by the name of Meskiaggasher founded a dynasty which ruled the whole region from the Mediterranean to the Zagros Mountains northeast of Sumer. The city of Kish then rose to dominance again, only to be supplanted by the city of Ur, whose first king, Mesannepadda, is said to have ruled for 80 years and made Ur the capital of Sumer. After Mesannepadda's death, Sumer again came under the rule of the city of Erech, under a king named Gilgamesh who became the supreme hero of Sumerian history—a brave, adventurous figure whose deeds were celebrated throughout the ancient world of western Asia. The next great ruler who appears in the



ARTIFACTS at left are Sumerian stone weights. The weight at top is one *mana* (505 grams); the weight at bottom, one *gin* (8.416 grams); the weight in middle, one *gin* 160 *shē* (15.896 grams). At right is a group of copper and bronze tools and weapons. They are, from top to bottom, two bronze drills, a copper axhead, a copper spearhead, a copper saw blade and a bronze adzhead.



DIADEM of Queen Shub-Ad, who lived about 2500 B.C., was found in the royal cemetery of Ur. The horizontal band of the diadem is fashioned out of beads of lapis lazuli. Mounted on the band are tiny leaves, fruits, flowers and figures of rams, all made of gold.

record was Lugalannemundu of the city of Adab; he is reported to have ruled 90 years and to have controlled an empire extending far beyond Sumer. But his empire also fell apart, and a king of Kish named Mesilim became the dominant figure in Sumer. Later rule over the country was won by the city of Lagash. The last ruler of the Lagash dynasty, a king named Urukagina, has the distinction of being the first recorded social reformer. He suppressed the city's harsh bureaucracy, reduced taxes, and brought relief to widows, orphans and the poor. One of King Urukagina's inscriptions contains the word "freedom"—the first appearance of this word in man's history. But within less than 10 years a king of the neighboring city of Umma overthrew Urukagina and put the city of Lagash to the torch.

The Fall of Sumer

The cities' incessant struggle for power exhausted Sumer. A Semitic people from the west, under the famous warrior Sargon the Great, marched into the country and established a new dynasty. Sargon founded a capital called Agade (from which came the name Akkadian) and made it the richest and most powerful city in the Middle Eastern world. He conquered almost all of western Asia and perhaps also parts of Egypt and Ethiopia. Sargon's sons held on to the empire, but his grandson, Naramsin, brought Sumer to disaster. For reasons unknown, he destroyed the holy city of Nippur, and soon afterward he was defeated by semibarbaric invaders from the mountains of Iran who overran Sumer and completely wiped out the city of Agade.

It took the Sumerians several generations to recover. But their civilization did come to life again, under a governor of Lagash named Gudea, whose face is the best known to us of all the Sumerians because a score of statues of him have been found in the ancient temples of Lagash. Gudea re-established contacts and trade with the rest of the known world and put Sumer on the path to prosperity. After Gudea, however, the rivalry among its cities broke out again and became Sumer's final undoing. The city of Ur, under a king named Ur-Nammu, defeated Lagash; Ur-Nammu founded a new rule called the Third Dynasty of Ur. It was to be Sumer's last dynasty.

Ur-Nammu was a strong and benevolent ruler. According to inscriptions that have recently come to light, he removed "chiselers" and grafters and established a law code which insured honest weights and measures and took care that the poor should not "fall a prey to the wealthy." Ur-Nammu's code is especially significant for the fact that instead of the barbarous rule of "an eye for an eye and a tooth for a tooth" common among early societies it established a money fine as punishment for assaults.

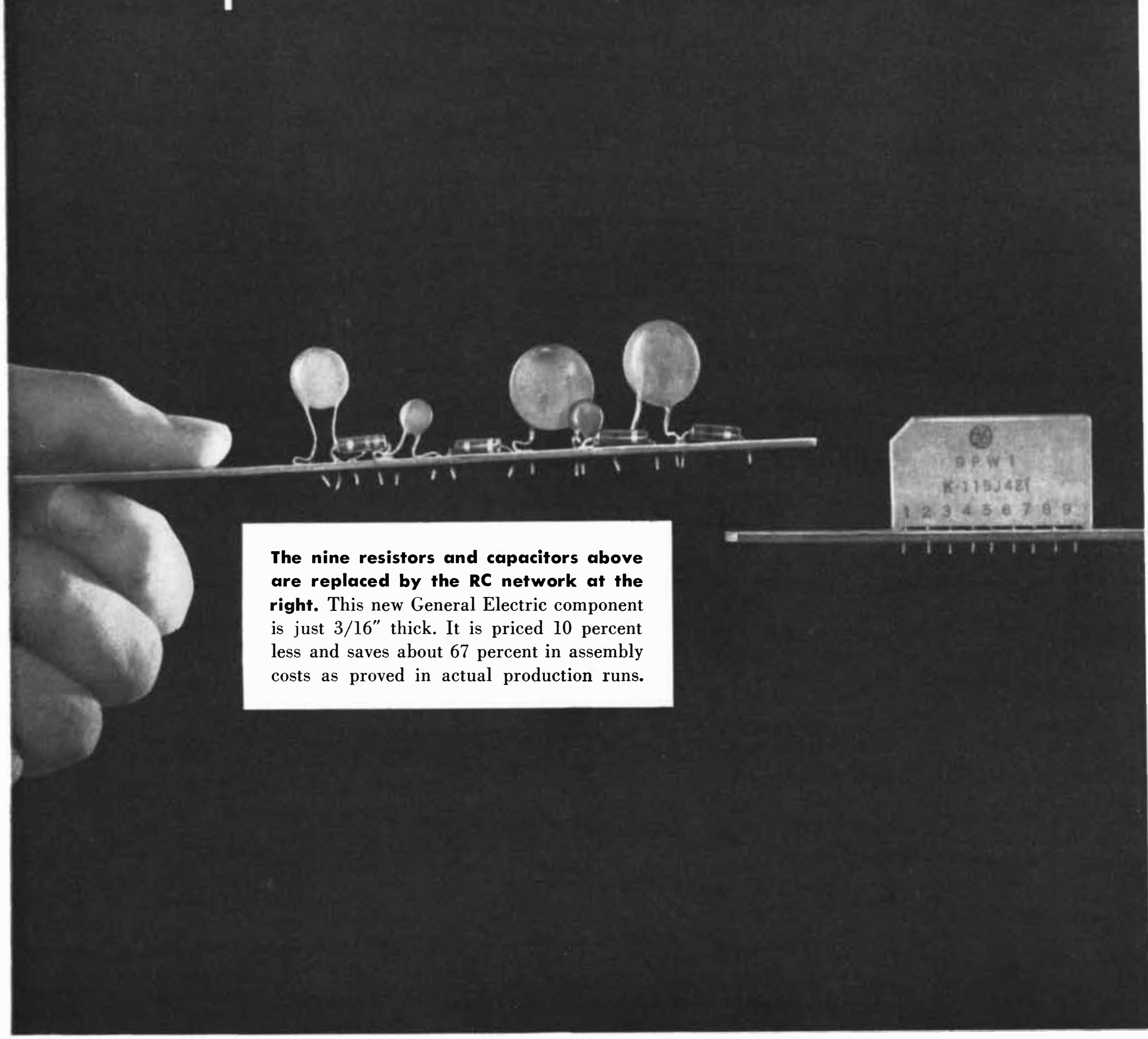
In spite of Sumer's civilized kings and prosperity, time was running out for the Sumerians. Their internal rivalries and the growing pressure of surrounding peoples soon overwhelmed them. Semitic nomads from the Arabian desert to the west (the Amorites of the Bible) took over the Sumerian cities of Isin, Larsa and Babylon. Ur itself was conquered by the Elamites to the east, who carried off its last king, Ibbi-Sin. In the following two and a half centuries the Semitic rulers of Isin and Larsa, and then Larsa and Babylon, struggled for control of the country. Finally, in about the year 1720 B.C., Hammurabi defeated Rim-Sin, the last king of Larsa, and Babylon emerged as the dominant city of southern Mesopotamia. The Sumerians were submerged by the Semites and lost their identity as a people. In time their name was erased from the memory of man; the Sumerian language disappeared as a living, spoken tongue, though for centuries it continued to be the written language studied in schools.

The Sumerians firmly believed that when man died, his emasculated spirit descended to a dark, dreary nether world. The spirit and fame of this proud, vigorous people certainly suffered a remarkable eclipse after their empire fell. But what their minds created survives throughout the living corpus of present-day civilization: it appears in the form of a Biblical proverb, a statutory law, a heroic folktale, an Aesopic fable, a zodiacal sign, a Euclidean theorem, the weight of a coin, the degree of an angle. And in the cuneiform tablets which were the Sumerians' pre-eminent gift we have found the earliest intellectual record of man's strivings toward civilization.

Editor's Note

The author wishes to thank the following individuals for their generous cooperation and help in the presentation of this article: F. G. Rainey, A. V. Kidder, Robert Dyson, Edmund I. Gordon, Jane Kohn, and the Board of Managers of the University Museum of the University of Pennsylvania.

New components made from technical ceramics cut costs



The nine resistors and capacitors above are replaced by the RC network at the right. This new General Electric component is just 3/16″ thick. It is priced 10 percent less and saves about 67 percent in assembly costs as proved in actual production runs.

Lead Metaniobate

A piezoelectric material recently developed by General Electric, Lead Metaniobate remains remarkably stable over the temperature range from −54°C to 265°C, an important fact in high-temperature instrumentation devices. It displays superior aging characteristics compared with other ceramic piezoelectric bodies. The high Curie temperature (570°C) allows repeated heat cycling with no effect on electrical output.

Thru-Con print wire board

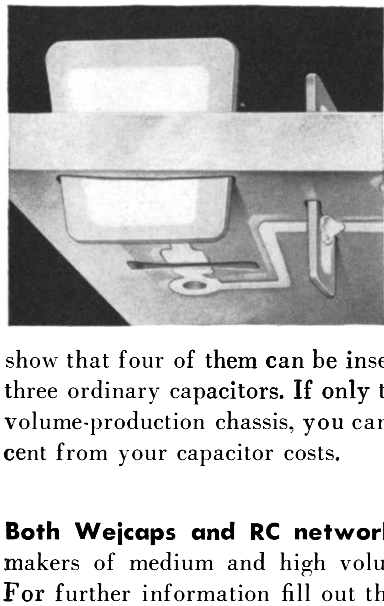
Now you can design a compact wiring pattern on both sides of the board *without* the cost of further processing to connect them. The "Thru-Con" board additive technique plates *through* the holes at the same time it plates the wiring pattern. This permits high-speed dip soldering remarkably free from rejects. No special eyelets or pre-cleaning is required. Assembly weight is reduced, inventory simplified.

# of electronic assemblies

Basic Improvements in RC Networks and Capacitors Developed by General Electric Research

Technical ceramics have remarkable electrical and mechanical properties that lead to the utmost simplification in component parts—as superior to present components as the auto was to the horse.

The new RC network shown at the left replaces a host of individual resistors and capacitors. The price saving can be ten percent or better. The assembly saving in print wire boards—inserting one unit instead of five or ten—averages about 67 percent. Furthermore, this small RC network results in a smaller overall assembly, at proportionate savings in board costs. Yet you are not restricted to the usual limitations due to environmental temperatures, for the new network operates at 95°C, ten degrees over the normal requirement.



Wejcaps. Wejcaps are small, flat capacitors that have no leads at all. They are merely wedged into print wire boards. Leads are an encumbrance. They get bent and broken. They are tough to align. They have to be crimped. Wejcaps eliminate these problems and cost 25 percent less. Tests on Wejcaps also show that four of them can be inserted in the time it takes to put in three ordinary capacitors. If only three Wejcaps are applied in your volume-production chassis, you can expect to cut as much as 20 percent from your capacitor costs.

Both Wejcaps and RC networks are available in a range that makers of medium and high volume assemblies can capitalize on. For further information fill out the coupon.

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PLASMOIDS

These little pieces of plasma (a gas of electrons and ions) are created in the laboratory with an electrical gun. They have an unexpected capacity for maintaining their identity

by Winston H. Bostick

In physics laboratories of several countries—notably the U. S., Great Britain and the U.S.S.R.—man is feeling his way gingerly toward harnessing thermonuclear power. The studies are centered on small "bottles" of hot gas which correspond to tiny samples of the sun (though they are not nearly so hot or dense). The gas is called a plasma. It is a collection of electrons and ions (electrically charged atoms). The behavior of this assemblage of particles is at once very simple and very complex. It challenges all the mathematical and experimental ingenuity of modern physics, and it has ushered us into a world of unexpected and exciting phenomena. This article is an account of some recent experiments which have generated remarkable bodies that we call plasmoids.

The properties of these bodies stem basically from two familiar phenomena of nature, both of which, oddly enough, go back to the same discoverer—William Gilbert, Queen Elizabeth's physician, who will forever be a great name in physics. In 1600 this imaginative experimenter placed an electrically charged knob of metal close to a flame and found that the metal lost its charge: the heated air had carried it away. Thus Gilbert discovered that a gas (an ionized gas, as we know now) can conduct electricity. The other physical phenomenon that governs the behavior of plasmoids is magnetism—a field in which Gilbert was also the first experimenter. Ionization and magnetism combine to produce what have recently become known as magnetohydrodynamic effects, and plasmoids are a magnetohydrodynamic phenomenon [see "Electricity in Space," by Hannes Alfvén; SCIENTIFIC AMERICAN, May, 1952].

The late Irving Langmuir of the General Electric Company began to study plasmas as long ago as 1921. Plasmas,

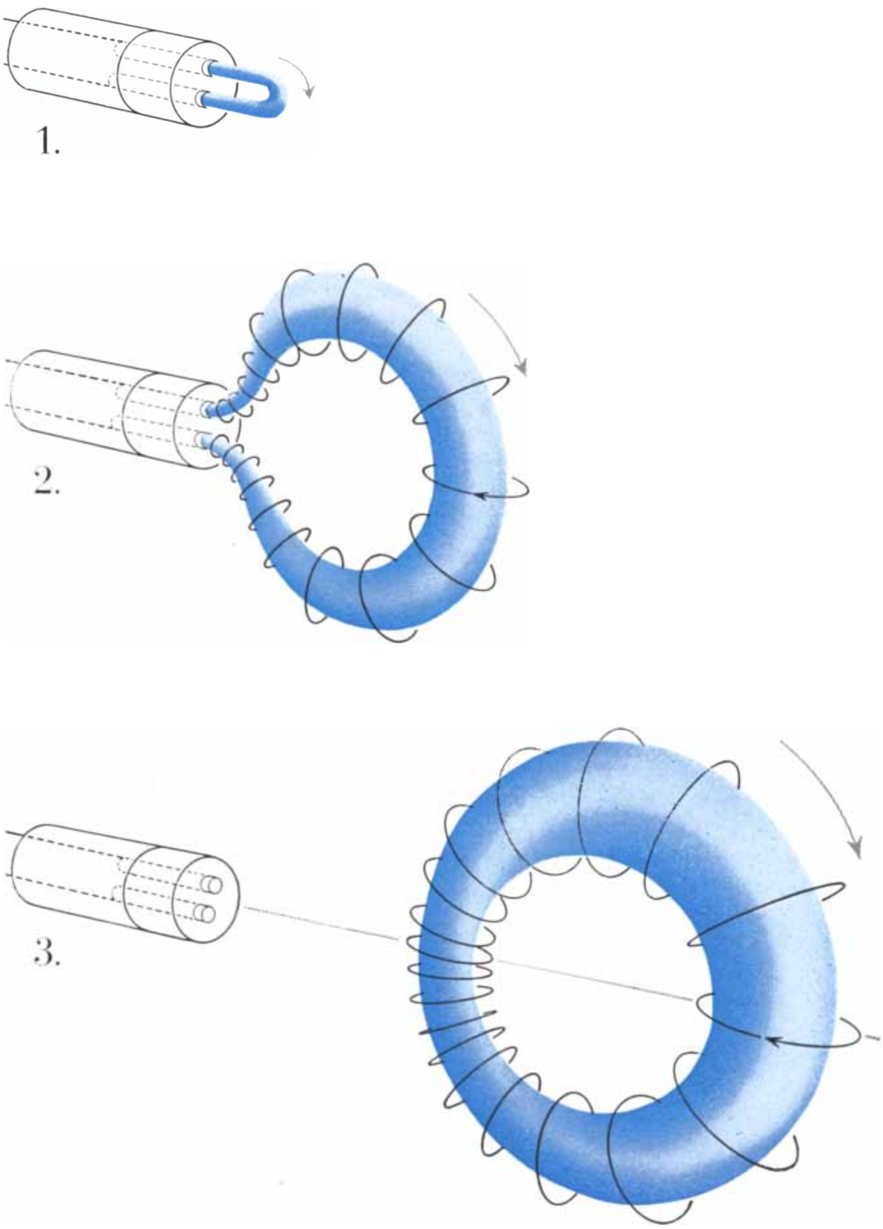
TWO PLASMOIDS are fired at each other in a vacuum chamber containing a strong magnetic field. The initial bursts from the guns are marked by the bright spots at left and right. The luminous streaks are the subsequent paths of the plasmoids. It can be seen that they repel and veer away from each other, so that each of the strange gaseous shapes retains its separate identity.

of course, are nothing new: whenever we look at a neon sign we see a plasma. It is produced by an electric discharge, which knocks electrons from the gas atoms in the tube; the released electrons collide with other atoms and produce more ions. This process continues until there are enough liberated electrons to make the gas a good electrical conductor.

Langmuir was interested in learning, among other things, the energy of agitation, or "temperature," of the electrons. The wall of the neon tube is cool, and so are the ions and gas atoms in the tube, because comparatively few atoms are ionized and the ions quickly distribute their energy among the neutral atoms. But the electrons are so much lighter that they lose little energy in rebounding from the more massive atoms or the tube wall. By ingenious experiments Langmuir measured the electrons' temperature and found that it amounted to about 20,000 degrees Fahrenheit—about twice as hot as the sun's surface.

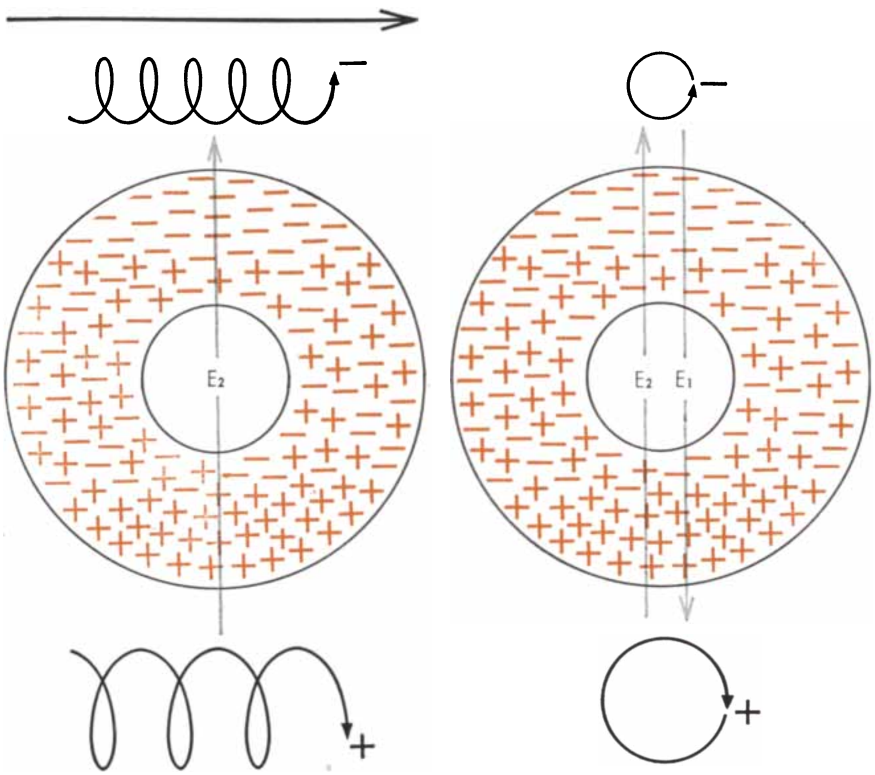
This high figure explains the interest in plasmas on the part of physicists who are now studying the possibilities for achieving controlled thermonuclear fusion. To fuse atoms of deuterium (heavy hydrogen) on a large scale requires a temperature of about 300 million degrees centigrade. Such a temperature is far beyond our reach in the laboratory, nor could a dense gas at this temperature be contained by any method we know at present. But for exploratory experiments it should at least be possible to raise a plasma to a temperature of scores of thousands of degrees, and the plasma can be contained if its density is sufficiently low.

The difficulty is that in a low-density gas, energized ions and electrons do not collide with one another often enough to raise the temperature greatly; instead they lose their energy in collisions with the walls of the container. But as everyone who has followed events knows, a beautiful solution to this problem has been found. It is the magnetic "bottle." Within a magnetic field, which swings the electrified particles in circular orbits, the plasma can temporarily be held in thrall as tightly as by any material container. The electrons and atoms collide only with one another, and the plasma becomes fully ionized.



FORMATION OF PLASMOID is diagrammed schematically. In drawing 1 a burst of plasma emerges from the electrodes of an arc gun. The gray arrow shows direction of current flow in the ionized gas. Loop enlarges (2) and breaks off (3). Black circles around the doughnut-like body are magnetic lines of force set up by current in the plasmoid itself.

In the University of California Radiation Laboratory at Livermore and at the Stevens Institute of Technology we have been studying magnetically confined plasmas with the help of a special plasma gun. It generates a plasma of deuterium, the potential fuel of thermonuclear fusion. There are two electrodes, made of titanium with deuterium atoms absorbed in them [*see diagram at left*]. A pulsed arc current of several thousand amperes, each pulse lasting about half a microsecond, is passed across the gap between the electrodes. This high current evaporates electrons and ions from the two electrodes. It also generates a magnetic field which, like a girdle, pinches the plasma into a slender column. The special feature of our gun is that the plasma emerging from the two "mouths" is bent into a loop, and it fires doughnut-shaped blobs of plasma. Just as, when a spring is bent, the turns of the wire are crowded closer on the inside of the loop than on the outside, so the magnetic field lines of the loop of plasma emerging from our gun are more crowded on the inside than on the outside. The strong magnetic pressure on the inside of the loop blows the plasma forward at high speed—up to 120 miles per second! Considering that the gun is smaller than a thimble and that the driving energy stored in the capacitor is only six joules—no more than is needed to



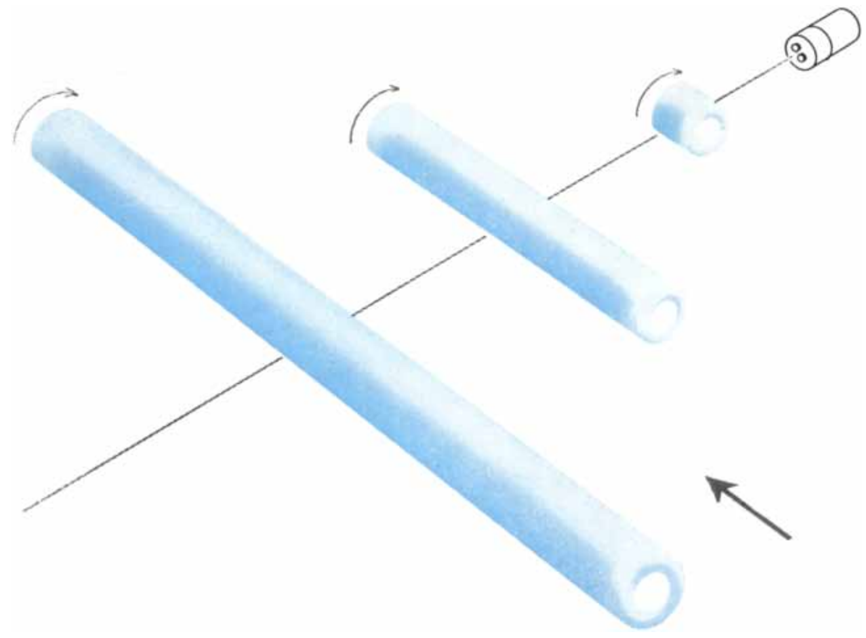
MOTION OF CHARGES in plasmoid moving across a magnetic field is seen in two frames of reference. In laboratory frame (*left*) the black arrow indicates motion of the loop across a magnetic field directed vertically up from the page. The gray arrow (E_2) shows the electric field produced by separation of charges. The upper curve is path of electrons; the lower curve, path of positive ions. In the plasmoid frame of reference (*right*) E_2 is offset by the charge-separating voltage E_1, and the charges have simple circular orbits.

light a six-watt bulb for one second—this is a truly remarkable performance. A velocity of 120 miles per second for deuterium ions represents a temperature of four million degrees. It suggests that with larger plasma guns of this kind we might begin to approach thermonuclear temperatures.

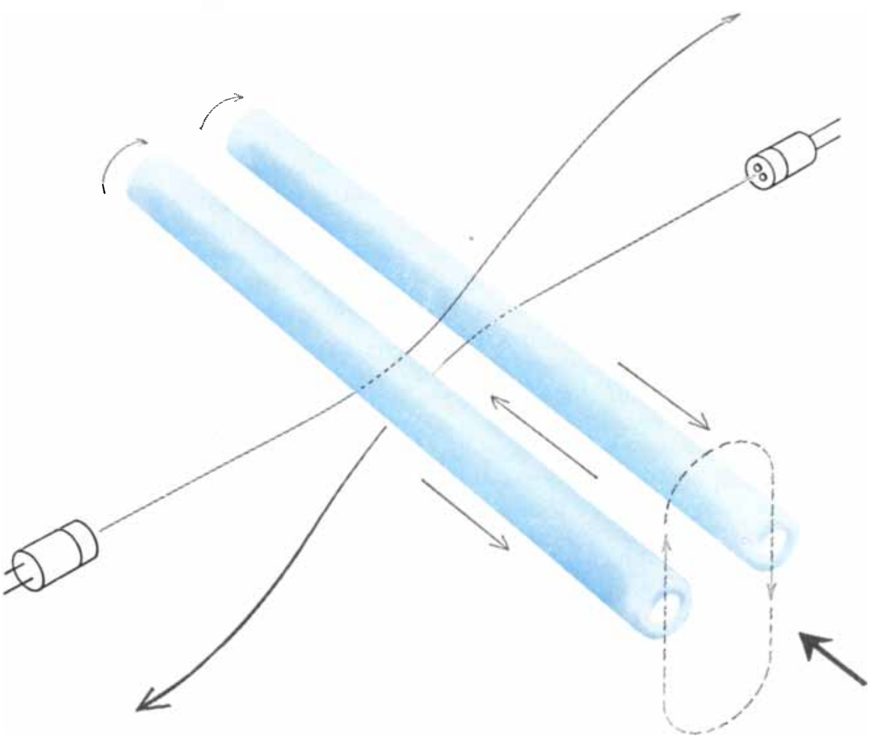
The velocities of the plasma bodies shot from our gun are comparable to the speeds of stars in galaxies and of flares shooting out from the sun. It seemed worthwhile to follow up the analogy. Would the high-speed plasma serve as a kind of laboratory model to throw light on the magnetohydrodynamic processes operating in the universe? We have studied it from this point of view, with what seem to me interesting and significant results.

Let us see first what happens when we fire a piece of plasma into a vacuum under an external magnetic field (that is, a field applied from outside the plasma itself, which is bottled within its own self-excited field). Although the plasma darts through our chamber at a speed in the neighborhood of 120 miles a second, fortunately it leaves a luminous wake which can be photographed with a high-speed camera, so that we can see its track. Now we would expect the electrons and ions in the plasma to be thrown into circular orbits as soon as they enter the externally applied magnetic field, so that the plasma would not move more than a very short distance from the gun. But the camera discloses the somewhat shocking fact that the plasma crosses the magnetic field with ease! How does it get through the field?

To follow our explanation the reader is advised to consult the accompanying diagrams [*above*]. As the plasma starts to move across the magnetic field, the electrons curve upward and the positive ions downward. This effect essentially produces an electromotive force, just as copper wires moving across a magnetic field do in an ordinary dynamo. An electromotive force can be thought of as the electric pressure exerted by an electric pump. If there is no outlet (such as an electric toaster) for the pump, no current will flow. Similarly this little piece of plasma has no outlet in the vacuum chamber, and no current can flow. Its



PLASMOID STRETCHES into a cylinder as it travels through a magnetic field. In this drawing the travel is in a straight line away from the gun at upper right. Curved arrows show direction of the plasmoid's spin; heavy gray arrow gives the direction of the field.



MUTUAL REPULSION of approaching plasmoids is presumably due to a strong magnetic field created between them. In this diagram a pair of plasmoids avoid each other, the plasmoid from the left moving up and the plasmoid from the right down as they approach. The magnetic field arises from a current (*oval broken line*) produced by the plasmoids' internal electric fields. The resulting magnetic field (*light straight arrows*) adds to the external field (*heavy arrow*) in the space between the plasmoids and subtracts in the space outside.

pump pushes against closed valves, so to speak, and merely creates an electrical pressure opposing that of the pump. Within the plasma frame of reference the direct and opposing electric fields cancel each other, and the magnetic field swings the electrons and ions in perfectly circular orbits. But from our outside point of view we can see that the opposing electric field (E_2), in conjunction with the magnetic field, moves the orbits, so that the plasma travels across the magnetic field. The particle orbits trace a track such as a marker at one point on the edge of a merry-go-round would leave on the ground if the merry-go-round were dragged along by a tractor while it was turning.

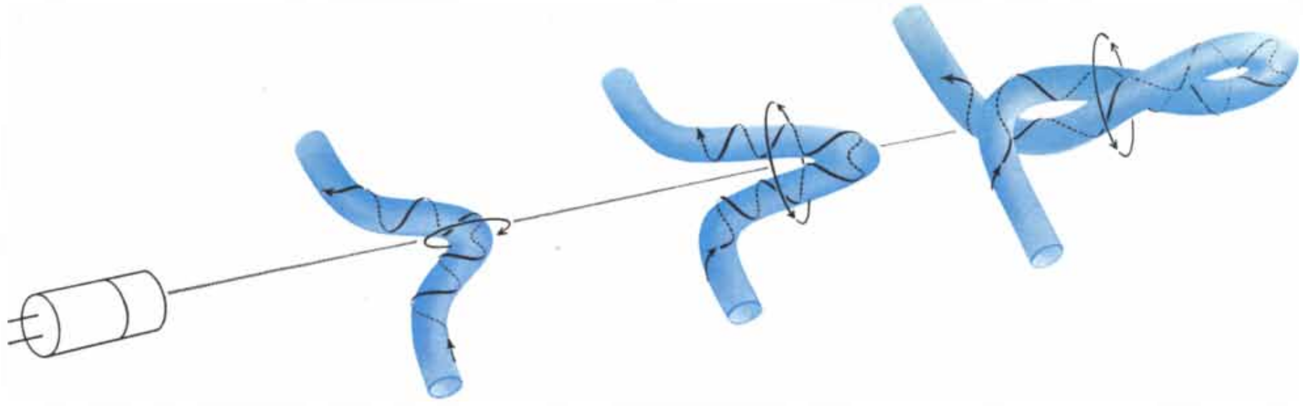
Apparently some ions and electrons in the plasma, escaping the full effect of electric field E_2, stay behind in stationary circular orbits. These ions and electrons recombine and give off light. Their luminous tracks are, in a manner of speaking, the funeral pyres of the particles which were sacrificed in laying down the electric field E_2 so that the main body of the plasma might pass across the magnetic field.

We can actually draw current from the primary electric field produced by the little dynamo contained in this plasma. If we put two small stationary probes connected by a resistance in the chamber (equivalent to plugging in a toaster), we get a pulse of current of about one ampere as the two regions of the plasma pass simultaneously over the probes.

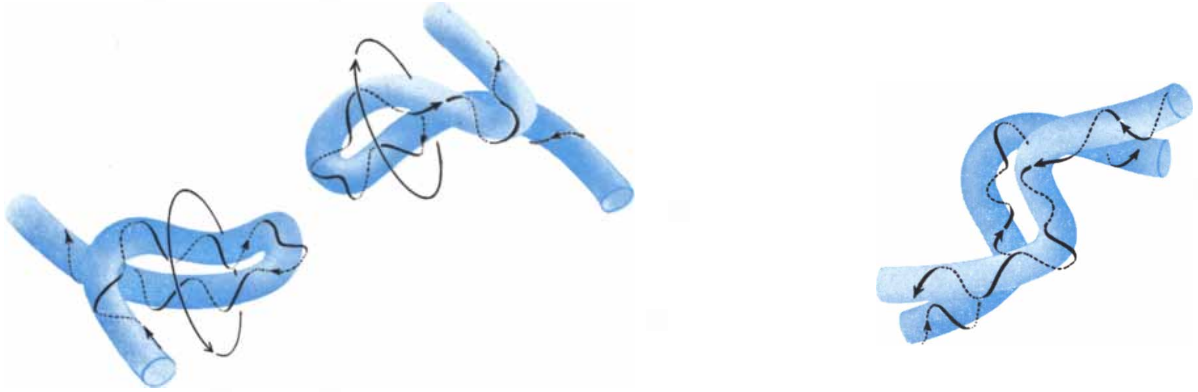
Further measurements with probes show that the plasma forms an ever-elongating hollow cylinder as it proceeds across the magnetic field [*see upper diagram at left*]. It is to this type of plasma—a self-generating, shaped body—that we have given the name plasmoid. And plasmoids, under laboratory manipulation, display some fascinating behavior.

What will happen if we fire two plasmoids at each other from opposite directions? We might suppose that when they meet their transverse electric fields will cancel each other so that both plasmoids stop dead. But in fact they bounce off each other like billiard balls! Apparently each dynamo acts as an outlet or short-circuit for the other, and a substantial current (several amperes) flows briefly. The current gives rise to a "cushion" of high magnetic-field pressure between the two plasmoids which pushes them away from each other.

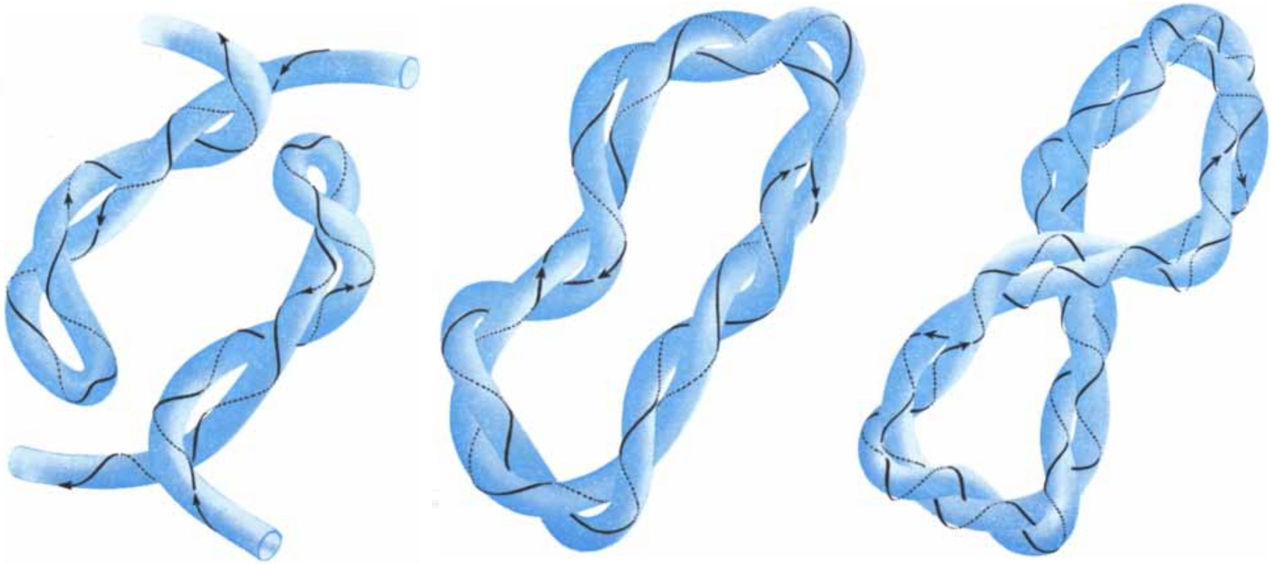
Occasionally two plasmoids crashing



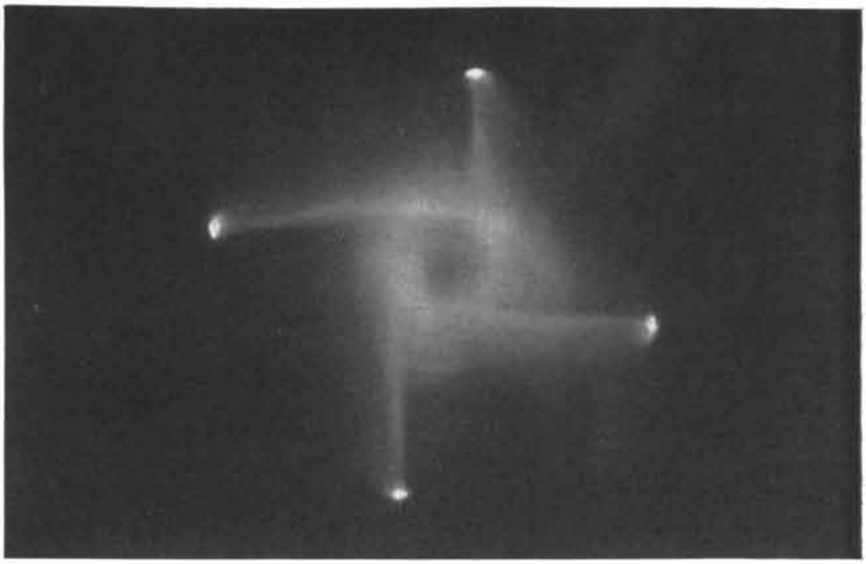
PLASMOID TWISTS when it is fired into a gas which slows it down. The helical arrows give direction of plasmoid's internal magnetic field. The ellipses give direction of the magnetic field produced by the plasmoid around itself and the direction of its spin.



PLASMOIDS MAY LINK TOGETHER if they approach each other in such a way that they can interchange portions of their internal magnetic fields. In this diagram a pair of twisted plasmoids meet one another head to head, blending into a new unit.



RING IS FORMED when a pair of twisted plasmoids meet head to tail, thus joining together at two points. Because of the electromagnetic forces which exist within this ring-shaped structure, it subsequently twists itself around its mid-point, forming a figure 8.



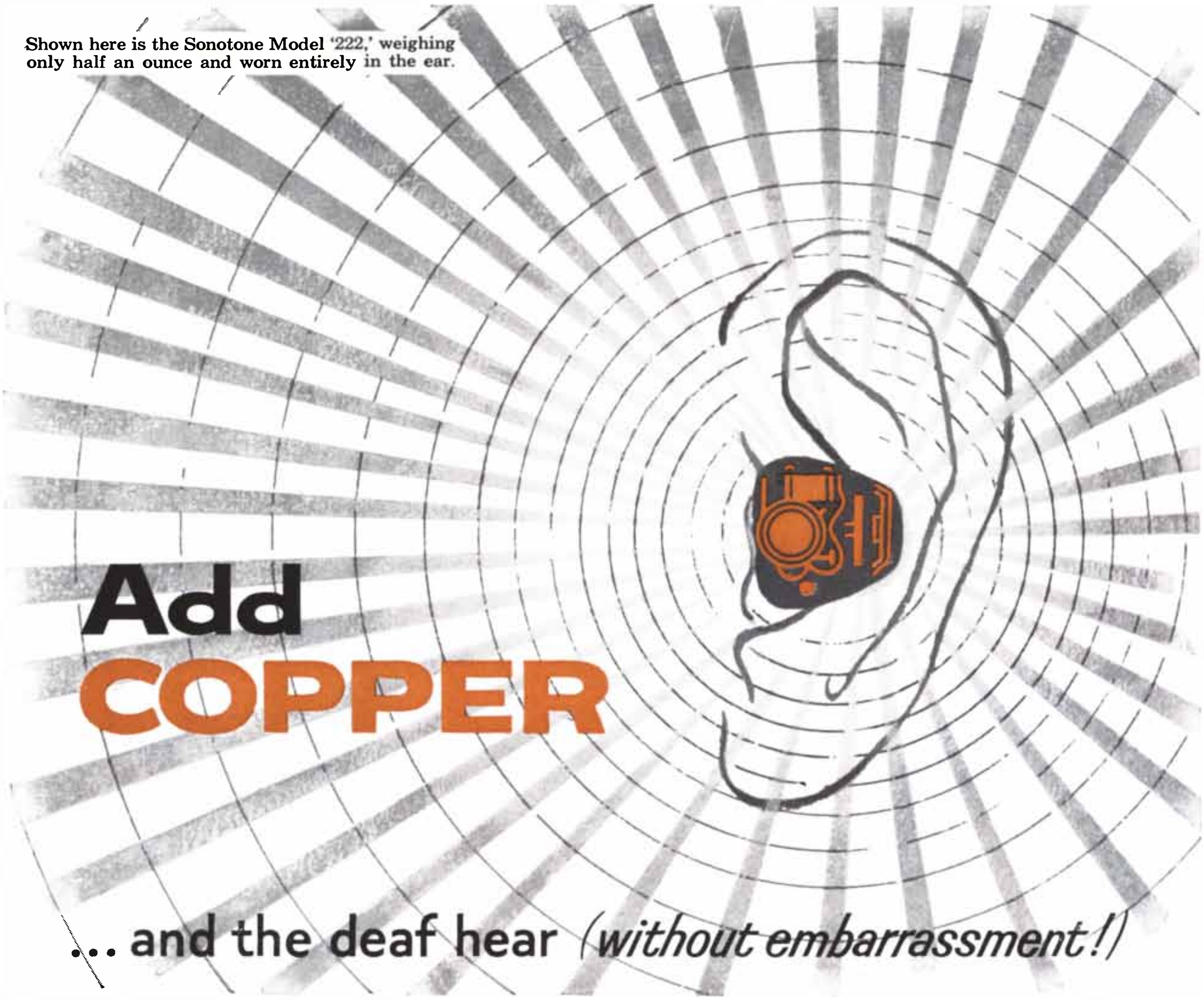
SPIRAL GALAXY SHAPE is produced when four plasmoids are fired simultaneously through a magnetic field toward a common center. The field is perpendicular to the page.

head on break into fragments, but even these fragments seem to behave as entities. In other words, we appear to be dealing with bodies which have strong powers of self-organization and preservation. We find these powers still more strikingly demonstrated when we go on to further experiments.

Suppose we fire a plasmoid not into a vacuum but into a thin gas. We introduce into the chamber a little deuterium gas, amounting to a pressure of about one micron. Now when a plasmoid is fired into the chamber through a magnetic field, the gas, which becomes somewhat ionized by the firing, allows current to flow. The current slows the movement of the plasmoid and also twists its path and its shape. When we fire four (or eight) plasmoids at one another from different directions, upon meeting near the center they whirl and form a ring with spiral arms [*see photograph above*]. The formation looks strikingly like a photograph of a spiral galaxy. If we fire two plasmoids at each other head on, they form an S-shaped figure resembling a "barred" spiral galaxy [*see photograph below*].

Just how are these interesting shapes formed? We can explain them on the basis of complicated interactions between the plasmoids and the magnetic field, which are diagrammed here for readers versed in electricity and magnetism who may be interested in the

BARRED SPIRAL results when two plasmoids are fired at each other. The photograph at the top of the page is a time exposure; the one at bottom is a two-microsecond "snapshot."



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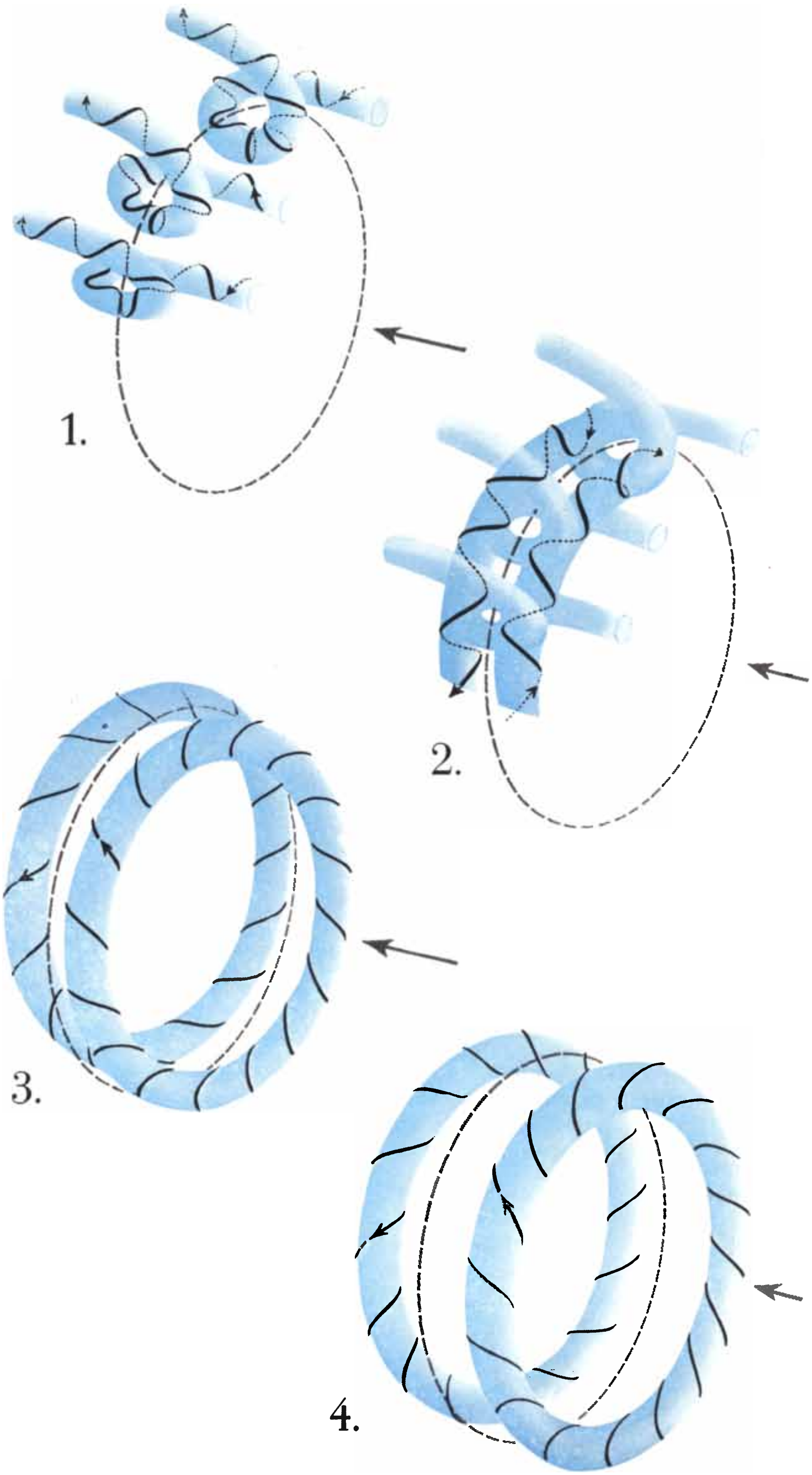


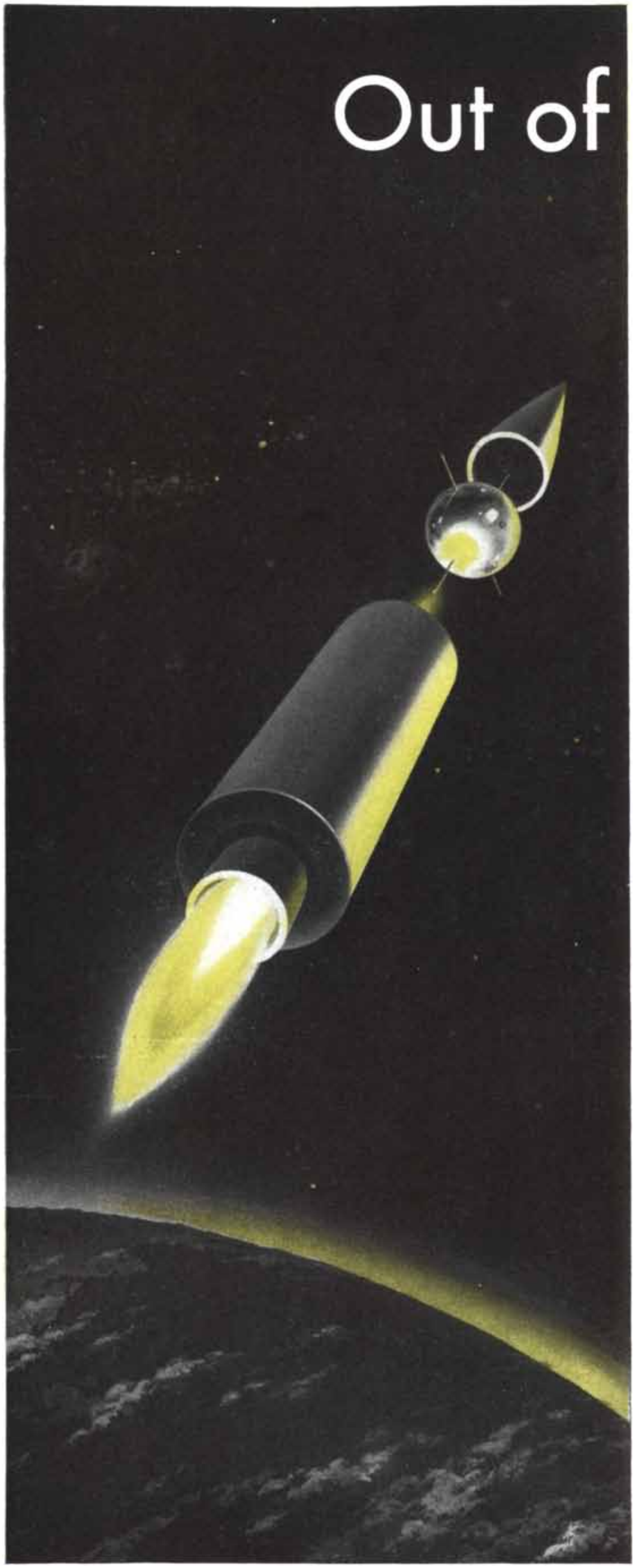
PAIRS OF RINGS, moving in opposite directions, may be formed by the merging of separate looped plasmoids as indicated in these drawings. Helical arrows show direction of the internal magnetic fields; the heavy gray arrows, the direction of the external field. Broken gray ellipse represents the center plane between the rings, from which each moves away.

mechanism [*see diagrams on page 91*]. A barred spiral, it appears, may be formed by plasmoids joining head to head; a ring spiral, by plasmoids joining head to tail. When the ring is oval-shaped, part of it flips over and forms a figure 8.

Photographs of plasmoids in three dimensions show that as a plasmoid moves across the magnetic field it is twisted into the shape of a left-handed screw [*see diagram at top of page 91*]. It is amusing to speculate on the possible relation of this fact to the recent breakdown of the parity principle, when it was found by particle experiments that the matter of our universe has a preferred left-handed spin [see "The Overthrow of Parity," by Philip Morrison; SCIENTIFIC AMERICAN, April]. If we reversed the poles of the magnetic field and the sign of the current in our plasma gun, our plasmoids would be right-handed instead of left-handed. The tempting speculation is that the matter of our galaxies may have been formed under the influence of vast galactic magnetic fields of one predominant orientation, which gave our matter a left-handed bias.

Under certain conditions our plasmoids form a pair of rings, which do not stay in the center of the chamber but move away from each other in opposite directions [*see diagrams at left*]. We believe that these rings are basically similar to magnetohydrodynamic whirls which, according to Alfvén, are apparently formed in pairs in the interior of the sun and may be responsible for sunspots. However, our plasma rings are not whirls in a fluid but are separate, independent "bodies." As such they represent a form of ordered organization by nature of which we have not been fully aware until now. Here is a case of electrons and ions collaborating with a magnetic field to form bodies which, though inanimate, assume orderly, characteristic shapes and possess a firm integrity.

We can look upon the combination of plasma and a magnetic field as a kind of self-shaping putty. Perhaps study of the forms assumed by this putty may help us to understand configurations such as the stars and galaxies. It may also throw light, at the other end of the scale, on the construction of fundamental particles such as the electron, the proton, mesons and neutrinos. They, too, may be made of a self-organizing putty: a putty composed of the electromagnetic field and its own gravitational forces, which, working together, create the bodies we know as particles.



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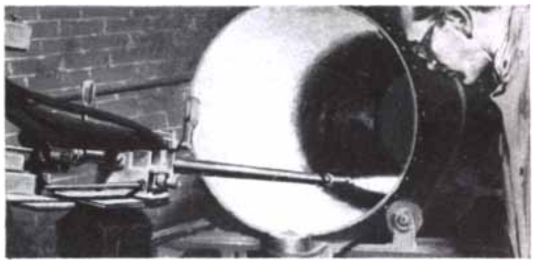

energy release required to reach this supersonic speed, the inside of its nozzle is protected with ROKIDE "A" aluminum oxide coating applied by the Metallizing Company of Los Angeles.

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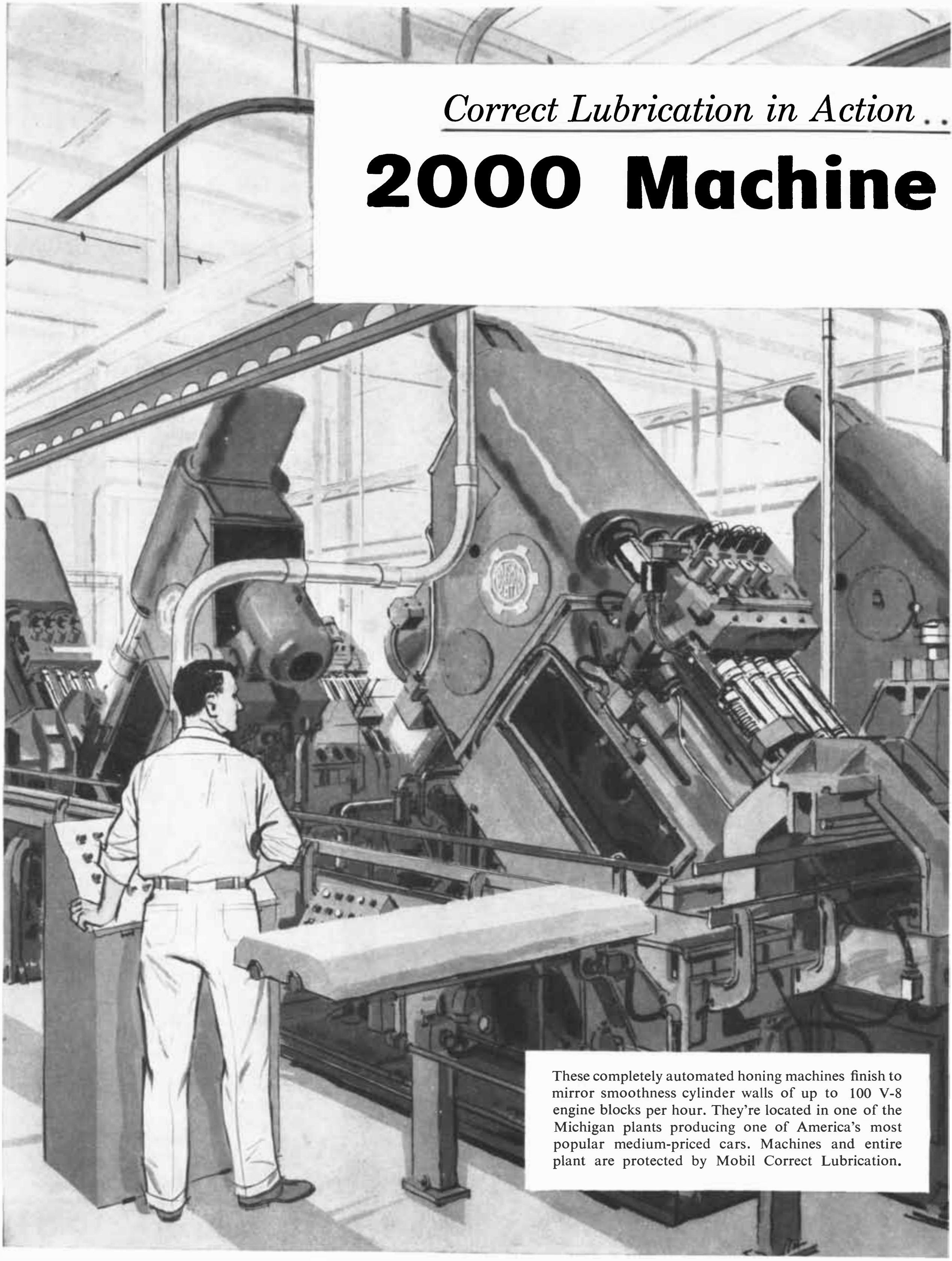

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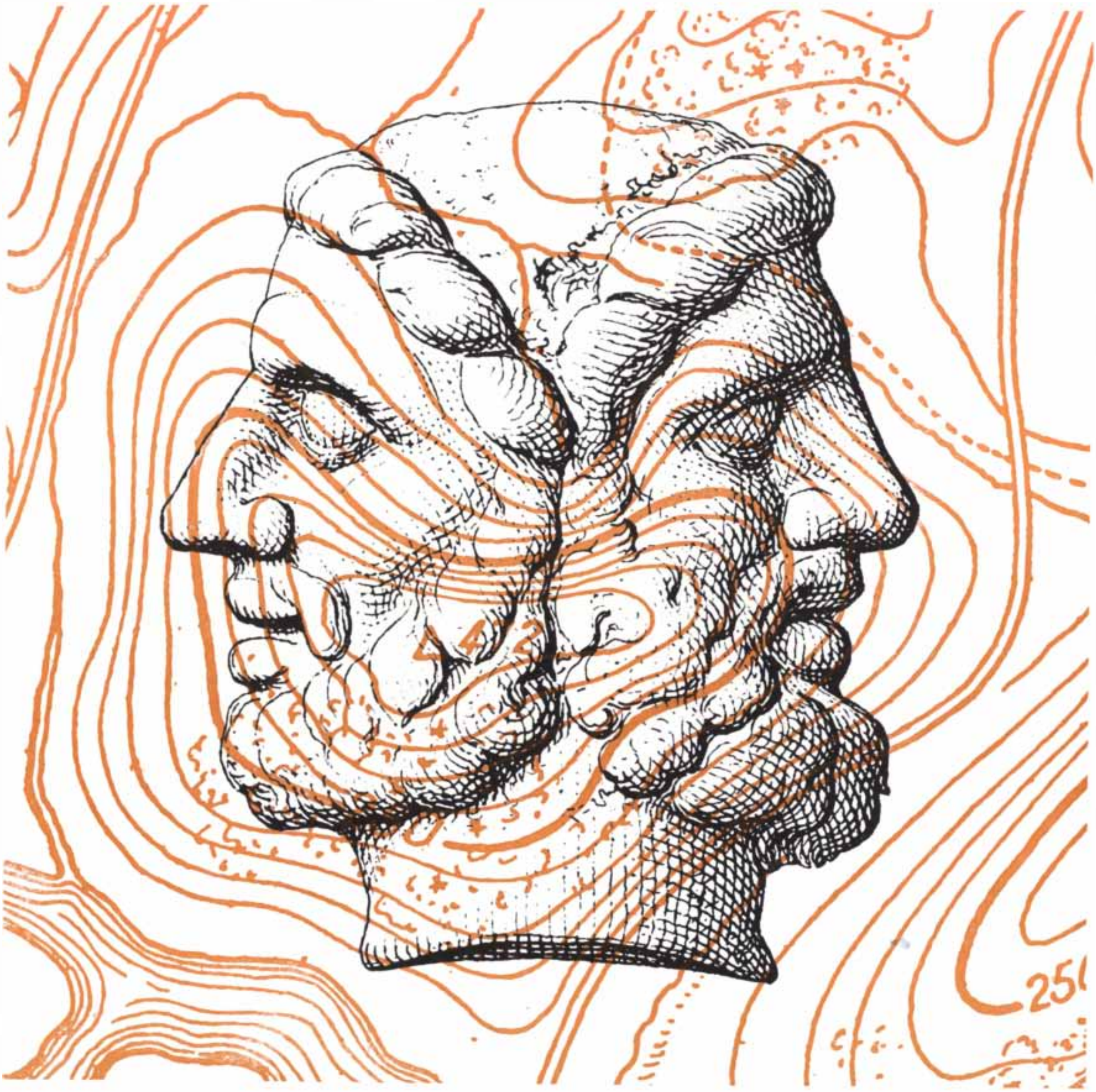

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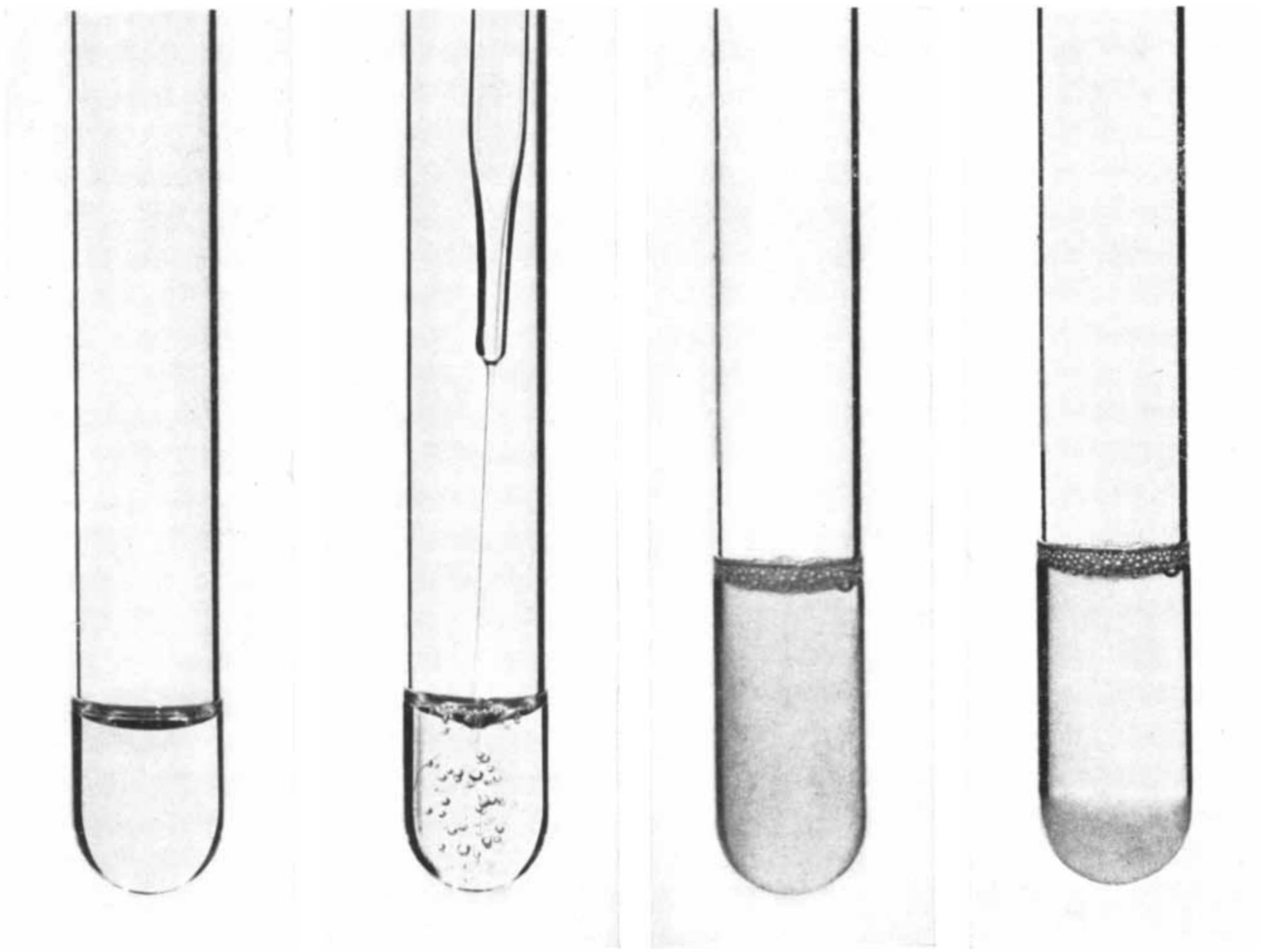
The Specificity of Antibodies

Research is beginning to show how these body proteins "recognize" and react with particular foreign molecules and not with others that have very nearly the same chemical structure and properties

by S. J. Singer

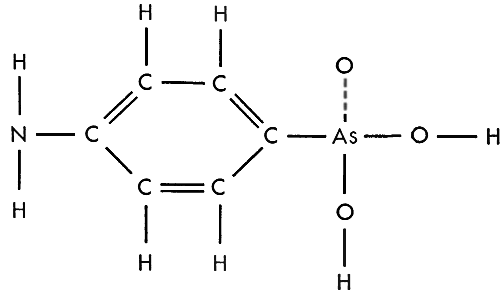
The chemistry of living matter involves many substances so specialized that each reacts with just one counterpart and no other substance. This specificity is vividly demonstrated by the antibodies that furnish resistance to infection. An antibody is generated in response to the presence in the bloodstream of a foreign substance called its antigen. The antibody combines with its antigen and brings about its removal from the blood. In a test tube the two substances often form a visible precipitate. Each antibody is tailor-made; it will react only with the antigen that evokes it or with a very similar substance.

Such specificity sets the molecules of biochemistry apart from those of ordinary chemistry. Inorganic chemicals react by classes. For example, any acid will react with any base, regardless of the details of composition and structure. A biological molecule, on the other hand, often has a built-in capacity to recognize



ANTIGEN-ANTIBODY REACTION is demonstrated. The tube at left contains rabbit antibody to bovine serum albumin (BSA). When BSA is added (*second from left*), a cloudy suspension is produced (*third from left*), which settles out in 10 minutes (*right*).

1.



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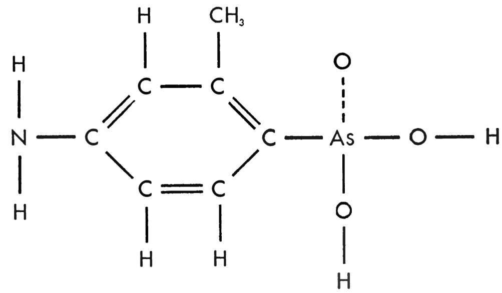

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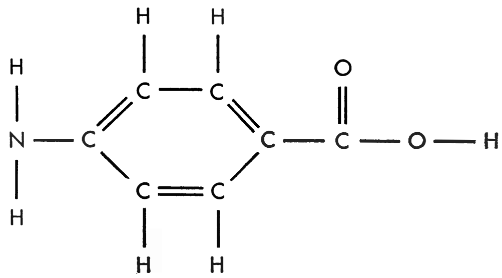
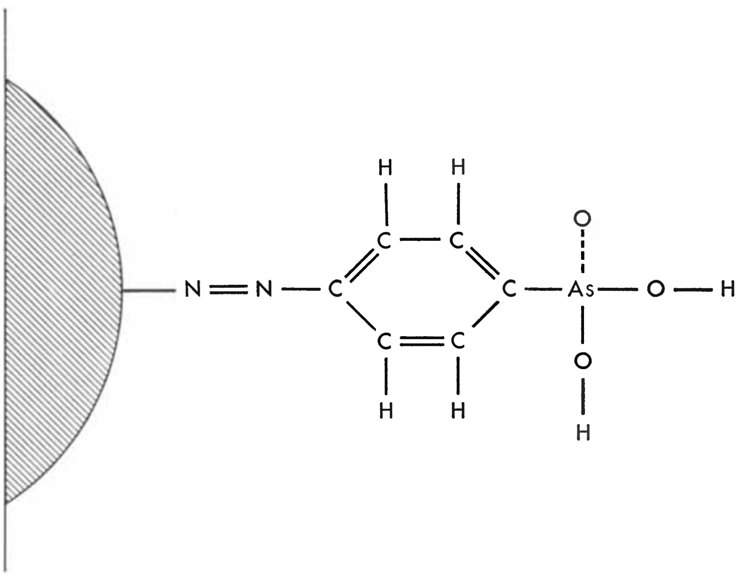




SMALL MOLECULES can be made to induce the formation of antibodies specific to themselves if they are attached to protein molecules. Formula 1 at top represents para-arsanilic acid. When it is attached to a protein such as egg albumin, indicated by the shaded region in the diagram at bottom, and injected into rabbits, the animals make antibody which reacts with this compound and also with para-arsanilic acid. Formulas 2 and 3 are compounds closely related to para-arsanilic acid. The antibody does not react with them.

and react with a particular molecular structure. This makes possible the rich variety of the chemical reactions that constitute the processes of life. Chemical specificity sometimes requires great complexity. For instance, to decompose urea, a molecule of eight atoms, nature has produced a giant molecule, the enzyme urease, which is made up of 80,000 atoms. Specificity is one of the most important studies in biology, for it holds the answers to such vital questions as why the poliomyelitis virus infects only the nerve tissues of animals, why sperm will fertilize only the eggs of its own species, why the body will accept grafts only of its own tissues.

How does a molecule "recognize" its particular chemical partner and why does it react with it alone? We are indebted to the study of antigens and antibodies for much of what we have learned about this matter in recent years. Antibodies are interesting subjects of experimental attack on the problems of specificity for a special and remarkable reason: the antibodies in an organism cannot be distinguished from one another except by their reaction with their antigens. They are all globular proteins and they are all found in the same fraction of the blood—gamma globulin. Efforts to show that difference in activity is associated with difference in the chemical composition of antibodies have so far proved fruitless. For example, the antibodies of a rabbit, which have been studied most thoroughly, all appear to be made up of the same amino acid units, usually about 1,500 in number, and in the same proportions. They cannot be distinguished from normal rabbit gamma globulins. The first five amino acids in the chain are arranged in identical sequence in both the antibodies and the "normal" gamma globulin. Since it is only their specificity to their respective antigens that distinguishes one antibody from another, we can hope that close study of the antibody-antigen reaction will tell us something about how this specificity is established.

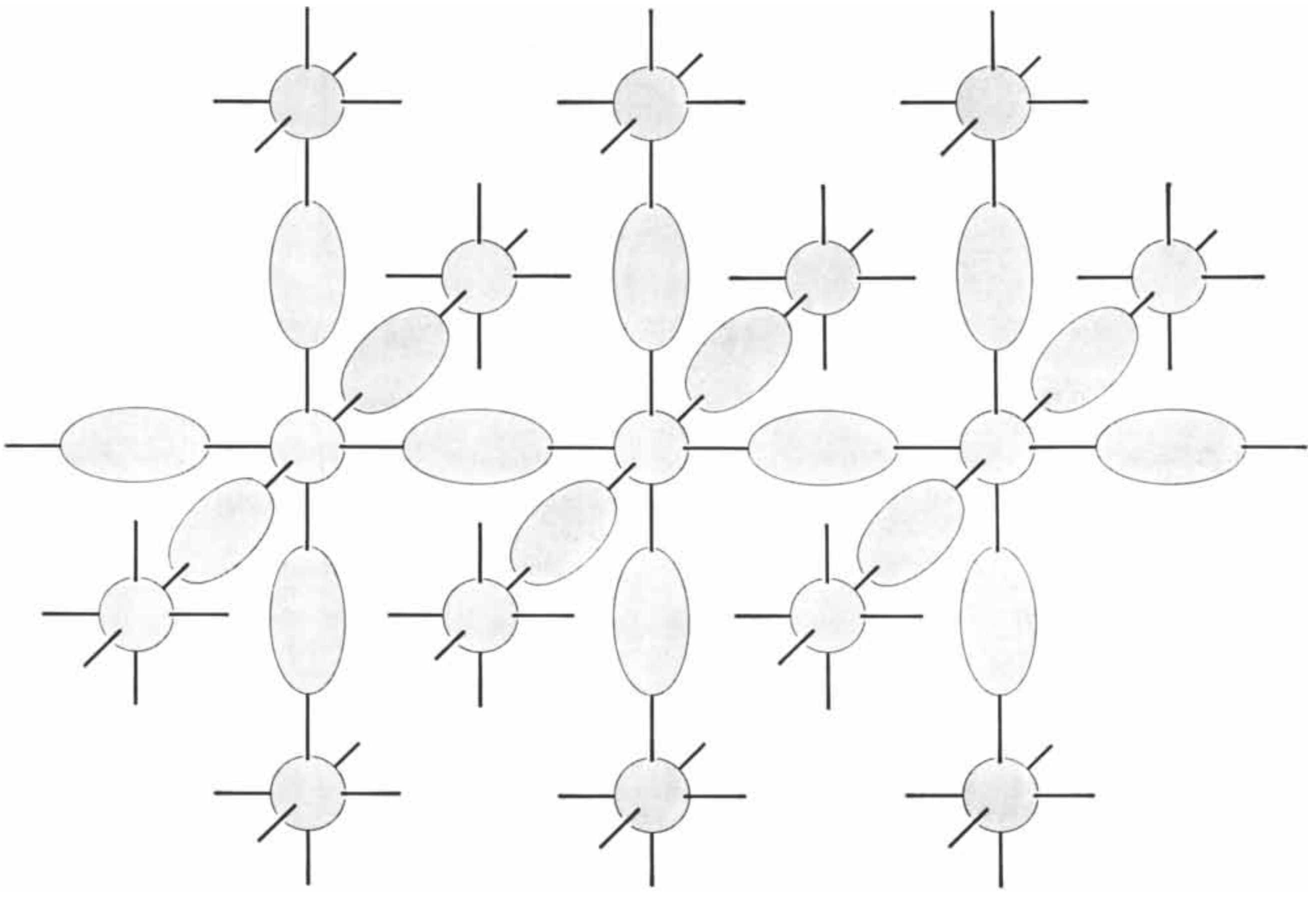
The modern study of the antibody-antigen reaction began about 40 years ago with the historic investigations of Karl Landsteiner. It had been established that antigens were large molecules, most often proteins. It was also known that not only toxic substances produced by infectious organisms but all proteins foreign to the organism acted as antigens. But because so little was known about the structure of these large molecules, the way to further under-

standing of the antigen-antibody reaction was blocked. Landsteiner opened the way by inducing animals to generate antibodies which were reactive to small molecules of known structure. The small molecules themselves were not antigenic, but Landsteiner made them so by coupling them to proteins. In one series of experiments he employed para-arsanilic acid [*see diagram 1 on page 100*] coupled to the protein egg albumin. This compound substance, when injected into a rabbit, induced antibodies which were proved to be capable of combining with para-arsanilic acid.

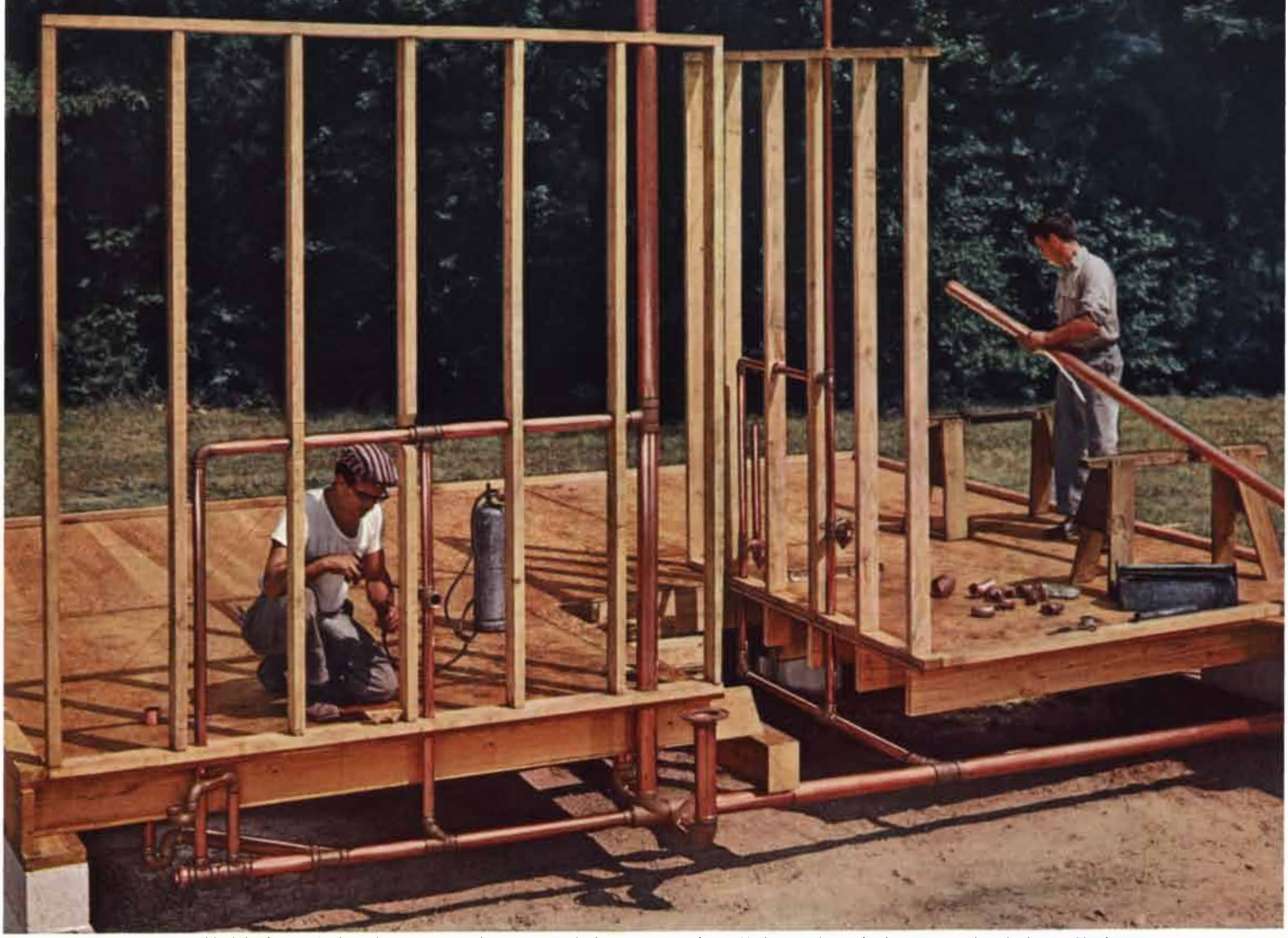
Landsteiner went on to test the effects of a whole series of variations in the structure of the small molecular appendage. These gave the first real measure of the exquisite specificity of the antigen-antibody reaction. For example, antibodies reactive to para-arsanilic acid reacted poorly with two very slightly different relatives of the substance [*see diagrams 2 and 3 on page 100*]. Landsteiner showed that antibodies could even distinguish between optical isomers—molecules which are identical in all respects except that one is the mirror image of the other. The precise recognition demonstrated in these and other experiments led to the conclusion that the antibody and antigen must make intimate atomic contact when they combine. The lock-and-key idea provides an excellent, if rough, analogy. Only contact between precisely complementary portions of the two molecules can explain the high specificity of the reaction. The presence of atomic "burrs"—an extra side group or a group of a different configuration—can prevent the antigen from fitting to an antibody made to the original structure. As for the optical isomer, it will fit the antibody no more easily than your left glove will fit your right hand.

How antibodies achieve such discrimination remains a baffling question. If they do not differ from one another in composition, then perhaps their amino acids are arranged in different sequences in their molecular chains. Or it may be that their molecular chains are folded differently, since variation in folding could arrange the chemically active groups of the antibody molecule in patterns to fit the complementary groups in the antigen. If we knew which of these alternatives is correct, we would have a real insight into how antibodies are made. It may be that the antigen or a portion of it acts as a template in the original synthesis of the antibody in the cells of the blood-forming tissues. On the other hand, the antigen may somehow act to modify the folding of the already synthesized chain.

We would like to know the answers to such questions because they have a bearing on the practical question of immunity. We remain immune to certain diseases long after infection or after the injection of a vaccine. Antibodies are found still circulating in the blood even though their antigens have apparently disappeared from the body. Since antigens are rapidly broken down by enzymes within the cells where antibody is made, it is difficult to see how antigen templates can survive long in the



ANTIBODY-ANTIGEN PRECIPITATE forms when antibody (*ellipsoids*) and antigen molecules (*spheres*) are mixed in the right proportion to produce a three-dimensional framework, a section of which is shown here in highly schematic form. Rods between the ellipsoids and spheres represent reactive sites; antibodies have two such sites, antigens six. A precipitate forms when they combine in a ratio of one antigen to three antibodies. In solutions which contain an excess of antigen, smaller, soluble aggregates form.



Model of a typical modern copper tube sanitary drainage system for a kitchen and two baths in a ranch-style home. Plumbing contractor (left) is shown making a solder connection, while his assistant (right) prepares to cut a 20-foot length of copper tube.

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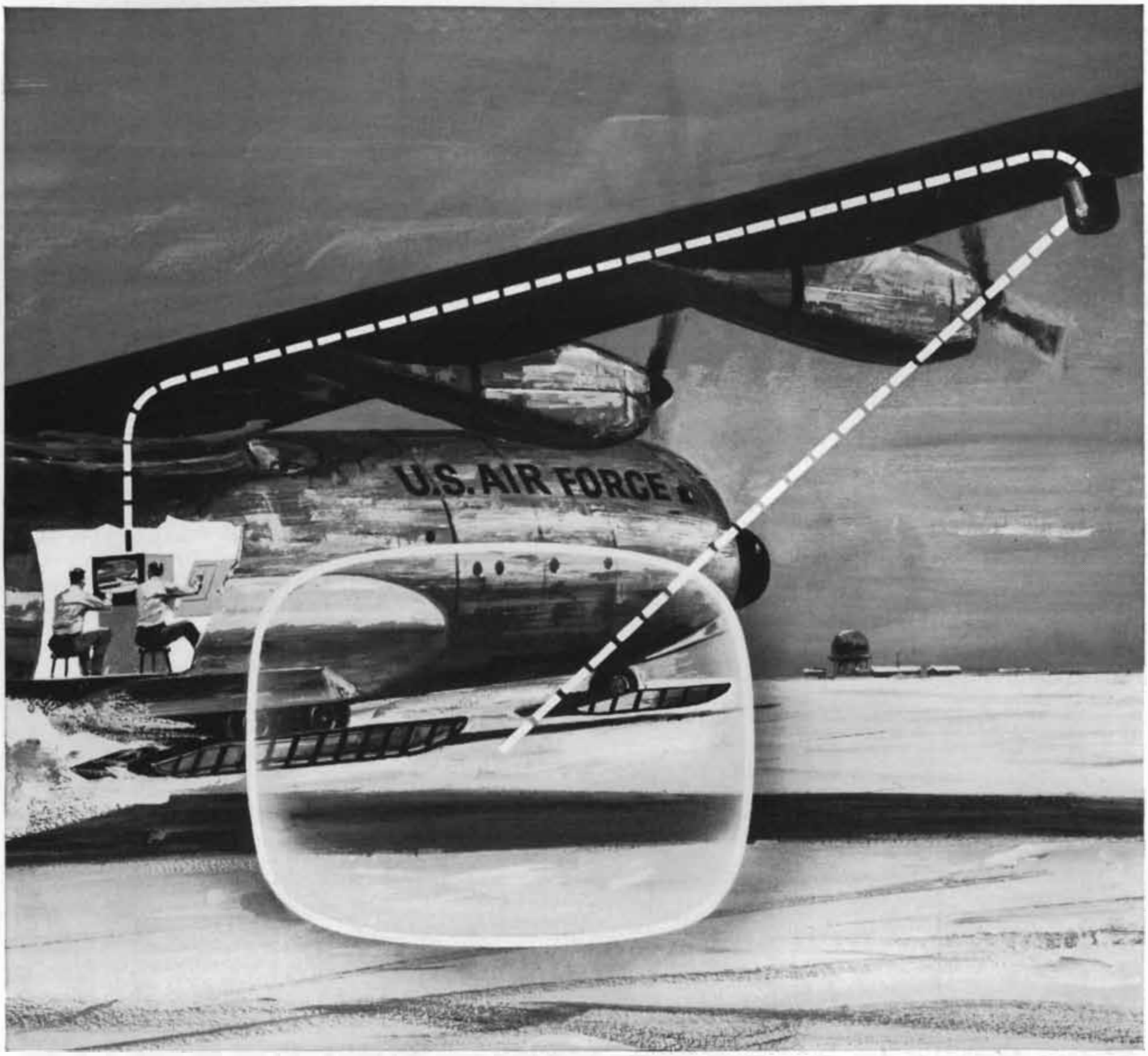

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cell. Just one template, however, may suffice to cause the production of millions of antibody molecules; it could easily persist in the cell beyond the reach of our power to detect it.

Despite our ignorance, we have learned enough to be able to practice artificial immunization with some success. The trick is to present the body with a template for the formation of the antibody and yet not infect it with the disease. Edward Jenner, the discoverer of vaccination, was able to do this some 150 years ago. The vaccinia virus apparently carries the atomic groups that make the template for the antibody to smallpox virus. More recently, by hit-and-miss methods, we have succeeded in altering viruses chemically to achieve the same purpose. This is how the Salk polio vaccine is made. Treatment of the virus molecule with formaldehyde apparently alters those amino acid groups in its structure that are involved in the process of infection. This "killing" process does not affect the part of the structure that acts as a template for the antibody.

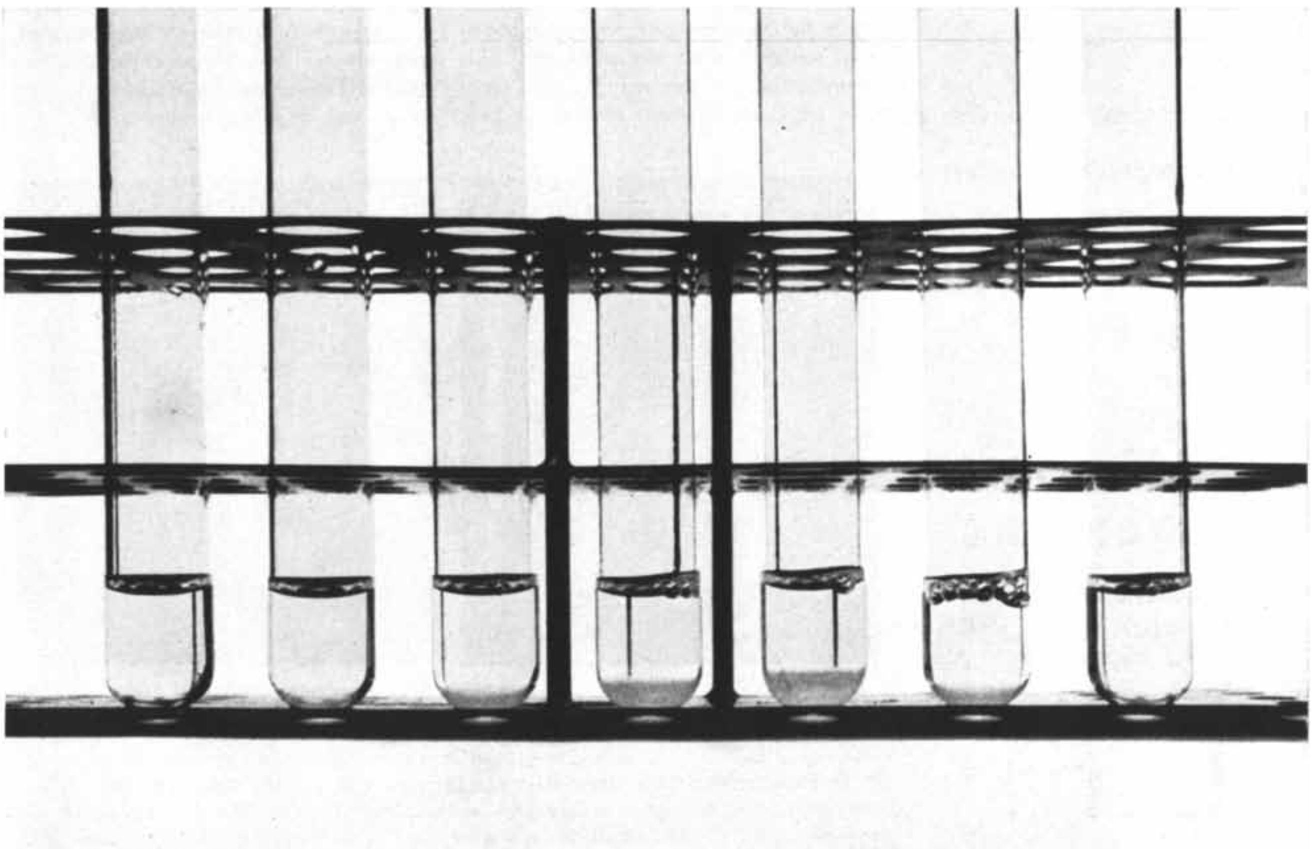
The foregoing of course applies only to active immunization, which produces prolonged resistance to infection. By borrowing gamma globulin (*i.e.*, antibodies) from an immune individual and injecting it into a susceptible one, we can confer passive immunization. But the antibodies disappear within weeks, and because the individual injected is no more able to produce antibodies than before, his immunity ends.

The mere combination of two molecules in a solution does not necessarily produce a precipitate. In fact, antibodies and antigens form an insoluble compound only when they are mixed in the right proportions.

A particularly useful antigen for experiments is bovine serum albumin (BSA). It can be prepared easily in high purity and is a very powerful antigen in rabbits: after repeated injections of BSA, as much as 30 per cent of a rabbit's gamma globulin may consist of antibody. Now if we react BSA with its rabbit antibody and increase the ratio of antigen to antibody in a series of test tubes, we get an increasing volume of precipitate. But this goes on only up to a certain maximum; in tubes containing still more antigen the amount of precipitate decreases. With sufficient antigen present, no precipitate comes down at all!

Determination of the antigen-to-antibody ratio that yields the maximum precipitate has taught us something important about how they react. As in ordinary chemistry, this ratio is related to the ratio of the valence numbers of the two molecules. When we analyze a precipitate of sodium phosphate, we find that the crystal is made up of sodium and phosphate ions in the ratio of 3 to 1: $Na_3\ (PO_4)_1$. The mixture of BSA and its rabbit antibody that yields their maximum precipitate corresponds to BSA_1 antibody 3. This establishes the ratio of the valences but not their actual number. BSA could have three active sites and the antibody only one, or BSA could have six and the antibody two.

Whether antibodies have only one reactive site or more than one used to be a subject of debate. The more-than-one hypothesis was advanced by the so-called framework theory of J. R. Marrack and Michael Heidelberger. Their theory gave a plausible explanation of the precipitation of antibody-antigen combinations. It holds that antibodies with more than one valence can hook on to more than one antigen at a time and thus build up large, three-dimensional "frameworks" which are too big to stay in solution. When there is an excess of antigen over antibody, the theory goes on to say, more small aggregates are



EFFECT OF VARYING PROPORTIONS of antigen and antibody is illustrated. All these test tubes contain the same amount of antibody to BSA. From left to right, however, the amount of BSA itself is increased. No precipitate forms when there is too much BSA.

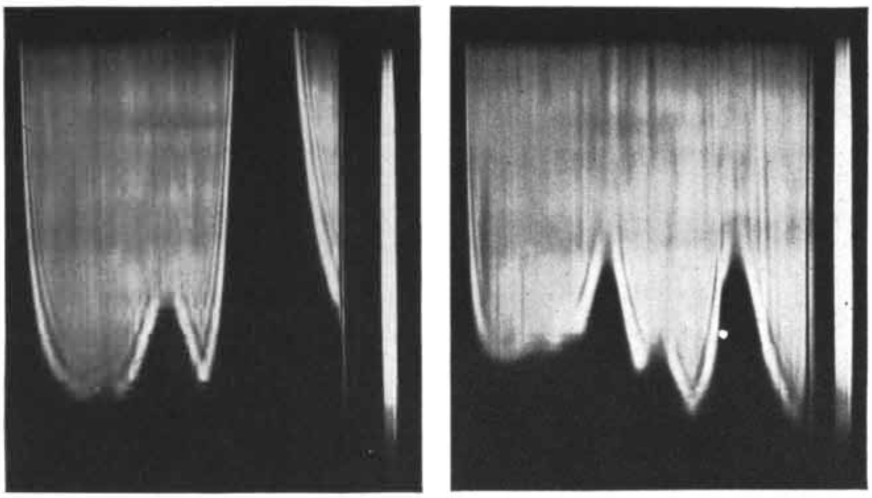
formed because the antibodies are used up in binding antigens rather than in accumulating on large frameworks. The reaction products therefore remain small enough to stay in solution.

Although the framework theory explained the experimental facts, the evidence was still inconclusive. Some scientists held to the hypothesis that the antibody has but one reactive site, on the principle that nature chooses the simplest way. They pointed to the fact that most giant molecules, notably the enzymes, appear to have only one reactive site, and they tried to explain the formation of precipitates in other ways.

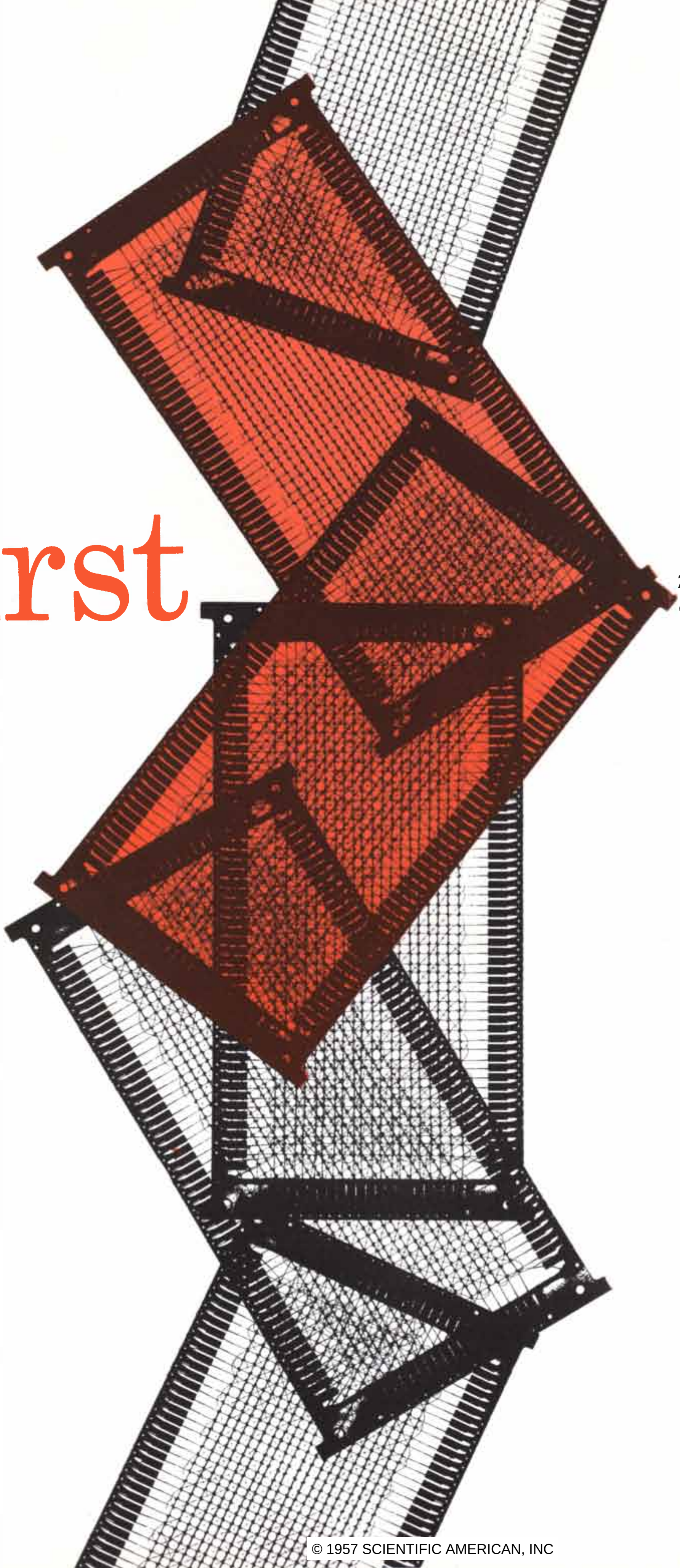
Within the past few years, however, our group at Yale University has developed some direct evidence in support of the framework theory and the multivalence of antibodies. In this work we have depended principally on the ultracentrifuge. By measuring the varying sedimentation rates of particles in solution, the instrument can detect and weigh the smaller antibody-antigen aggregates. They show up as distinct peaks in the ultracentrifuge pictures [*see below*]. In solutions containing a heavy excess of antigen, so that each antibody is bound to the maximum number of antigen molecules with which it can combine, the dominant peak in our pictures proved to be the one indicating an aggregate of two antigens with one antibody. This showed that the antibody has two reactive sites. In solutions containing progressively smaller excesses of antigen we have found larger and larger aggregates. We have thus been able to "see" the growth of antibody-antigen frameworks on the way to precipitation.

The same ultracentrifuge pictures help us to estimate the forces involved in the antibody-antigen reaction. The more aggregates are formed, the stronger the forces must be. Measured by the quantity of aggregates shown in our pictures, the forces turn out to be surprisingly weak. They are much weaker than those binding together the atoms of a molecule. This places a limit on the number and the kinds of groups (especially bearing electric charges) that can possibly be present in the complementary reactive regions of the two molecules.

The next big step in antibody research will be to learn in detail how the atoms are arranged in the reactive region of an antigen or antibody molecule. That step in turn will bring us into direct experimental contact with these further questions: How does the reactive site on an antibody attain a structure complementary to that of its antigen? Are the same two portions of the antibody molecule involved in antibodies reactive to different antigens? The answers, added to what we have already learned about the specificity of the antibody-antigen reaction, will help illuminate many other vital and more complicated molecular interactions in living matter.



ULTRACENTRIFUGE PICTURES display peaks corresponding to molecules of different weight, with the heavier molecules to the left and the area under each peak reflecting the quantity of molecules present. As the centrifuge spins, these peaks move to the left at different rates, because the sedimentation rate increases with weight. These two pictures show the peaks produced by two different antibody-antigen solutions. The peak to the right in both pictures is due to uncombined antigen molecules. In the picture at left the small peak corresponds to aggregates in which two antigens are bound to each antibody. A small peak corresponding to these aggregates can also be seen at center in the picture at right. To the left of this peak is a larger peak probably corresponding to an aggregate of three antibodies to each two antigens. Still heavier aggregates are indicated by shadows to the left of this peak.



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CONGENITAL DEFORMITIES

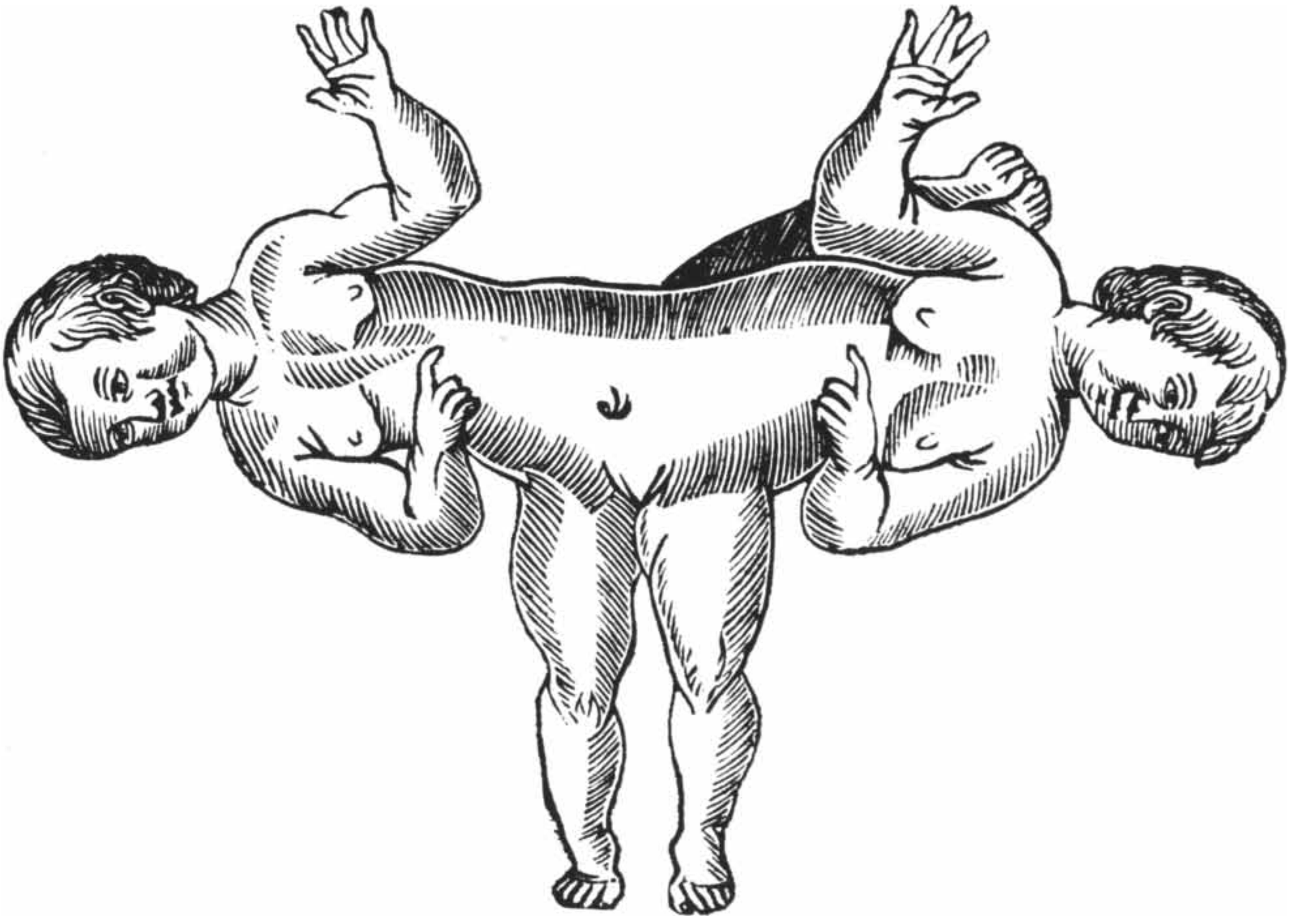
It is now known that many of them are caused, not by hereditary factors, but by injuries during gestation. The kind of deformity is related to the time of early life at which the injury occurs

by Theodore H. Ingalls

"And surely we are all out of computation of our age, and every man is some months elder than he bethinks him; for we live, move, have a being, and are subject to the action of the elements and the malice of diseases, in that other world, the truest microcosm, the womb of our mother."

It has taken medicine 300 years to appreciate the truth and importance of these words which Sir Thomas Browne wrote in 1642 (in *Religio Medici*). The life of an individual begins not on the day he is born but when he is conceived. And life's grisliest tragedies take place, as often as not, in the womb. The catastrophe goes unnoticed at the time: it may be signaled only by a rash or some other symptom of an infection of the mother. Far more often there is no sign of the tiny tragedy until the baby is born—with two heads, or a single eye, or a cleft palate, or a dwarfed body, or unseeing eyes, unhearing ears or a blighted mind.

The embryonic period of life has had only perfunctory attention from medi-



CONJOINED TWINS are depicted in *Monstrorum Historia* (*History of Monsters*), published in Bologna in 1642. This is a genuine deformity, often called Siamese twins. In ancient and medieval times such deformities provided the basis for fanciful monsters.

cine until recently. It was allowed to slip into a blind spot between genetics, obstetrics and pediatrics. Only within the last 15 years has the realization come that many—probably most—congenital deformities are not foreordained by heredity but are preventable incidents of development in the womb. Today investigation of the causes of these deformities is laying the basis for a new field of preventive medicine which we might call prenatal pediatrics or prenatal public health—concerned with that part of the population which is in its mother's womb. I believe that it will become possible to prevent many congenital deformities by improving the preparation for pregnancy and by careful attention to stresses and diseases during the pregnancy period.

The concern with congenital deformity has its roots in antiquity: in the legends of fauns with pointed ears, of sirens with fishlike tails, of Cyclops, the one-eyed giant, and of Janus, the two-headed god of the Romans, whose ability to look both forward into the future and backward into the past is commemorated in the name of the month of January and who was venerated with the respect naturally commanded by anyone gifted with two heads and extraordinary powers of perception. These fanciful creatures of course had a basis in fact. The birth of a deformed baby in ancient times evoked fear and awe. The event was a portent that needed to be interpreted (the word monster itself comes from the Latin *monstrare*, to show). In savage cultures such babies were often sacrificed to the gods or thrown into a river as possessed of evil spirits; even in less crude societies the mothers were sometimes brought to trial on metaphysical grounds and occasionally were burned at the stake.

In recent times the blame has been transferred mainly to the genes. The brilliant experiments of Gregor Mendel with peas seemed to provide a complete basis for explaining the birth of freaks in terms of genes and chromosomes. Family heredity and the accidents of mutation and natural selection supplied an altogether intelligible explanation.

Today we know better. Let no one suppose that what we have learned belittles the importance of heredity and the genes in forming individuals—freakish as well as normal. Inheritance *is* responsible for some deformities, and for susceptibilities that lead to imperfect development. It is also true that the genes determine whether an individual is destined to have a single head, two eyes and two legs. But months after conception it may develop that possession of normal features was settled only in theory, not in fact. An embryo that began its life with perfectly normal genes may, by the time it is born, have only one eye or two heads or three legs. And experiments on animals have demonstrated conclusively that crippling deformities arise from injuries to the embryo at certain stages of its development.

This thought was proposed more than a century ago by a French zoologist, Isidore Geoffroy Saint-Hilaire. It was presented in his three-volume study, published in 1832, called *The General and Particular History of Anomalies of Organization in Man and Animals.* Geoffroy Saint-Hilaire concluded that congenital deformities were "the effects of disturbances and adverse influences happening during the course of development" in the womb, and he urged that the causes of these accidents of pregnancy were a vital subject for further research—"a subject important, immense and capital."

Half a century later another Frenchman, Camille Dareste, took up such research, exploring the reasonable proposition that sickness should have profound effects upon the embryo, particularly in the early stages when the embryonic organs were in a "semifluid state." Dareste's experiments, carried out unsystematically and mainly with hen's eggs, were not convincing. It was not until half a century later that laboratory work on pregnant mammals and a freak epidemic in Australia proved that Geoffroy Saint-Hilaire and Dareste were right.

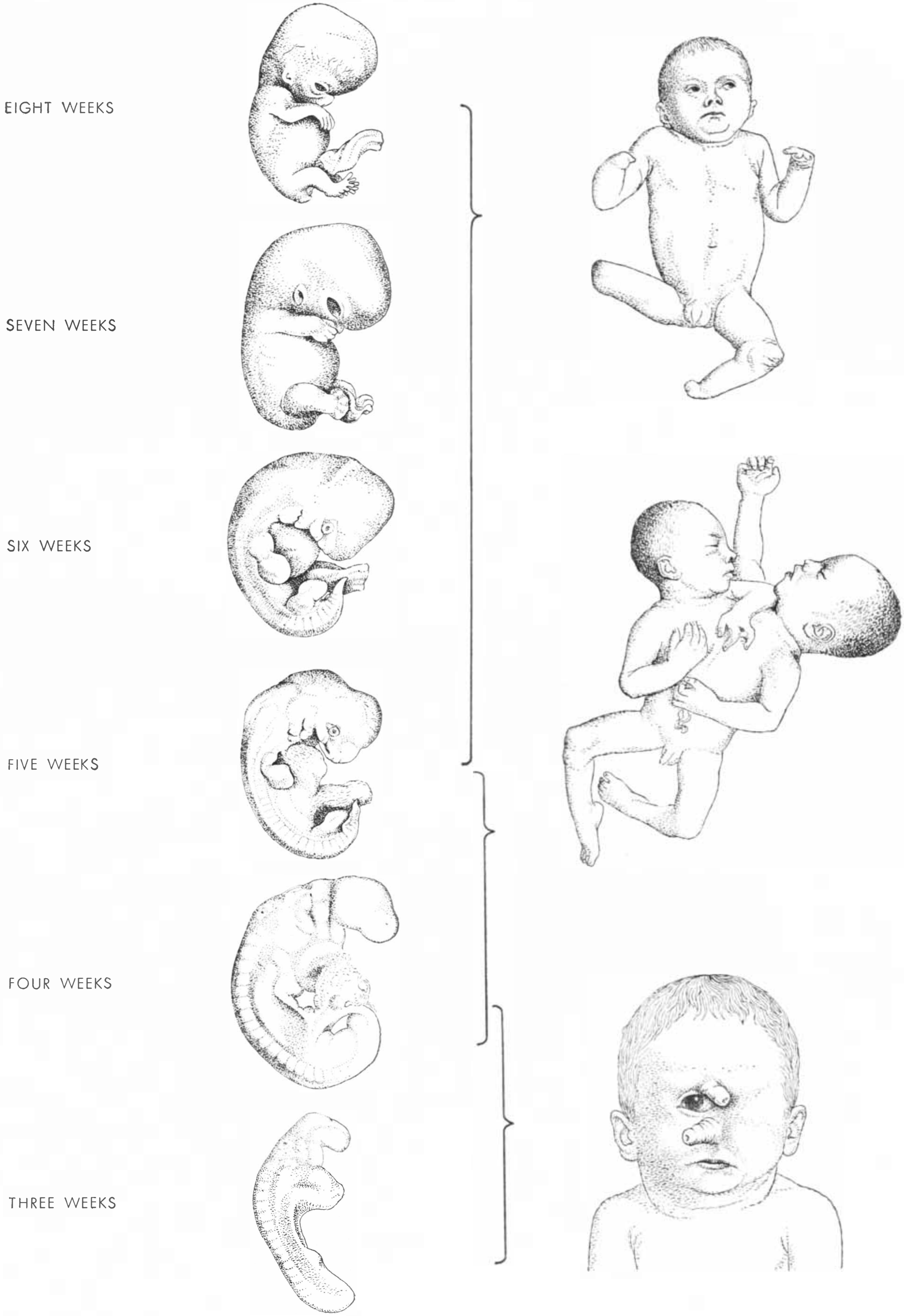
The epidemic was an outbreak of German measles in 1941. A year later medical researchers discovered with amazement almost amounting to incredulity that the mild disease had left a train of blind, deaf, heart-diseased and mentally retarded infants among the babies born to pregnant women who had had the infection. The discovery jolted physicians everywhere. It was a shocking thought that the birth of deformed babies could no longer be dismissed fatalistically (and complacently) as an act of God or a genetic accident.

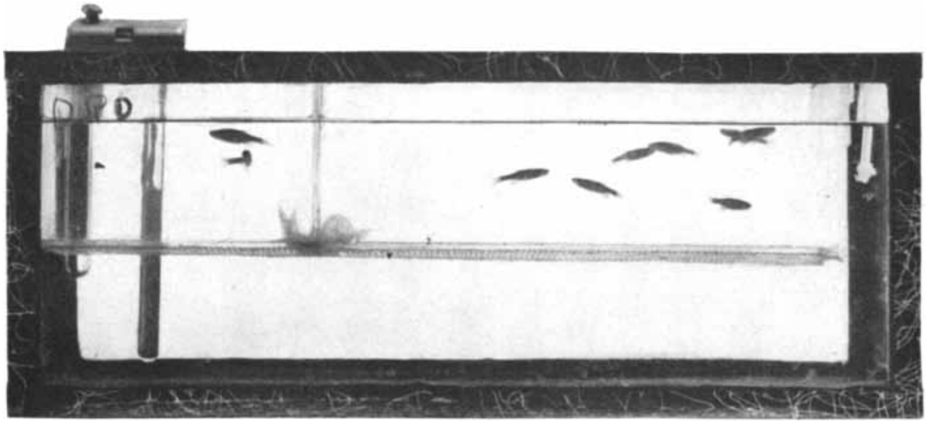
Medical research in the 1940s and early 1950s opened other new insights into the importance of the unborn baby's environment during its life in the womb. It was discovered that a mother's sensitivity to Rh-positive blood could produce in her baby the fatal blood disease called erythroblastosis. Exposure of premature babies to excessive oxygen pressure in incubators was found to cause blindness [see "The Strange Case of the Blind Babies," by Theodore H. Ingalls; Scientific American, December, 1955]. Physicians investigating the aftermath of Hiroshima observed that pregnant women who had been exposed to the atomic bomb gave birth to mongoloid babies. Swiftly the meaning of many disconnected researches and observations became clear. There was no longer room for doubt that congenital deformities could spring from mishaps to the mother of various kinds: German measles, serious blood disturbances, deep anesthesia and surgery, automobile accidents, heavy exposure to X-rays and so on.

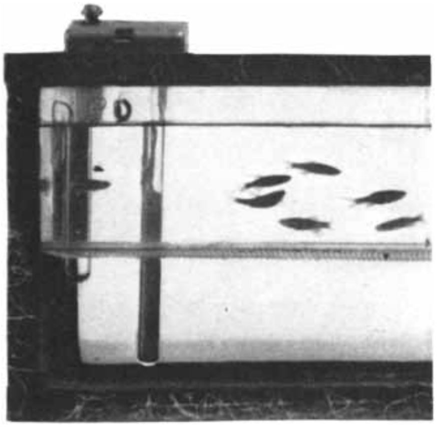
Just what consequences will ensue from these insults to the unborn baby depends upon the time they occur. We can draft a timetable or calendar which relates deformities to the age of the embryo at the time of injury.

The stresses that produce a one-eyed baby must come at the very beginning of the embryo's life, during the first week or two after fertilization of the egg, for at this time the primordia from which the two eyes will develop are so close together as to be virtually single. Next in order comes the stage at which conjoined (so-called Siamese) twins may originate, from an injury which prevents separation of the two individuals. In about the third week of development a critical injury may result in the heart or viscera being left outside the chest cavity, or in failure of one or both legs or arms to develop, because this is the time when the heart and viscera are still outside the body cavity and the limb buds are starting to grow. An injury in the fourth week, when the windpipe is budding off from the gullet, may produce the

THREE DEFORMITIES are related to the period of embryonic development at which the injuries that cause them may occur. The drawings on the left side of the illustration on the opposite page show the normal development of the human embryo from three to eight weeks. The deformity at bottom is cyclopia, the main feature of which is a single eye; this deformity is probably caused by an injury about the third week of gestation. The deformity in the middle is conjoined twins, which may result from injury to the cephalic (head) region of the embryo at about the same time, but probably after the eyes are paired. The deformity at top, characterized by incomplete limbs, is probably caused by injury between five and eight weeks, when the limbs are forming.


EIGHT WEEKS
SEVEN WEEKS
SIX WEEKS
FIVE WEEKS
FOUR WEEKS
THREE WEEKS



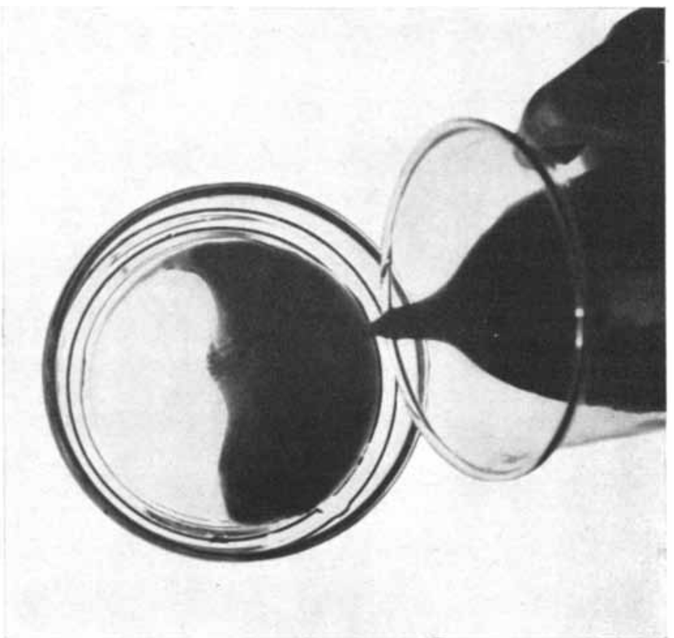


EXPERIMENTS WITH FISH were performed at the Harvard School of Public Health to determine the effects of lack of oxygen on the development of vertebrate embryos. In the photograph at left is a tank of zebra fish, a tropical species. The male fish (*left*)

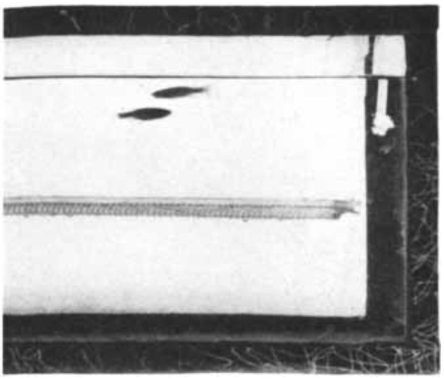
well-known defect which leaves an opening between the windpipe and gullet—so-called tracheo-esophageal fistula. In the fifth week, when the lenses of the eyes are forming, the embryo is vulnerable to congenital cataract. In the seventh week it may be doomed to a cleft palate, for the two halves of the palate normally start to close at that time. In the eighth week an injury may produce mongolism; it is then that the embryo begins to develop the base of the brain and skull, the wall of the heart, the nasal bones and the fingers—all structures that are blighted in mongolism. In the ninth week, when the inner ear is undergoing rapid differentiation, a mishap to the mother may result in a deaf baby.

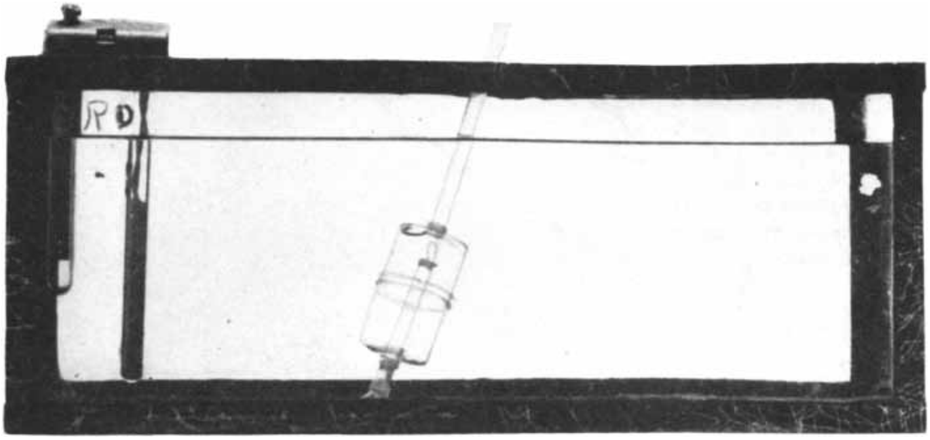
This is only part of the list of defects that can be created at the respective ages of the embryo. Part of the picture has been verified by the histories of mothers stricken with German measles and other mishaps. One mother gave birth to a mongoloid baby after almost suffocating from carbon monoxide poisoning in the second month of pregnancy. Another, who bore mongoloid twins, had been in a head-on automobile collision on the 59th day of pregnancy. A third had had a tooth pulled under gas and oxygen anesthesia late in the second month of pregnancy. Two Hiroshima women in about the third month of pregnancy, caught less than a mile away from the atomic bomb explosion center, had mongoloid babies.

Plainly the whole matter calls for orderly scientific studies. In the department of epidemiology at the Harvard School of Public Health we have been carrying out systematic experiments on colonies of fish and of mice. The fertilized eggs of fish are especially suitable for studying effects of damage to the embryo in its earliest stages, and pregnant mice have been used to study ab-



FERTILIZED FISH EGGS are placed in a glass dish in the photograph at left. In the second photograph from left, after the fertilized egg has divided one or more times, the dye trypan blue is added to the dish; this dye interferes with respiration of the



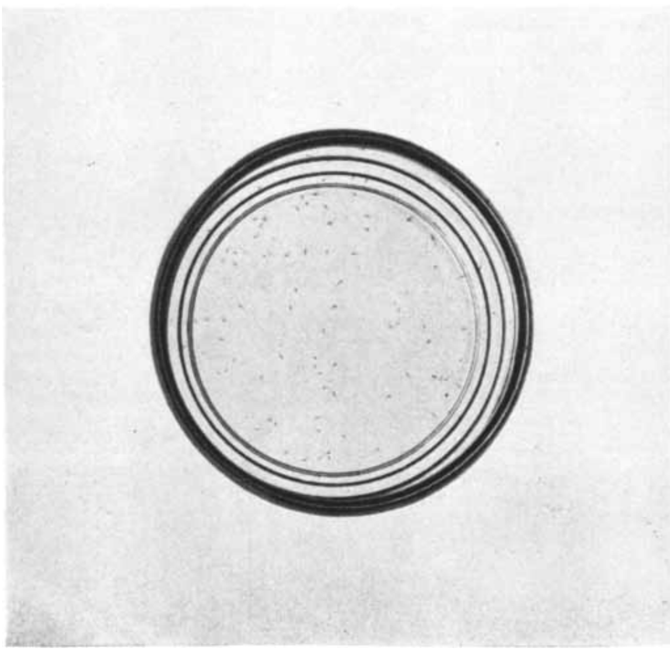


are separated from the female (*right*) by a vertical translucent screen. In the photograph in center the screen has been removed; the females lay their eggs and the males fertilize them. In the photograph at right the fertilized eggs are collected from tank.

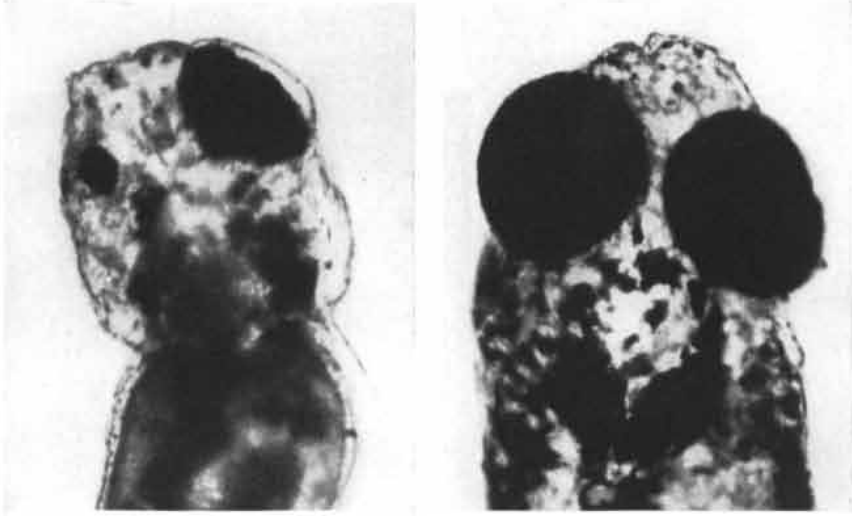
normalities produced in the last two thirds of pregnancy. The standard stress we have applied on these animals is lack of oxygen, known to be a cause of congenital deformity. For the fish, we create a deficiency by scrubbing oxygen out of the aquarium water with nitrogen. The mice we put in a low-pressure chamber simulating altitudes of 25,000 to 30,000 feet—equivalent to taking the animals to the top of Mount Everest. Our procedure is to subject the experimental organisms—fish eggs or pregnant mice—to lack of oxygen for three to five hours at a given stage of development and later study the effects on the offspring.

The earliest stage at which my co-workers and I have been able to induce a deformity in the fish is during the first division of the fertilized egg. Deprivation of oxygen at this time may cause fish to be born without eyes. The same treatment of eggs when they have reached the stage of division into 16 cells results in the development of fish with very small eyes or only a single eye and without rumps. At mid-gastrulation (when the single-chambered blastula develops into the two-chambered gastrula) the injury may result in the formation of "Siamese" twins. (Twinning, it should be borne in mind, may affect only a part of an animal's body, producing an extra finger, hand, foot or other organ.)

We have not yet been able to induce such severe deformities in mice, presumably in part because few of the embryos survive exposure to a drastic stress in the earliest stages. But stresses imposed on pregnant mice on and after the ninth day have produced a regular pattern of congenital defects in their offspring. These include a cleft palate, lack of eyelids and defects of the skull, brain, skeleton and spine. The critically vulnerable time for the embryonic mouse's central nervous system and skeleton is the 9th and 10th days. A cleft palate is



dividing cells. In the third photograph the dividing cells have been placed in another dish, but remain stained by the dye. In the fourth photograph the dish contains fish about three days old. These are now examined under the microscope for congenital deformities.

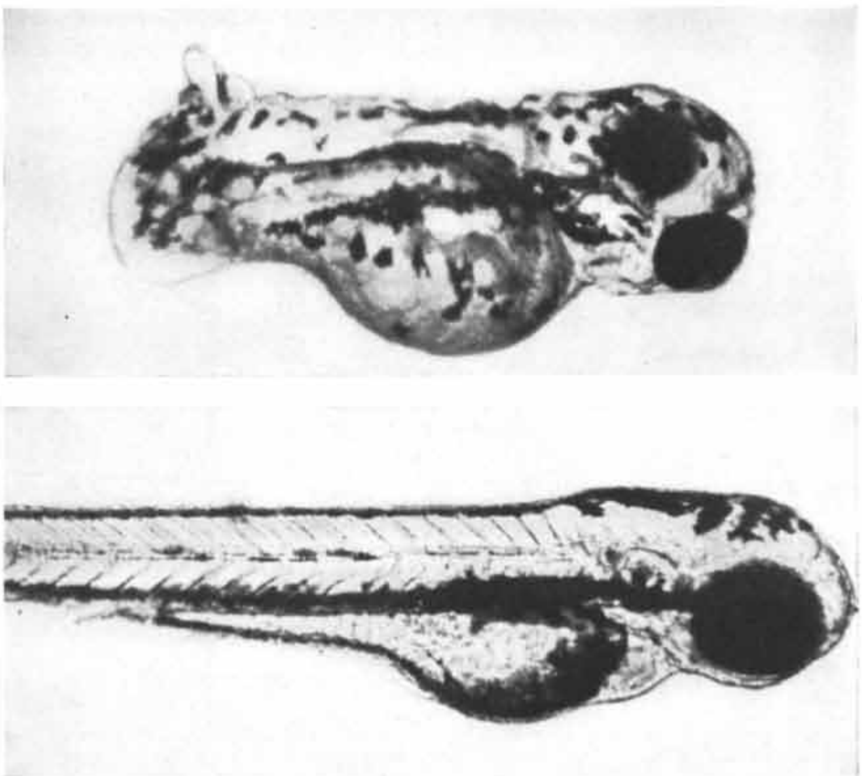


SMALL LEFT EYE of the zebra fish in the photograph at left was caused by lack of oxygen when the fish consisted of from two to eight cells. At right is a photograph of a normal fish.

induced on the 14th and 15th days; the lack or incomplete development of eyelids, about the 17th and 18th days.

Other workers have tested a number of stresses on the mice besides deprivation of oxygen—for example, X-ray injury, vitamin deficiencies, cortisone intoxication. Each of these agents can produce a cleft palate, provided that the stress takes effect on or before the 14th or 15th day of pregnancy.

I would sum up all the observations and experiments in a clear-cut theory: Cyclopia (one eye), Siamese twins, mongolism, congenital heart disease, deafness and cataract—these and many lesser anomalies are members of a series of defects produced by severe stress at



LACK OF RUMP in the zebra fish in the photograph at top was caused by lack of oxygen when the fish consisted of about 64 cells. In the photograph at the bottom is a normal fish.

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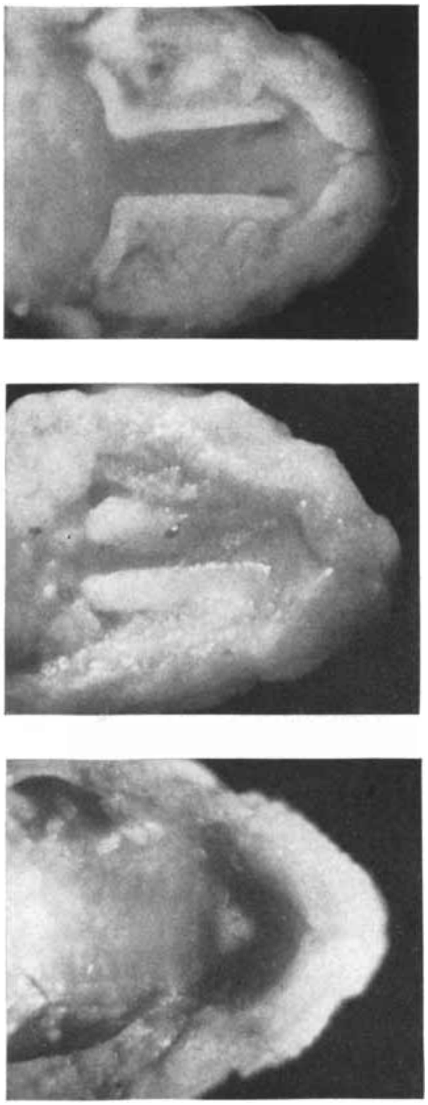
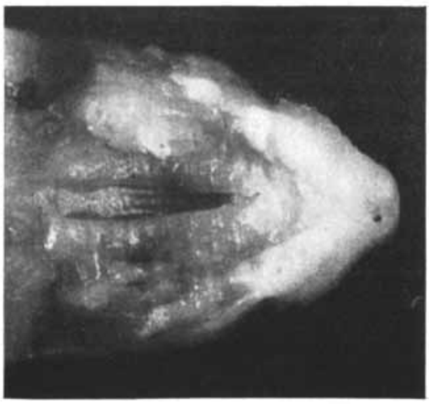


PALATE of normal mouse embryo is photographed at $14\frac{1}{2}$ days (*top*), $15\frac{1}{2}$ days (*middle*) and $16\frac{1}{2}$ days (*bottom*) after conception. At top and middle the palate is cleft; at bottom the halves of the palate are joined.



CLEFT PALATE occurred in a mouse embryo which had been deprived of oxygen $14\frac{1}{2}$ days after conception. Age of embryo from which palate was removed was $18\frac{1}{2}$ days.

various critical stages of the development of the embryo. They are the scars of injury to the unborn child in the womb. Each deformity is like a "still" picture taken from a moving picture strip, representing abnormal development of the particular affected organs.

This is not to deprecate the enormous contribution of genetic factors to the defects we observe in living organisms. But whereas the genetic dangers have been well recognized, the hazards of the embryo have not. There have been great fears, for example, as to the consequences of the bombing of Hiroshima for future descendants of the survivors. So far, however, no evidence of mutations among children of the survivors has emerged, while on the other hand we have direct and tragic evidence that the embryos then being carried by pregnant women did suffer. Fifteen babies born to mothers who were standing within a mile and a half of the explosion center were born with shortened skulls and defective brains.

The hopeful moral is that many congenital deformities can be prevented. The monstrosities that have appalled and frightened mankind since antiquity should become avoidable as we learn more about the mishaps of pregnancy that may give rise to them. When we have brought German measles under control, we shall undoubtedly reduce significantly the number of children born with congenital cataract and even more serious defects. By seeing to it that pregnant women avoid deep anesthesia or severe hemorrhage we may be able to prevent much blindness, mental retardation and cerebral palsy. We can make inroads into the number of cases of mongolism by paying more attention to the pregnancies of older women. We can further reduce the hazards of the population in the womb by close and careful attention to the health of prospective mothers; severe diseases of the blood and circulatory system, infections and diabetes seem to be dangerous. Pregnant women should, if possible, avoid X-ray treatments, operations, major dental work and long airplane flights. A single stress may not be decisive, but a combination of them must be cause for concern.

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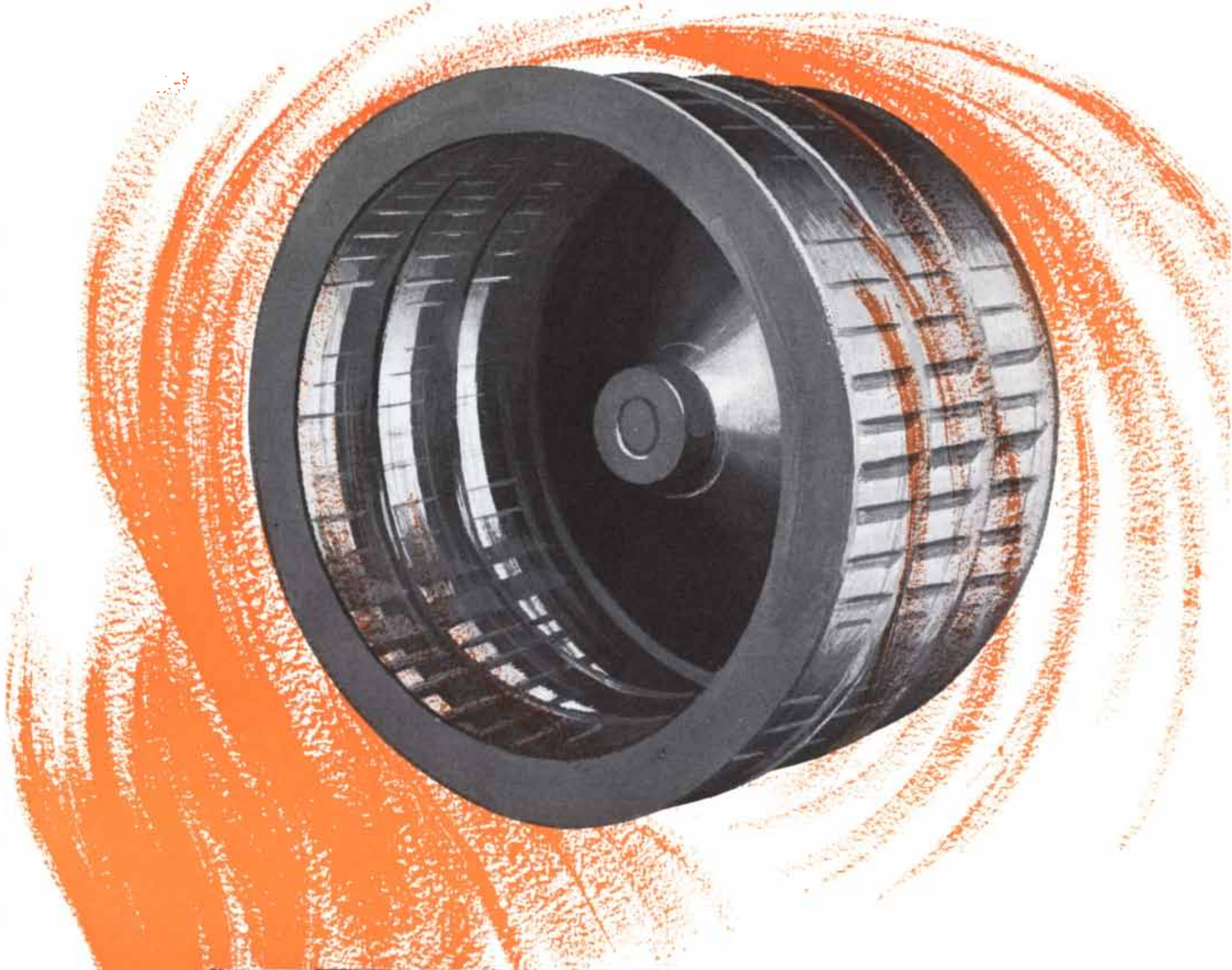

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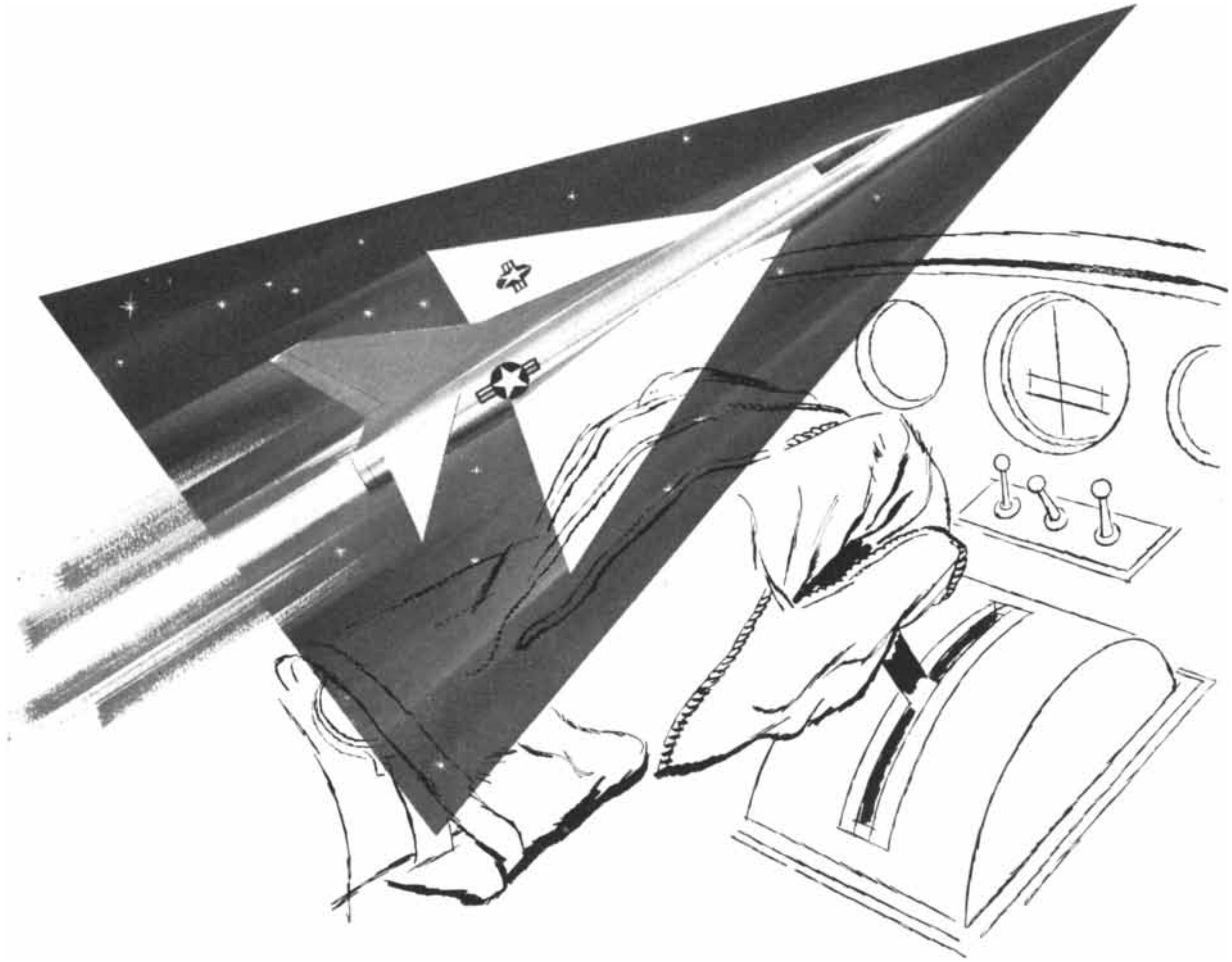

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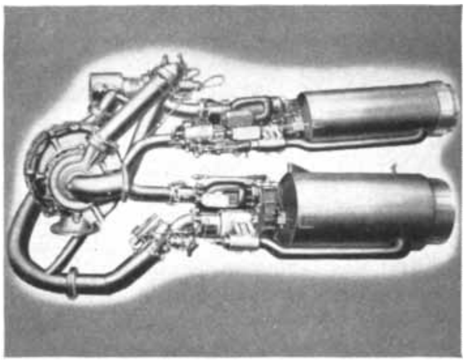

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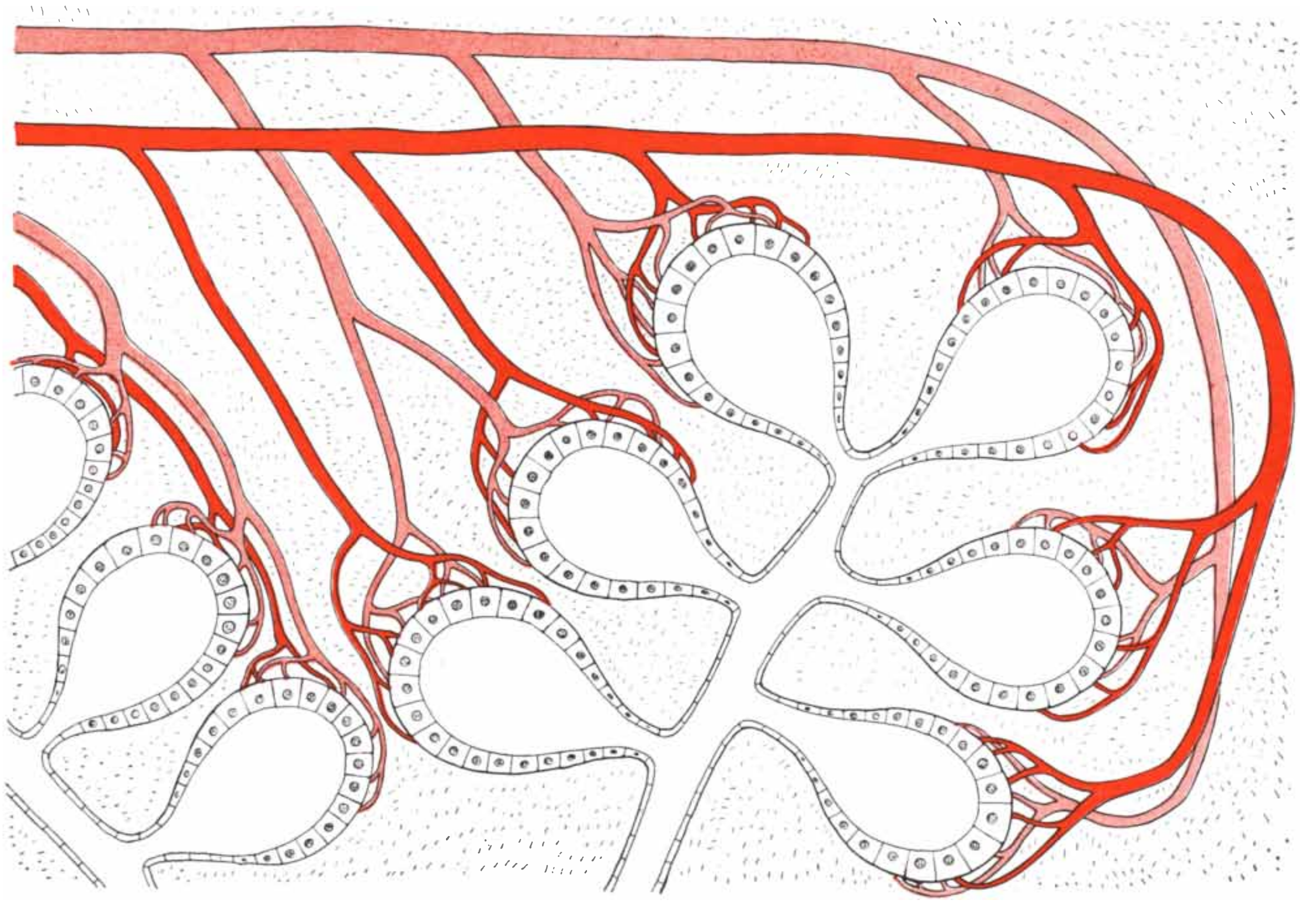
The Synthesis of Milk

How does a mammal make milk out of blood? The answer is sought by new experiments in which substances in the blood are labeled with either radioactive or nonradioactive isotopes

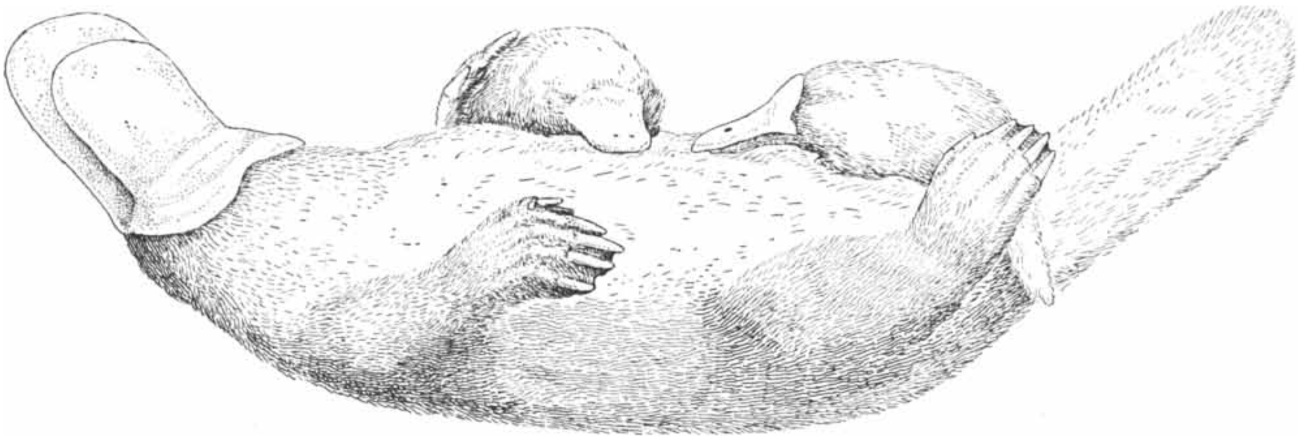
by J. M. Barry

Probably not many parents have been spared the embarrassing conundrum: "What makes a red cow give white milk when it eats only green grass?" Those who do not like to admit ignorance may be comforted to know that biologists do not have a complete answer to the question either; in fact, until very recently they were pretty much in the dark about how milk is made. Thanks to investigations with isotopic tracers, some definite information on the subject is now forthcoming.

The principal scene of this fascinating story is, of course, the mammary gland, or udder. It manufactures milk from foods or raw materials brought to it by the blood; as is well known, the production and secretion of milk is controlled by hormones. The milk is synthesized in cells; these are organized



MILK-SECRETING CELLS surround little sacs or alveoli. This semi-schematic cross section shows a few of the alveoli and the ducts which drain the milk secreted into them. The arterial capillaries are shown in dark red; the venous capillaries, in light red.



DUCK-BILLED PLATYPUS, the primitive Australian mammal, has an extremely simple mammary gland (*see drawing at bottom of this page*). In this drawing a female platypus feeds young by lying on her back and allowing them to lick milk from her abdomen.

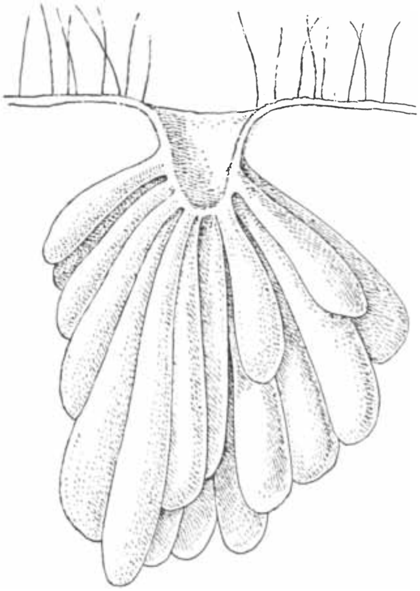
into different structures in various species of mammals. The duck-billed platypus, lowest mammal on the evolutionary scale, has extremely simple mammary glands: its milk oozes through small pores of the belly onto the fur, where it is sucked up by the young. In the higher mammals, such as a cow or a human female, there is a complex structure for collecting and discharging the milk. The milk-forming cells line tiny spheres called alveoli [*see diagram on preceding page*]. The cells secrete the milk into the center of each alveolus, and it passes out through a small duct; the ducts of all the alveoli join like tributaries of a river and eventually drain into a storage cistern from which the milk can be drawn off through a teat. The general form of the mammary gland has been compared to that of a bunch of grapes, with the grapes representing the alveoli and the stalks representing the ducts—but there is a vastly larger number of alveoli than there are grapes in a bunch.

Our question is: How do the mammary cells produce milk from the substances furnished by the blood? Milk is a unique substance, differing in composition from any other body fluid. It has the same vitamins and minerals as other tissues, but its three main components have a special chemical character. They are fats (the cream), lactose (a sugar) and proteins. The principal proteins of milk are found nowhere else in the body—casein and beta-lactoglobulin. Lactose, the sugar, also exists only in milk, though it is composed of two common sugars—glucose and galactose. The fats in milk fall into two categories; one group is the same as the fats in blood and other body tissues, the other is unique to milk. The common fats are compounds made up of glycerol and long-chain fatty acids—that is, chains of 16 or 18 carbon atoms. Milk contains these fats. But it also contains special fats with short-chain fatty acids—chains of 2, 4, 6, 8, 10, 12 and 14 carbon atoms.

The milk of various animals differs widely in the percentage of fat, lactose and protein. Cow's milk averages about 4 per cent fat, 5 per cent lactose and 3 per cent protein (most of the rest, of course, is water). Human milk has about the same proportion of fat, a little more lactose and a little less protein. Mare's milk is very similar to human milk. The milk of porpoises is an anomaly: it is about 50 per cent fat and 11 per cent protein. Presumably its comparatively small water content is attributable to the fact that the porpoise has to obtain its body fluids by desalting sea water, which takes energy.

How does the blood fluid of mammals compare in composition with their milk? That is to say, what supply of nutrients does the milk-making machinery have to draw upon? The main organic components of the blood plasma are fats, proteins, amino acids, glucose and lactic acid, plus acetic and propionic acids in the cow and goat. To find out which of these substances are taken up by the mammary gland to make milk, two methods are available. We can analyze the blood before and after it has passed through the gland, or we can use isotopic tracers. I shall discuss first the blood-measurement method, which has been used for some 50 years.

Let us say we wish to determine how much glucose the gland takes from the blood streaming through it. We measure the weight of glucose per liter of blood in a sample of the arterial blood, and we make the same measurement on a sample of the venous blood coming from the mammary gland [*see diagram on page 124*]. If the venous blood has less glucose than the arterial, we know that the gland has taken glucose from the blood. But in order to learn how much glucose the gland absorbs from the bloodstream for the manufacture of a liter of milk, we



THE MAMMARY GLANDS of the platypus consist of sacs which empty into a porelike depression. The glands have no nipples.

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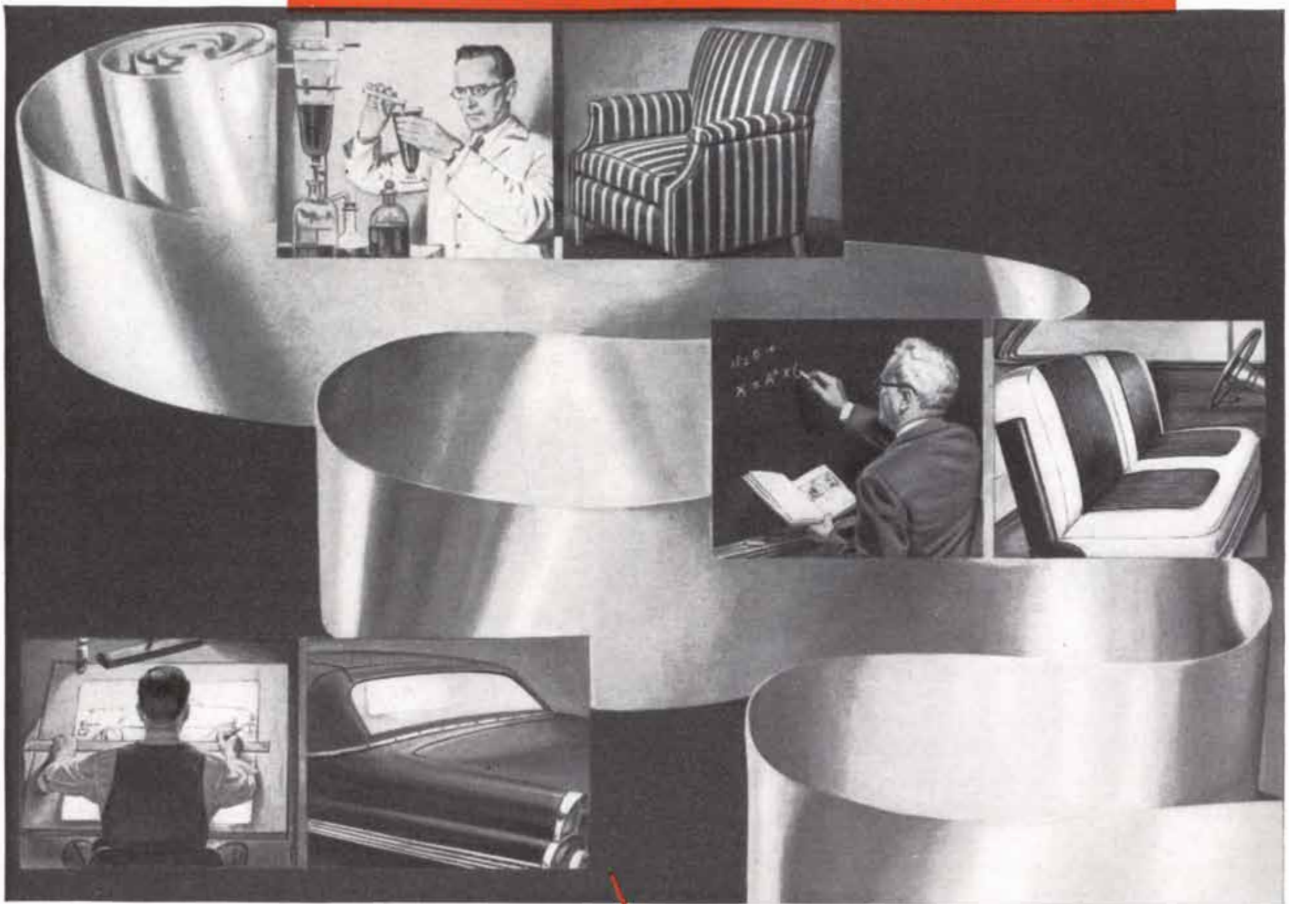

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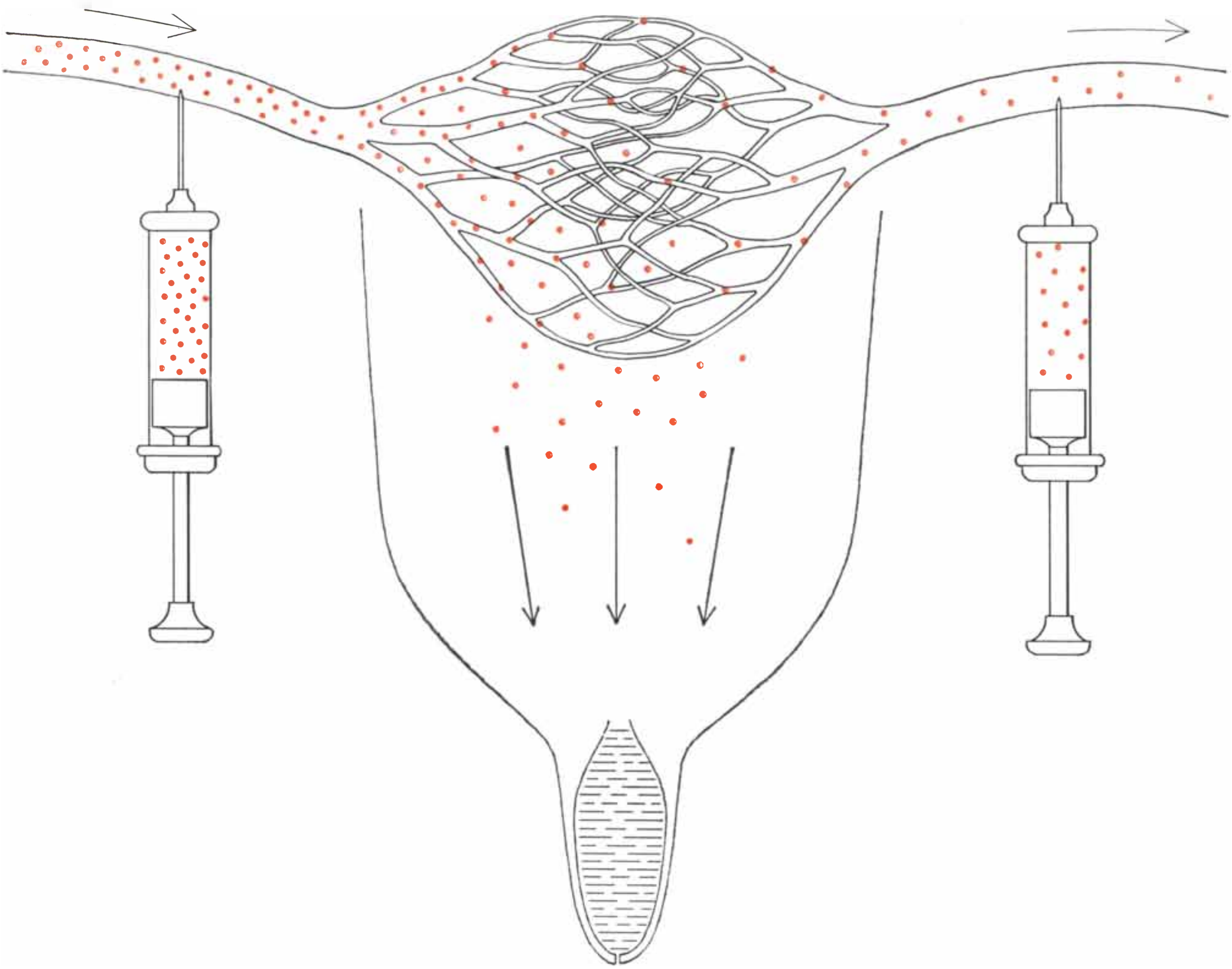


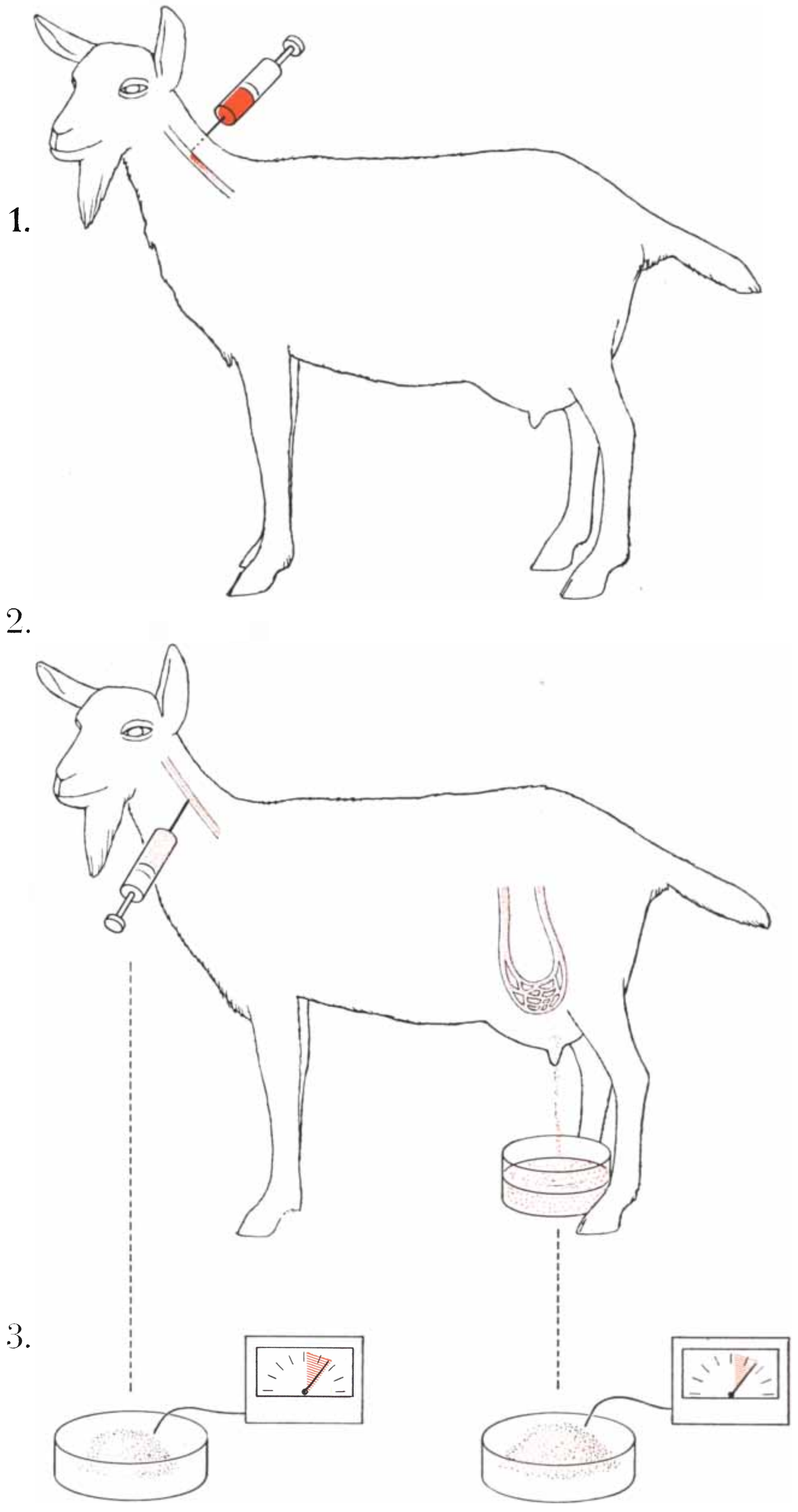
ARTERIES AND VEINS OF COW'S MAMMARY GLAND are tapped in one type of experiment to determine the raw materials of milk. Nutrient substances (*colored dots*) which the gland (*center*) removes to synthesize milk are present in greater concentration in blood carried into the gland by the artery (*left*) than in blood leaving the gland by the vein (*right*). Samples of blood are taken from the artery and the vein near the gland, and differences in the content of glucose or other substances are then determined.

must find out how many liters of blood flow through the gland for every liter of milk produced. A rough measure of the rate of flow can be obtained with a flowmeter inserted in the blood vessels. By means of such measurements C. W. Turner and his associates at the University of Missouri estimated that the flow of blood through the mammary gland of a goat amounts to 150 to 250 liters for each liter of milk secreted. Another way to estimate the rate of flow is to measure the amount of a substance (a convenient one is calcium) in a liter of milk, determine the difference in concentration of this substance in the arterial and the venous blood, and from these figures calculate the rate of blood flow through the gland. Using this method, J. C. Shaw and W. E. Petersen at the University of Minnesota concluded that in a cow about 400 liters of blood flow through the mammary gland for each liter of milk produced.

Although the blood-measurement technique is simple in principle, in practice it is beset with difficulties. The main trouble is that the arteriovenous difference in concentration of most substances is small, and therefore hard to measure with precision. Another trouble is that the concentration of various compounds in an animal's blood may fluctuate erratically when the animal is upset. Since the taking of the arterial blood sample from a cow involves thrusting a hypodermic needle through its rectum into the iliac artery, only the combination of a skilled operator and a placid cow is likely to give results with any meaning.

The blood-comparison technique gives us only a rough idea of what the mammary gland takes from the blood. It tells us nothing about how the gland uses these substances to manufacture milk. For example, while these studies show clearly that the gland takes up glucose, we are left in the dark about whether the glucose is used to make the lactose of milk or merely to provide energy for the gland's chemical processes. The same goes for the gland's uptake of acetic acid: this substance might be used either for synthesizing fats or for supplying energy.

It is here that the tracer technique has come to our aid in recent years. With



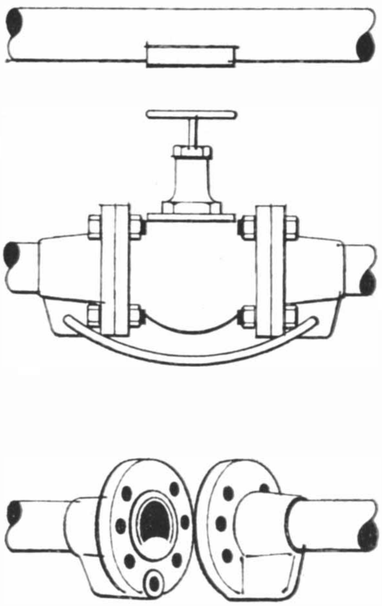
SYNTHESIS OF LACTOSE, a sugar found in milk, from glucose, a sugar found in blood, was traced in the goat. Glucose labeled with radioactive carbon was injected into the jugular vein of the goat. Glucose was then isolated from a sample of blood; lactose, from a sample of milk. Samples of each sugar were burned, and the carbon dioxide given off was converted into barium carbonate. The radioactivity of barium carbonate from each sugar was equal (*dials at bottom*), showing that lactose is made entirely from glucose in blood.

isotopic tracers we have been able to learn what nutrients the mammary gland uses to make the various components of milk.

The general principle of the tracer method is well known. The experimenter labels a given compound by incorporating in it either a radioactive isotope or a heavy isotope of a particular atom, and he can then follow the fate of this compound, or products derived from it, with a Geiger counter or a mass spectrometer (which identifies the heavy isotope). In a problem such as the one with which we are concerned, the application of the technique becomes somewhat complicated, because the metabolism of the body continually breaks down most of its organic substances and uses the atoms in building almost every type of compound. If, for instance, we label glucose in the blood with radioactive carbon 14, radiocarbon atoms may later turn up in almost every organic component of the milk. We must therefore resort to a statistical device, which is illustrated by the following analogy.

Imagine a fairground which people are continually entering and leaving. It has two entrances (A and B) and one exit. Suppose we want to find what proportion of the people who leave at the exit came in through entrance A. We can do this by having a man label with a colored ribbon one in 10 of the persons who come in at this entrance. A second man stationed at the exit counts the proportion of persons leaving who are wearing colored ribbons. If one in 10 is labeled, we know that all of them came in through A and none through B. If the proportion is one in 20, then half of them must have entered at A and half at B; if it is one in 100, nine tenths came in through B and one tenth through A.

We use isotopic tracers in exactly this way. Suppose we want to learn whether the lactose in milk is derived only from glucose in the blood or from other organic nutrients as well. For the purposes of this study we can consider that carbon atoms may come into the lactose manufactured in the mammary gland via two sources: (A) the blood glucose, or (B) all other carbon compounds in the blood. We mark a certain percentage of the carbon atoms fed into entrance A by injecting into the blood some glucose labeled with radiocarbon. Now we can determine how much of the carbon in lactose comes from blood glucose by measuring the radioactivity of the lactose. If its carbon atoms show the same proportionate amount of radioactivity as the blood glucose carbon does, then all



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of the carbon in the lactose must have come from the glucose; if the activity is less, some of the carbon must have come from elsewhere.

O. K. Reiss and I performed this experiment on a goat at the University of Chicago, and the results showed clearly that the mammary gland of the animal derives all of the carbon for its lactose from blood glucose. We found that the radioactivity of the lactose in the goat's milk reached the same level as that of the blood glucose about two hours later, which indicates that it takes about two hours for milk to be manufactured and secreted from the mammary gland.

We have accounted, then, for the lactose in milk. Next, what of the fats: from what sources do they come? Farmers have long had some knowledge on this point from rough tracer experiments of their own. They know that if they give cows foods containing soft fats of low melting point, the cows' milk yields soft, greasy butter. This suggests that at least part of the fat in milk comes ready-made to the mammary gland via the bloodstream. Further evidence for the same conclusion is furnished by the fact that some of the milk fats are identical with fats found in the blood, and also by uptake measurements which show that the mammary gland absorbs such fats from the blood. A recent experiment by R. F. Glascock in England clinched the proof. He labeled the blood fats of goats with tritium, the radioactive isotope of hydrogen, and by this means proved that these fats go directly into the formation of milk.

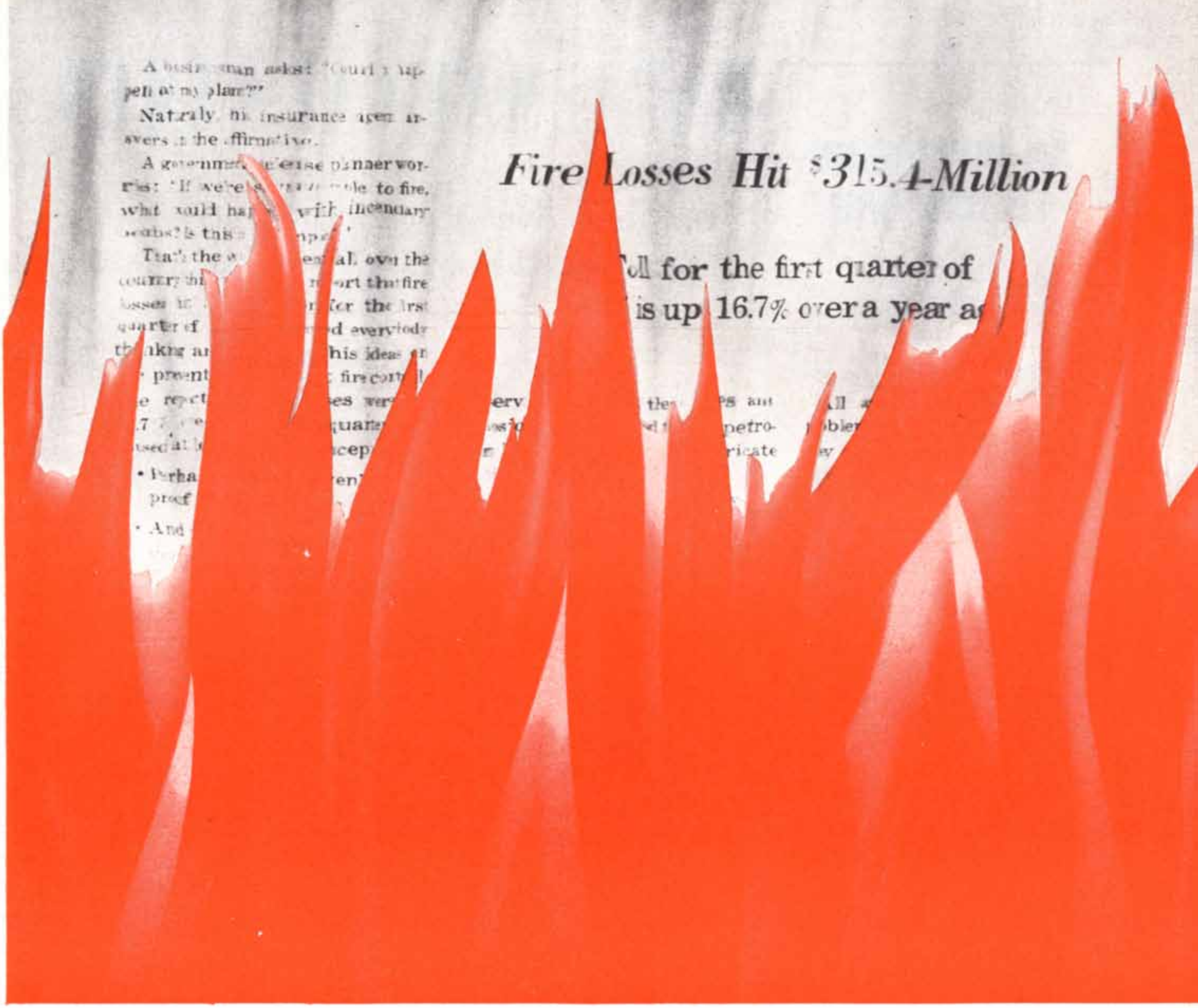
But as I have already mentioned, milk also contains certain fats (with short-chain fatty acids) which are found nowhere else, and these have been investigated recently by other tracer studies. Blood analyses had suggested that they are synthesized from acetic acid taken from the blood. S. J. Folley and G. Popjak in England therefore injected acetic acid labeled with radiocarbon into the bloodstream of a goat and then examined samples of the goat's milk. The milk's short-chain fatty acids turned out to have a high level of radioactivity, which proved that they had been formed completely, or almost completely, from the acetic acid supplied by the blood. On the other hand, the long-chain fatty acids in the milk had almost no radioactivity, as was to be expected from the previous findings that these fats are supplied preformed by the blood.

As for glycerol, the compound that combines with fatty acids to make a fat, Folley and Popjak proved by tracer experiments that the source of the glycerol used by the mammary gland to synthesize fat is glucose, taken from the blood.

Finally, there is the question of milk's proteins. Does the mammary gland make casein and beta-lactoglobulin by converting proteins taken from the blood, or by a complete synthesis from amino acid building blocks, either supplied by the blood or formed by the gland itself? My co-workers and I at the University of Oxford, and T. S. Work and his colleagues at the National Institute for Medical Research in London, have explored these questions with tracers. Experimenting on goats and rabbits, we traced labeled amino acids and also labeled blood proteins. The experiments showed that free amino acids in the blood are the source of at least 90 per cent of the amino acids in the milk proteins. We found no evidence that the mammary gland manufactures amino acids itself or that it converts blood proteins into milk proteins.

This last finding has a significant bearing on a debated point as to how proteins in general are made in the body. The question at issue is: Can the body convert one protein into another by partly breaking it down and recombining the segments in a different order, or can it build proteins only from the basic amino acid building blocks? Our experiments on the mammary gland indicate that protein synthesis must start from scratch—with amino acids. That is to say, if one protein molecule is to be converted to another, it must first be broken down completely into its individual amino acids. It seems that the mammary gland possesses a mechanism which selects amino acids from the 20 different kinds in the blood and arranges them in the specific sequence that forms the casein molecule—just as a typist selects letters from the 26 on her keyboard and arranges them in the sequence "c-a-s-e-i-n."

Now that we know what materials the mammary gland uses to make milk, we can go on to explore how it manufactures this useful fluid. The fascination of the study is reward enough, but of course it is also likely to have a practical value. It has already been learned, for instance, that when the butterfat content of a cow's milk falls below normal because the cow has fed on young spring grass or a concentrated food low in roughage, the fat content can be raised by feeding the cow sodium acetate or, more practically, some food that increases its supply of acetic acid.



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MATHEMATICAL GAMES

How to remember numbers by mnemonic devices such as cuff links and red zebras

by Martin Gardner

Everyone uses mnemonic devices—ways of memorizing bits of information by associating them with things that are easier to remember. In the U. S. the most familiar of these devices is surely the rhyme beginning: "Thirty days hath September. . . ." Another well-known mnemonic device is: "Every good boy does fine" (for EGBDF, the lines of the musical staff).

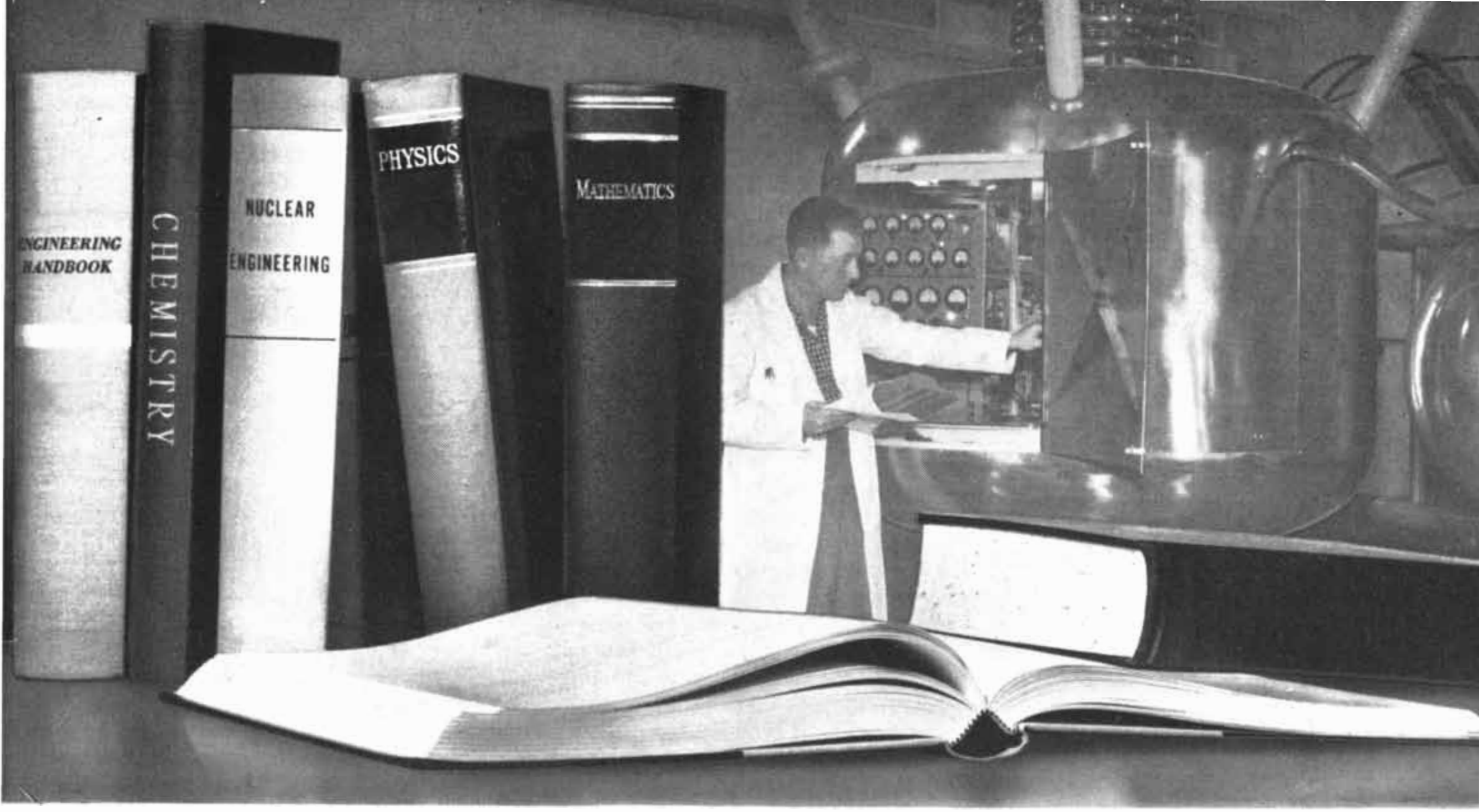
Mnemosyne was the goddess of memory

The same principle can also be applied, with ingenious variations, to the memorizing of numbers. Such tricks come easily to mathematicians. When Bertrand Russell visited New York in 1951 he told a newspaper columnist that he had no difficulty in recalling the number of his room at the Waldorf-Astoria —1414—because 1.414 is the square root of 2. The British mathematician G. H. Hardy wrote of calling on his friend Srinivasa Ramanujan, the Indian mathematical genius, in a taxicab numbered 1729. Hardy remarked that this was a dull number. "No," Ramanujan promptly replied. "It is a very interesting number. It is the smallest number expressible as a sum of two cubes in two different ways" (12 cubed plus 1 cubed, or 10 cubed plus 9 cubed). It must be admitted that even among mathematicians such an intimate acquaintance with numbers is rare.

The most common mnemonic device for remembering a series of digits is a sentence or rhyme in which the number of letters in each word corresponds to the digits in the desired order. Many such memory props have been worked out in various languages to recall *pi* beyond the usual four decimals. In English they range in length from the anonymous "May I have a large container of coffee?" through Sir James Jeans's "How I want a drink, alcoholic of course, after the heavy chapters involving quantum mechanics" to this doggerel contributed by Edouard Prevost to a publication of Graham Transmissions, Inc.:

Now I—even I—would celebrate
In rhymes inept the great
Immortal Syracusan rivaled nevermore,
Who by his wondrous lore,
Untold us before,
Made the way straight
How to circles mensurate.

I know of no similar aids in English to recall *e*, the other common transcendental number. However, if you memo-



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Los Alamos Scientific Laboratory is a non civil service operation of the University of California for the U. S. Atomic Energy Commission rize *e* to five decimal places (2.71828), you automatically know it to nine, because the last four digits obligingly repeat themselves (2.718281828). In France *e* is memorized to 10 places by the traditional memory aid: *Tu aideras à rappeler ta quantité à beaucoup de docteurs amis* (You will be aided in remembering your quantity by many friendly teachers). Perhaps the reader can construct an amusing English sentence that will carry *e* to at least five decimals.

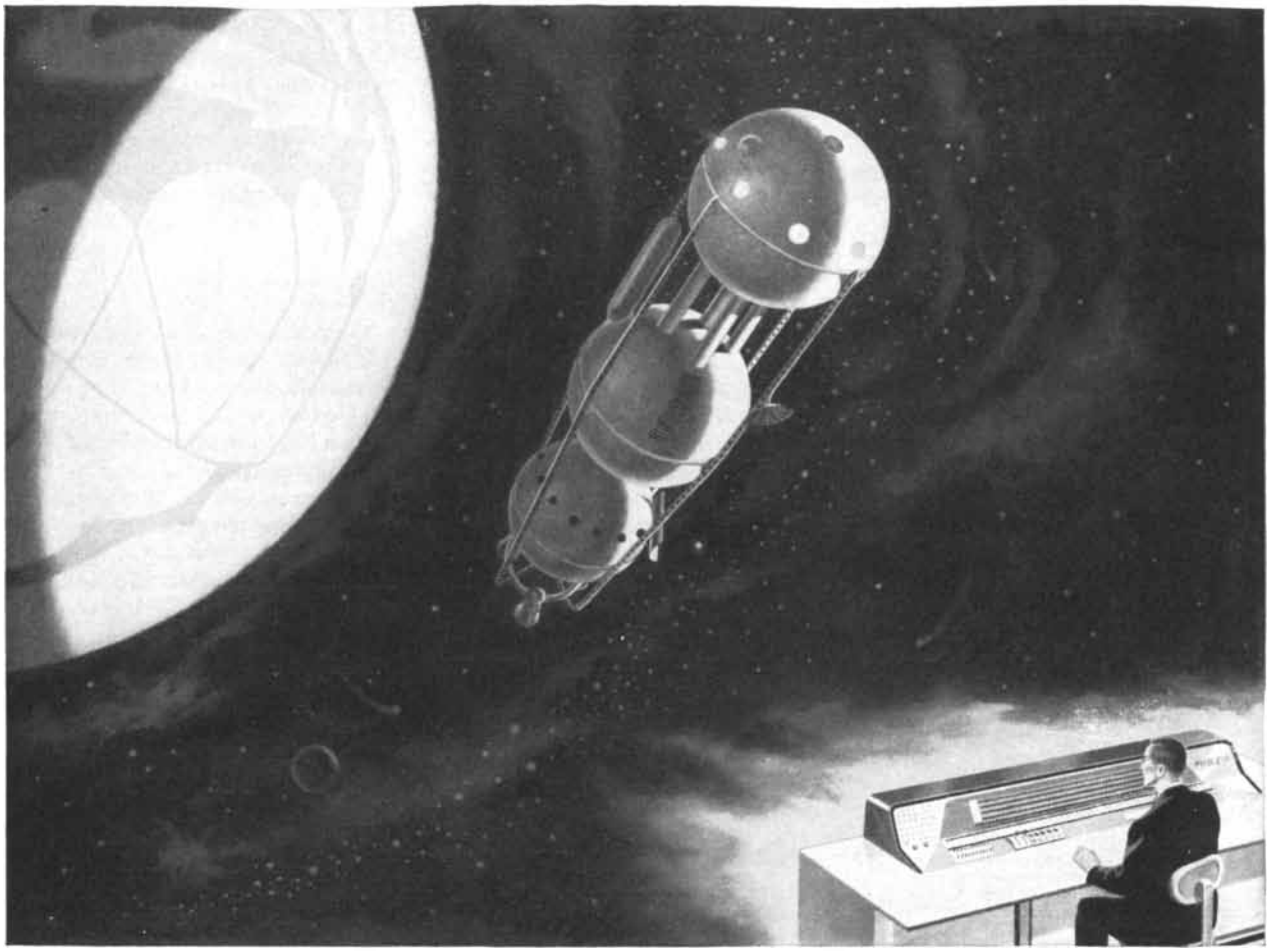
Is there a mnemonic system which, once it has been mastered, will enable one to memorize quickly any series of digits? There is such a system, and it has been developed to a high degree by modern memory experts. Not only can the system be used to give an impressive dinner-table demonstration of memory; it also can be highly useful in memorizing important mathematical and physical constants, historical dates, house and telephone numbers, license plates, social security numbers and so on.

Although the art of mnemonics goes back to ancient Greece (the term comes from Mnemosyne, the Greek goddess of memory), it was not until 1648 that a German named Stanislaus Mink von Winckelmann disclosed what he called his "most fertile secret" for memorizing numbers. The secret consisted in substituting consonants for digits, then adding vowels wherever required so that words could be formed. The words were then easily memorized by other mnemonic methods.

Winckelmann's original number alphabet was crude, but numerous improved versions were soon worked out in many languages. The great Gottfried Wilhelm von Leibniz was sufficiently intrigued by the notion to incorporate it into his scheme for a universal language; Lewis Carroll devised what he regarded as an improvement over the number alphabet in Richard Grey's *Memoria Technica*, a popular British work on mnemonics published in 1730. (A reproduction of Carroll's notes on his number alphabet will be found in Warren Weaver's article "Lewis Carroll: Mathe-

DIGITS	CONSONANTS	MEMORY AIDS	
1	**T, D**	**T** has one downstroke	t
2	**N**	**N** has two downstrokes	**n**
3	**M**	**M** has three downstrokes	**m**
4	**R**	**R** is the fourth letter in "four"	FOU**R**
5	**L**	**L** is 50 in Roman numerals	50
6	**J,** soft **G, SH, CH**	**J** looks like 6 when reversed	**J 6**
7	**K,** hard **G,** hard **C**	**K** can be printed with two sevens	1<
8	**F, V, PH** as in photo	**F**, in lower-case script, has two loops like the figure 8	*f* **8**
9	**P, B**	**P** looks like 9 when reversed	**P 9**
0	**Z, S,** soft **C**	**Z** is the initial of "zero"	**Z**ERO

A "number alphabet" in which consonants stand for digits



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matician," in SCIENTIFIC AMERICAN for April, 1956.)

The modern form of the number alphabet, as currently used by all English-speaking memory experts, is shown in the chart on page 132. This must be thoroughly fixed in the memory before the system can be used profitably. On the right side of the chart are suggestions which may help in memorizing the table. The reader will note that only consonants are employed, and that where two or more consonants stand for the same digit, they have similar sounds. Three consonants—W, H and Y (spelling "why")—do not appear on the chart.

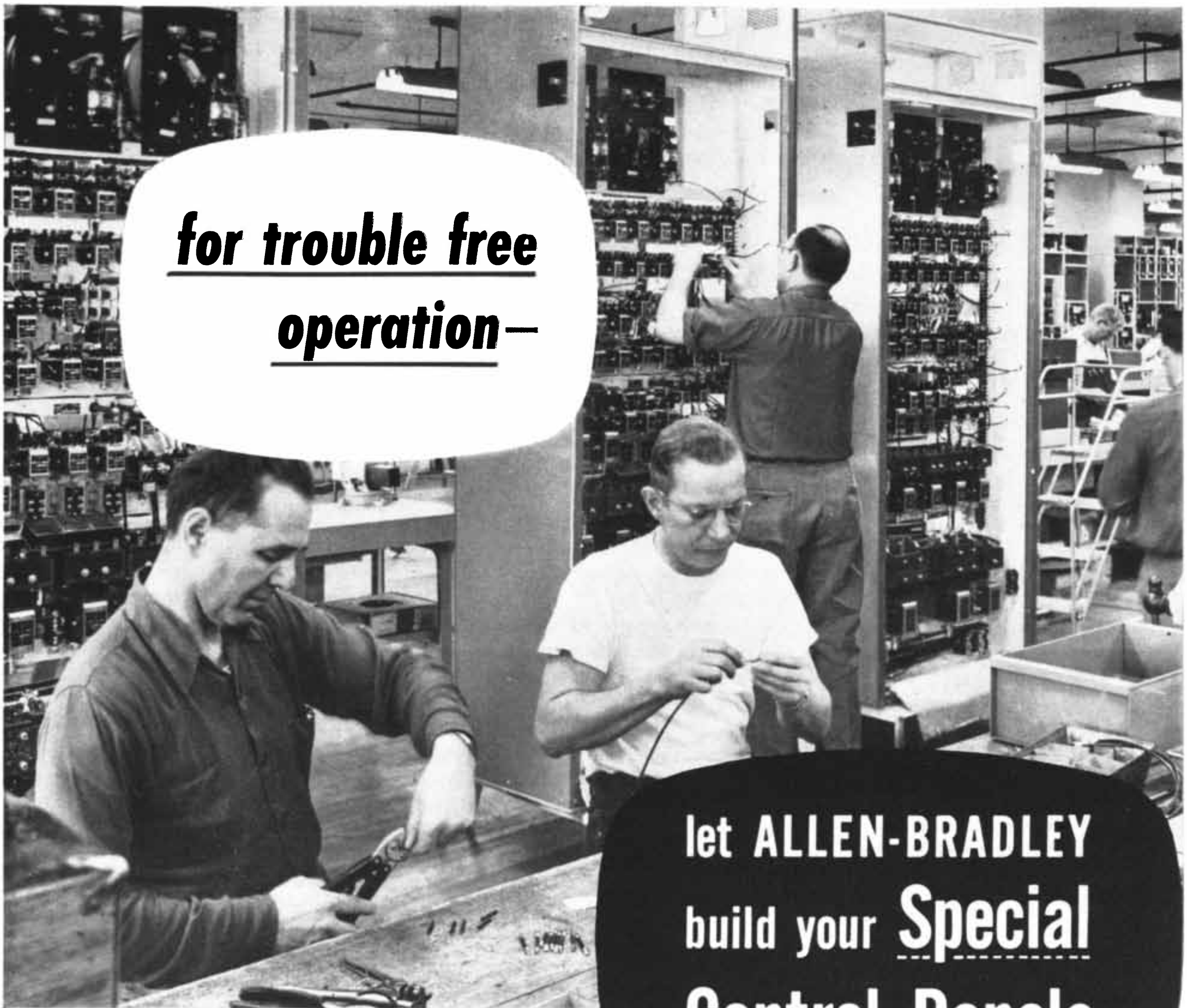
Suppose we wish to use this system for remembering that mercury boils at 357 degrees centigrade. Our first step is to find a word in which the consonants, taken in order, will translate into 357. Such a word readily comes to mind—*MiLK*. The next step is to associate this word by a vivid mental picture with the word "mercury." One way to do this is to imagine Mercury, the messenger of the gods, winging his way through the clouds with a container of milk in his hands. The more preposterous the mental image the easier it is retained by the mind. When we wish to recall the boiling point of mercury we have only to follow the chain of associations from the element to the Greek god to milk to 357. This may seem like a roundabout means of memorizing a number, but no better artificial system has yet been discovered. It is astonishing how firmly the links of the chain remain planted in the mind.

Consider some additional examples. The atomic number of the element indium is 49. We can recall this easily by linking India with the word *RuPee*. Neptunium has an atomic number of 93; we imagine Neptune puffing an *oPiuM* pipe. For tantalum, element 73, we might picture Tantalus plugging the hole in his tantalizing cup with a wad of chewing *GuM*. Platinum, number 78, can be recalled by thinking of yourself sporting a pair of *CuFF* links. Double letters, such as the f's in "cuff," are regarded as single letters. The number alphabet is strictly phonetic. Silent consonants, as well as W, H and Y, are ignored.

The chart on this page shows how the

NUMBER	SQUARE ROOT	MNEMONIC KEY
2	1.414	**R**AT **R**ACE. Think of two rats racing.
3	1.732	**K**I**M**O**N**O. Three suggests triangle. Think of a kimono decorated with a pattern of small triangles.
5	2.236	E**N**ME**SH**. Five suggests pentagon. Think of the pentagon hopelessly enmeshed in red tape.
6	2.449	**R**A**R**E **B**EE. Six suggests hexagon. Think of the hexagonal cells of a beehive. Crawling over the cells is a two-headed bee.
7	2.645	**SH**EE**R** **L**INEN. Seven suggests the dance of seven veils. Think of the veils as made of sheer linen.
8	2.828	**F**U**NN**Y **F**ACE. Eight suggests "ate." Think of taking a bite and making a funny face.
10	3.162	**T**OU**CH** **N**OSE. Ten suggests the fingers. Think of touching your nose with all ten of them.

How the number alphabet can be used to memorize square roots



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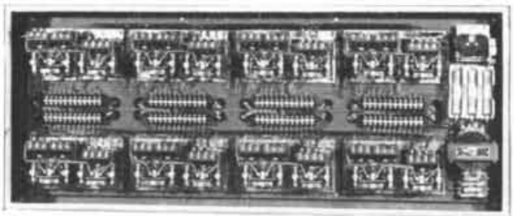

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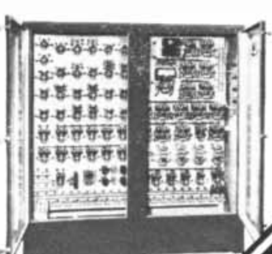

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system can be used for memorizing to three decimal places the square roots of 2, 3, 5, 6, 7, 8, 10. Only the first three consonants of each key word or phrase are considered. They stand for the three decimals of the corresponding square root. (The digit preceding the decimal point need not be considered since it is obvious.) Many other words can of course be substituted for those chosen here. It is usually best, in fact, to work out your own key words and mental associations rather than adopt those of someone else; your inventions will be closer to your own experience and therefore easier to recall.

Larger numbers can be memorized by taking figures in pairs or triplets, devising a suitable word for each group and linking the words in a chain of striking mental pictures. A telephone number, for example, would be fixed in the memory by a chain of images connecting the person or firm to the exchange, then to two words which stand for the digits in the phone number.

It is by means of such chains of mental pictures that professional memory experts are able to repeat long lists of random digits immediately after the list has been read aloud to them. This seemingly incredible feat is well within the powers of anyone who troubles to spend a few weeks of daily practice in mastering the number alphabet. As a first step try memorizing the eight digits in the number on a dollar bill. Take the digits two at a time, forming words in which the first two consonants of each word

An image for the boiling point of mercury

correspond to a pair of numbers. For example, if the number is 41-09-15-85, these pairs can be translated into the four words: *ReD*, *ZeBra*, *TeLescope*, *FLower*. Think first of a *red zebra*. It holds a *telescope* to its eye. The telescope is trained on a distant *flower*.

In choosing words, nouns that provide vivid pictures are of course preferable, though adjectives can often be linked conveniently to a following noun, as in *red zebra*. In most cases the first words that come to mind are preferable, and each word should be linked to the next one by the most ridiculous image you can imagine. With practice, appro-

A red zebra stands for the number 4109

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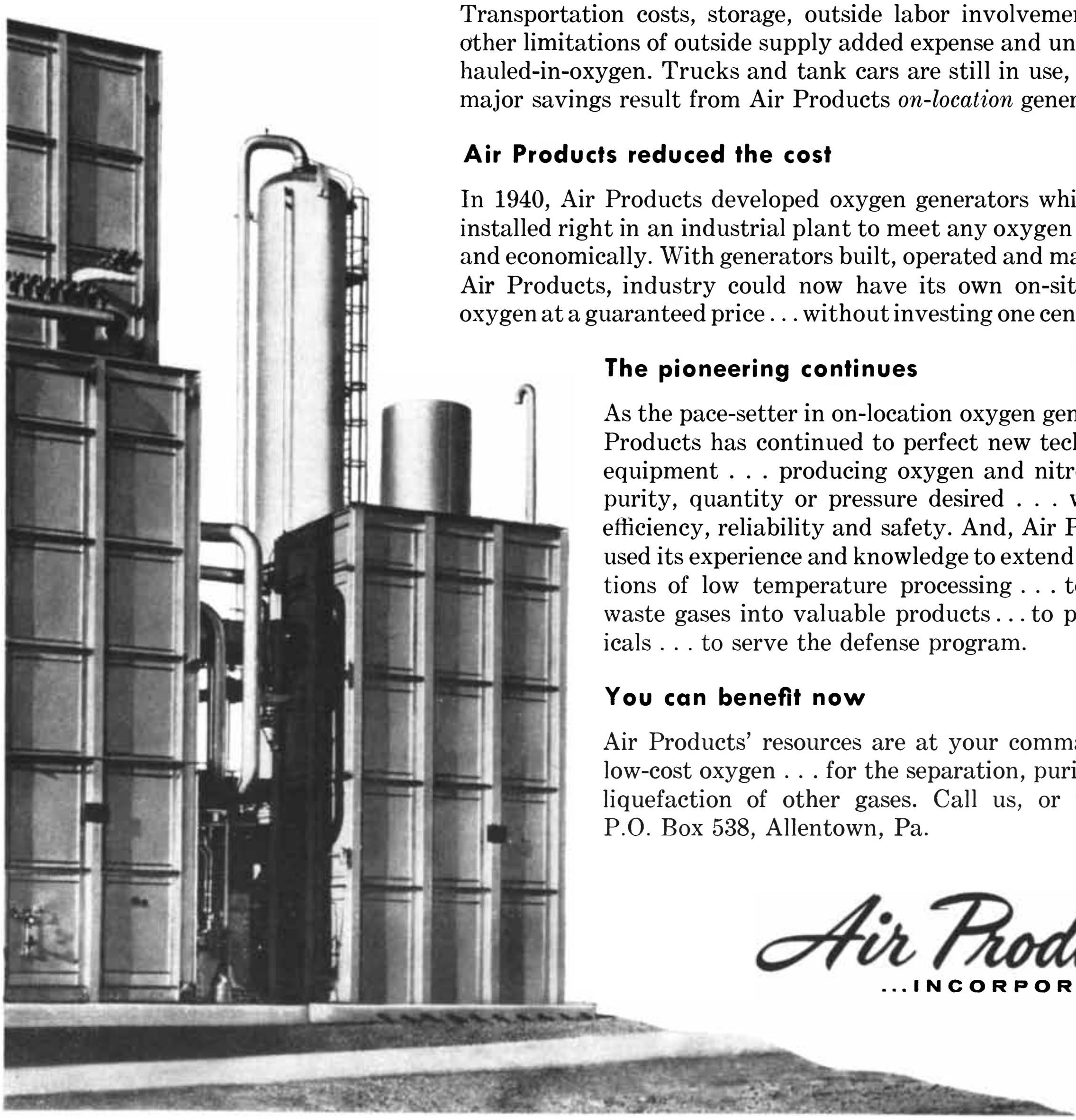

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Memory experts are able to form chains of mental associations with extraordinary speed because every pair of digits immediately suggests to them a picture word taken from a previously memorized list. Thus they do not waste time in groping for suitable words. Some experts work with pre-memorized word lists for three-digit groups. To aid the students of his memory school in New York, Bruno Furst provides them with a printed number dictionary listing a variety of appropriate words for each number from 1 to 1,000. Such lists are not necessary, however, unless you intend to develop great proficiency in the art. Suitable words can always be devised as you go along if the numbers are read to you slowly, and you will discover that it is not at all difficult to memorize a series of 50 random digits by this method. Fortunately long chains of quickly improvised mental pictures do not remain long in the mind, so if you repeat the stunt a day or so later there will be no confusion of the new key words with those of the previous demonstration.

In the discussion of the game of Hex, to which this department was devoted in July, it was not mentioned that the game was independently invented in 1948 by John Nash, then a student at Princeton University. The popularity of the game among Princeton students of mathematics resulted from this version, which was developed and extensively analyzed before news reached Princeton of the earlier Danish invention.

Image for the atomic number of neptunium

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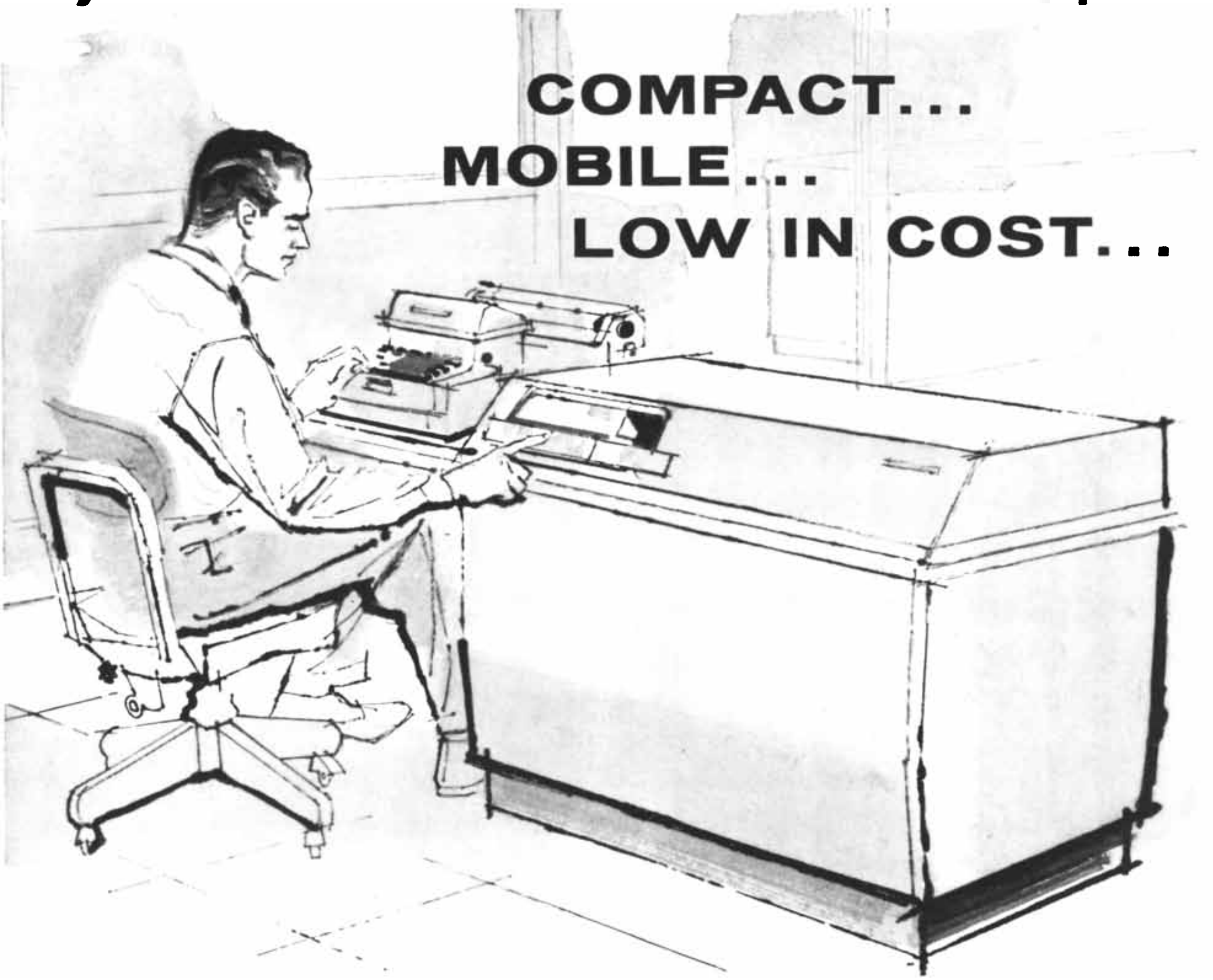

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THE AMATEUR SCIENTIST

The surface details of the sun are revealed by a small telescope and artful photography

The photograph on page 144 shows a part of the sun's visible disk, or photosphere, as it appeared on February 13, 1956. The clearly defined spots and sharp granules demonstrate how effectively the sun can be photographed in white light with a small telescope and an ordinary camera. The picture was made, partly for amusement and partly to show what can be accomplished with simple equipment, by J. H. Rush, a physicist of Boulder, Col., who insists that all science is essentially an amateur pursuit. "By that," he writes, "I mean that when science quits being fun and becomes just a way to make a living or a reputation, one is no longer a scientist."

By this standard Rush has been a scientist since he was 12. "One night I went out to draw a bucket of water from the cistern on the Texas farm where I grew up. I was facing north, and as I stood leaning back against the tug of the pulley rope with nothing much on my mind I recognized the Big Dipper. Stars I had always seen before as a random scatter suddenly fell into a beautiful pattern. Life was never the same again! Shortly thereafter I managed to find some nondescript lenses and fitted them into a caricature of a telescope. It wasn't much as telescopes go, but its power and my enthusiasm both approximated those of Galileo and his first instrument. Curiously I cannot remember my first look through a respectable telescope. It was years later and by that time I knew too much to be greatly impressed.

"But I still enjoy tackling problems in science with equipment normally available to amateurs. The sun is a particularly appealing object in this sense. Its abundant light permits excellent photography without need for large telescopes or precision clock-drives. It also has the advantage of shining in the daytime! Amateurs have reported varying degrees of success in photographing sunspot details and the granulation of the photosphere in white light, but many have failed to recognize the full potential of this simple method and the possibility of employing it for recording certain information about the sun which is greatly desired.

"The granular pattern of the photosphere presents some of the most puzzling questions in solar astronomy, and is the subject of increasingly intensive study. The idea is generally accepted that the photosphere is the outside of an opaque layer of gas through which energy is transported out of the interior of the sun by convection. On this theory bright granules are the tops of rising columns of very hot gas, and dark granules are cells of cooler gas descending back into the interior. Or maybe it is the other way round. In any case, the convection turbulence that appears as mottling or granulation of the photosphere in white light is believed to be intimately related to the spicules of the overlying chromosphere. These spikelike jets, which can be observed only at total eclipse or with coronagraph telescopes at high altitudes, seem to be projections to higher levels of the uprushing gas of the convection cells, which has become transparent. The spicules seem to represent a key process in the maintenance of the corona and in other phenomena of the sun's atmosphere.

"The subject is complex, but enough has been said to indicate that the granular pattern of the 'quiet' photosphere is at least as significant a clue to the sun's behavior as the more spectacular sunspot regions. Moreover, granule cells are easily observed in the gray penumbrae of spots. In at least one instance they have been observed in the dark umbra itself. These and other observations of spot detail pose intriguing questions as to the relation between sunspots and the undisturbed photosphere, and the nature of the spots themselves.

"The most obvious approach to the study of the granulation is to determine the frequency distribution of granule sizes, and to find out whether this distribution varies in the vicinities of sunspots, or with solar latitude, or during the sunspot cycle. Several studies under very good seeing conditions have indicated that the granules vary in size over a wide range, the most frequent diameter being about 800 kilometers. These studies do not agree as closely as one would like, and theoretical reasoning—supported by some recent observations—suggests that granules much less than 800 kilometers in diameter must be still more numerous. Why are they not observed? Mainly because the earth's atmosphere is too unsteady. Instrumental defects and heating contribute to the difficulty. Few observers have claimed to find meaningful granular detail much below one second of arc, which is about 725 kilometers at the distance of the sun. Yet so important is this question to a better understanding of the processes going on in the sun that a project is now under way to mount a 12-inch telescope with a photoelectric sun-pointing mechanism on a balloon and photograph the granulation from an altitude of 80,000 feet [see "Science and the Citizen"; SCIENTIFIC AMERICAN, September].

"The problem of extending the observations to granules smaller than one second of arc is not for the amateur, unless he is an instrumental genius. But details of that size and larger often can be photographed, if one is patient and uses suitable techniques, and such observations may contribute toward an understanding of certain solar problems. Besides, the work is fun. Rather than generalize, I shall tell in some detail of an instrumental arrangement and technique that I have used with good results for photographing the granulation and sunspots.

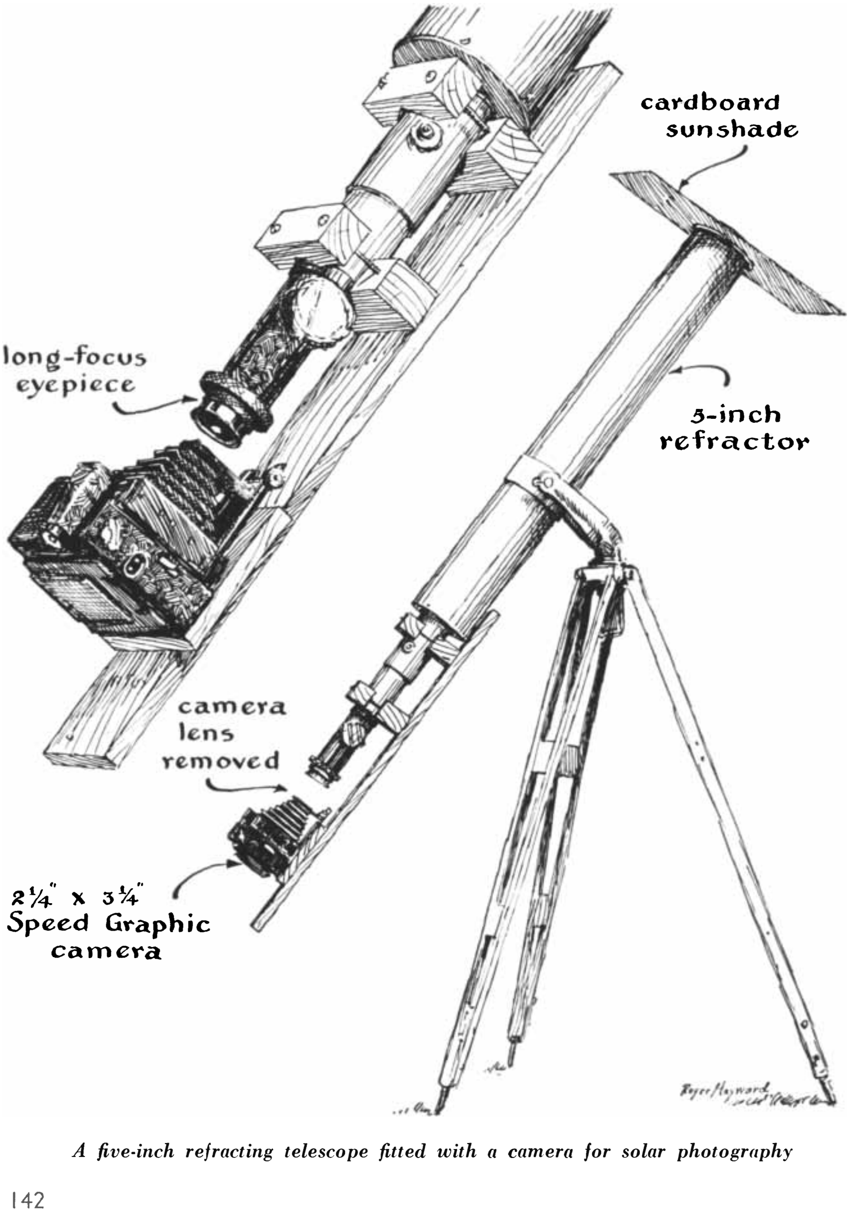
"This work was done in the late winter and spring of 1956 in the physics department at Texas Technological College. The school is located at Lubbock on a high, flat plain at an altitude of about 3,500 feet. The region probably would be excellent for general astronomical work, if it were not so arid and bare of permanent vegetation. The air usually contains a great deal of suspended dust, and thermal turbulence is serious—particularly during the months when the ground is exposed. The visual seeing is usually good at sunrise. It deteriorates rapidly as the ground is heated, and by noon is usually so poor that it prohibits any worthwhile observing.

"Seeing is not a simple matter, however. I found during the period in which I made regular observations that the image of a sunspot usually looked as if it were under water ruffled by the wind. Despite the 'rubbery' appearance of the image the fine detail in it appeared to be good. Apparently a considerable area of image could be displaced at a visible rate, perhaps 10 oscillations per second, without much blurring or distortion of internal detail. Photographs confirmed this impression. A speed of even 1/125 second was enough to 'cut through' the slow, visible disturbances and yield good detail. A variety of evidence indicated that the long-period, large-amplitude seeing disturbances that were disastrous to visual work originated very near the ground, while the type of bad seeing that blurred and distorted the fine photographic detail originated at high altitudes and was relatively independent of local conditions and the time of day. In this connection, it is interesting to note that W. A. Miller of the Radio Corporation of America Laboratories (to whom I am indebted for much of the 'know-how' of such observations) has obtained many excellent pictures of the solar granulation at Rocky Point, Long Island —but only when the sky was hazy! When the sky cleared, the seeing went to pieces.

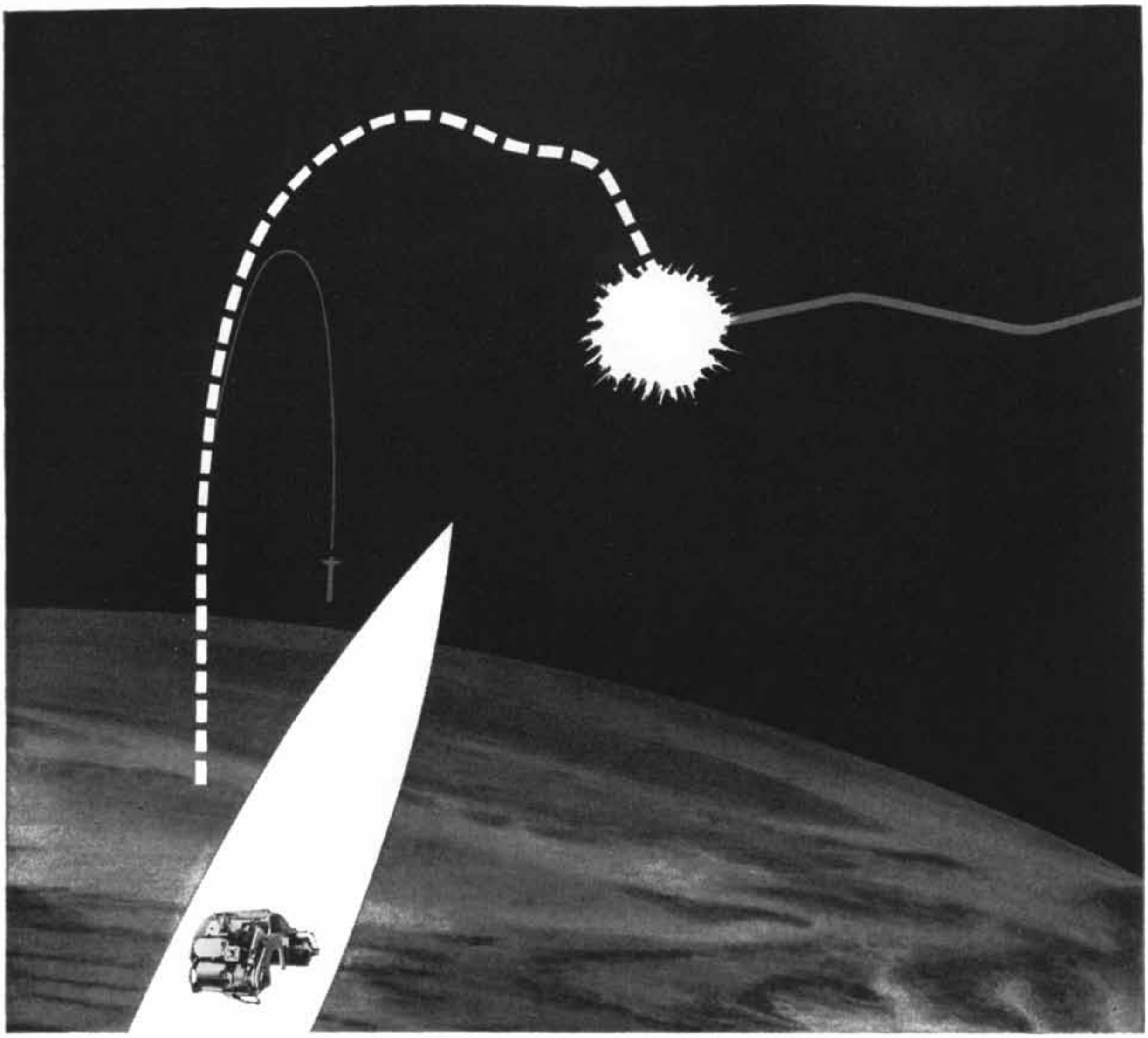
"The best photographic seeing I found at Lubbock occurred about the end of January, 1956, when the sun came out after a week of heavy snow and cloudy weather. On that day the transient spectral colors (not halos) that are common at 10,000 feet in the Rockies appeared in light clouds near the sun, and the sky was the deep blue that is seen at the top of a mountain. Excellent conditions persisted long enough for me to obtain the photographs reproduced here of the great sunspot group that traversed the visible hemisphere of the sun from about February 10 to 23. The printed reproductions cannot, of course, do justice to the exquisite detail in the negatives, which in the best pictures was very near the theoretical resolving power of the five-inch objective that I used. The photographic seeing gradually deteriorated as the windy spring season came on and the clean air once more was burdened with suspended dust. By May opportunities for good photographs were rare.

"The equipment I used is illustrated in the accompanying drawing [*at left*]. The High Altitude Observatory of the University of Colorado lent us a portable refractor with an excellent five-inch objective of about 60 inches focal length. To this I fitted a large low-power eyepiece taken from an ordnance telescope, and a Speed Graphic camera with the lens-and-shutter assembly removed. To hold the camera in alignment with the telescope, I clamped a one-by-four-inch stick to the telescope tube and mounted the camera on the stick. After focusing and loading the camera I simply steadied the stick between my knees while leaning forward to check the position of the solar image on the focal-plane shutter screen, and fired the shutter. No motion blurring ever appeared. The mechanical details of this arrangement are unimportant; I mention them only to indicate that good results in work of this kind can be obtained without elegant design or precision workmanship.

"The logic of such an improvised setup is devious, as any experimenter knows. In this case it went somewhat as follows. I had a five-inch objective with an ideal resolving power of about one second of arc. Not wishing to sacrifice any of this resolving power by stopping down the aperture to reduce the brightness of the image, and having no shutter speed greater than 1/1,000 second, I had to magnify the primary image sufficiently to hold the exposure time to something greater than 1/1,000 second on very slow emulsion. A large image makes visual focusing practicable and saves a lot of tedious photographic calibration—and also saves having to make



A five-inch refracting telescope fitted with a camera for solar photography



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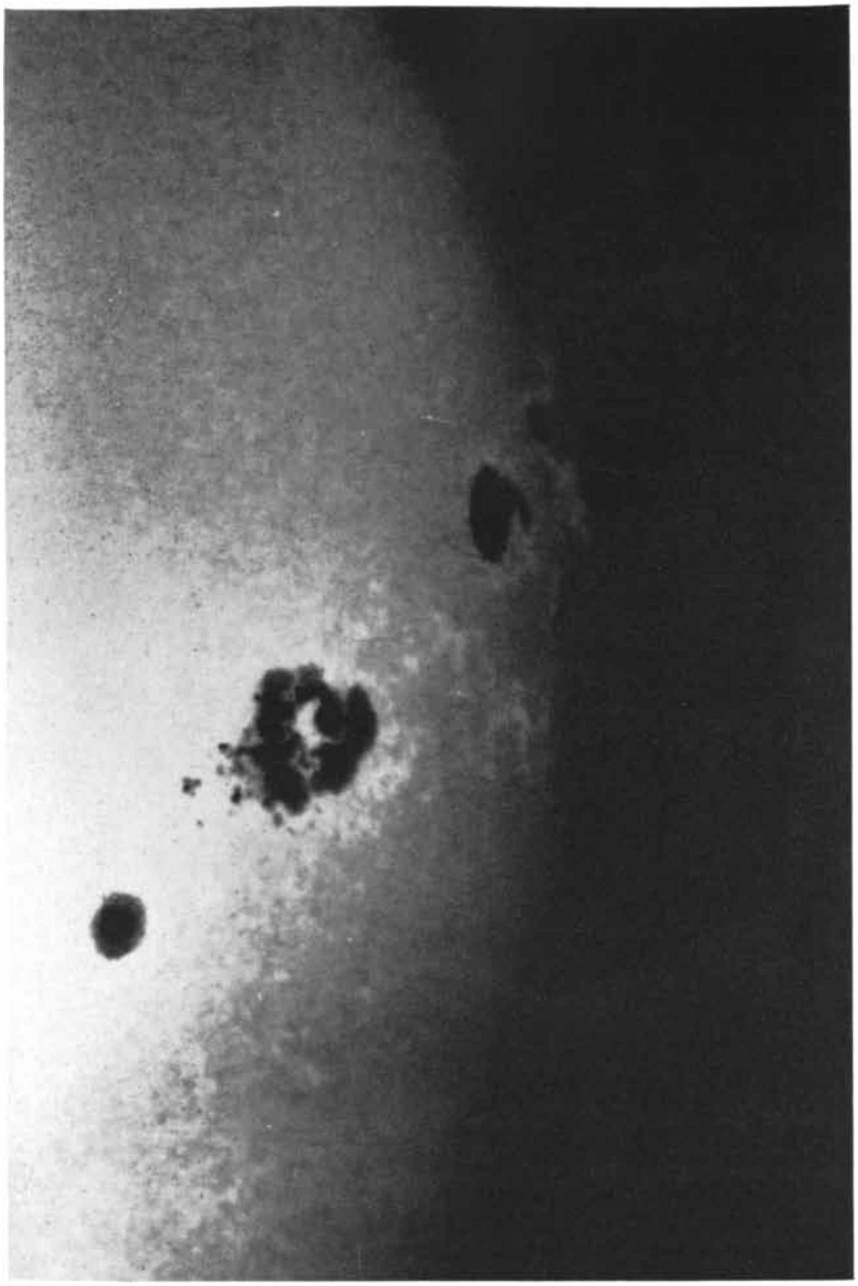

Spots and granules on the surface of the sun were photographed on February 13, 1956

a camera mount stable enough to hold such an adjustment from one observing period to the next.

"The physics department's Speed Graphic made negatives 2¼ by 3¼ inches. I settled on a solar image diameter of about three inches, mainly because that was the size that resulted from mounting the camera on a certain one of several holes I had bored in the stick. The adjacent holes corresponded to image sizes that departed too far from the exposure requirements. The plateholders were designed for cut film only, but I wanted to use some Eastman 549-GH glass plates I had cadged from High Altitude Observatory along with the telescope. I cut the plates small enough to fit inside the film slides and stuck them to pieces of cut film with pressure-sensitive adhesive cement (ordinary rubber cement or two-sided masking tape probably would work). One such plateholder with an undeveloped plate served as an excellent focusing screen. The usual ground glass was useless for this purpose; but the yellowish, fine matte surface of the emulsion yielded an image by reflection that was easily viewed and rich in detail. I found it possible to focus critically by eye, racking the eyepiece lens through a small range relative to the fixed objective and camera. However, a low-power reading telescope would have been helpful.

"No light-tight cover between telescope and camera was necessary. A large piece of cardboard fitted over the objective cell shaded the equipment from direct sunlight. Since the image was nearly three times as bright as full sunlight, the indirect light that reached the plate was insignificant. I racked the camera bellows back out of the way while focusing, and then extended it during exposure just for safety.

"Lest this account leave the impression that one can throw together anything handy and come up with good solar pictures, it may be worthwhile to point out the essential technical features of the arrangement. First, of course, is the objective. Besides being of excellent quality, it must be large enough to resolve significant small detail. The resolving power of a telescope is inversely proportional to the diameter of the objective aperture, and it is convenient to remember that—subject to some qualification—a five-inch objective can just resolve distinct details one second apart in the object. Even a two-inch instrument will reveal granular details in the photosphere; but these will lack the crisp quality and fineness of structure that can be obtained with a larger instrument at times of superlative seeing. A refractor has some advantages over a reflector, because of the superior optical corrections that are possible in a two-element lens and because of the tendency of a mirror to warp slightly in the heat of the sun. But although I have not tried a small reflector for solar work, I see no reason why a good mirror judiciously used should not give satisfactory granulation detail near the center of its field.

"For the finest work it is best to use a long telescope and photograph the primary image. The amateur, however, is usually limited to a telescope too short to produce an image large enough to avoid compromising resolution with the grain of the photographic emulsion. Furthermore, the f ratio for a short telescope of four or five inches aperture is so great that the necessary exposure time becomes impossibly short for any ordinary shutter. Filters can be used to reduce the light intensity, but they have serious drawbacks. A filter placed near the focus is exposed to intense heating, and any lack of uniformity in its density will show up with startling strength on the high-contrast emulsions that must be used for granular work. A filter near the objective is free from these disadvantages; but it must be as large as the objective, and of

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57	La_2O_3. LANTHANUM OXIDE	528 529	99.99 99.997	0.01 Pr, 0.001 Ce. 0.0025 Pr, 0.0005 others
58	CeO_2. CERIC OXIDE	215 216	99.8 99.9	0.2 (largely La + Pr + Nd). 0.1 (largely La + Pr + Nd).
59	Pr_6O_{11}. PRASEODYMIUM OXIDE	726 729.9	99 99.9	1 La + Nd + smaller amounts of Ce and Sm. 0.1 Ce + Nd.
60	Nd_2O_3. NEODYMIUM OXIDE	628 629 629.9	95 99 99.9	1-4 Pr, 1-4 Sm, 0.5-1 others. 0.1-0.4 Pr + 0.1-0.4 Sm + 0.5 others. 0.1 (largely Pr + Sm).
62	Sm_2O_3. SAMARIUM OXIDE	822 823	99 99.9	0.2-0.7 Gd, 0.2-0.6 Eu, and smaller amounts of others. 0.1 (largely Nd + Gd + Eu).
63	Eu_2O_3. EUROPIUM OXIDE	1012 1011	98-99 99.8	1-2 Sm + smaller amounts of Nd + Gd + others. 0.2 (largely Sm + Gd + Nd).
64	Gd_2O_3. GADOLINIUM OXIDE	928.9 929.9	99 99.9	1 Sm + Eu + trace Tb. 0.1 Sm + Eu + trace Tb.
65	Tb_4O_7. TERBIUM OXIDE	1803 1805	99 99.9	1 Gd + Dy + Y. 0.1 Gd + Dy + Y.
66	Dy_2O_3. DYSPROSIUM OXIDE	1703 1705	99 99.9	1 (largely Ho + Y + Tb + small amounts of others). 0.1 Ho + Y + traces of others.
67	Ho_2O_3. HOLMIUM OXIDE	1603 1605	99 99.9	1 (largely Er + Dy + small amounts of others). 0.1 Er + Dy + traces of others.
68	Er_2O_3. ERBIUM OXIDE	1303 1305	99 99.9	1 Ho + Dy + traces Yb and Y. 0.1 Ho + Tm.
69	Tm_2O_3. THULIUM OXIDE	1405 1403	99.9 99	0.1 Er + Yb + trace Lu. 1 Er + Yb + trace Lu
70	Yb_2O_3. YTTERBIUM OXIDE	1201 1202	99 99.9	1 Er + Tm + trace Lu. 0.1 Tm + trace Lu + Er.
71	Lu_2O_3. LUTETIUM OXIDE	1503 1505	99 99.9	1 Yb + Tm + traces of others. 0.1 Yb + Tm + traces of others.
39	Y_2O_3. YTTRIUM OXIDE	1112 1115 1116	99 99.9 99.9+	1 Dy + Gd + traces Tb and others. 0.1 Dy + Gd + traces Tb Approx. 0.05 Dy + Gd.

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similarly high optical quality, or it will affect the definition. Consequently it is usually more practical to introduce a second lens to form a magnified image of reduced brightness, even though any such additional optical element necessarily causes some further deterioration in image quality. In a system designed for this work the second lens would be carefully computed to match the objective and the conjugate distances at which it would be used. But the amateur usually does what I did at Lubbock. He picks up the most likely looking piece of glass that is handy and tries it to see what will happen. I was lucky.

"The ordinary camera leaf-shutter, working near the lens, is not satisfactory for solar photography. The exposure time is so short that the shutter has hardly opened before it starts to close. Thus if the shutter is used at the magnifying lens, the average aperture during the exposure is not circular and is substantially less than the full aperture of the optical system, so that the resolving power is reduced. If the shutter is operated at the primary image, various

This photograph was made with the same equipment on February 14, 1956


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This photograph was made on February 19, 1956

portions of the field receive different exposure times. The only good way out of the dilemma is to use a moving-slit type of shutter (such as the shutter of a Graflex camera) at the primary image or just in front of the film. The latter location is preferable, of course, unless you are using a specially made shutter for the small aperture at the primary image. The main criterion of quality for a focal-plane shutter is uniform speed of travel. Sometimes such a shutter, particularly an old one, is unsatisfactory for high-contrast work because its progress across the image field is jerky and results in bands of varying density on the negative. This trouble may appear on high-contrast emulsions despite satisfactory shutter performance in ordinary pictorial work. I had no such trouble with the new Speed Graphic that I used.

"Given an adequate telescope with a good shutter, the remaining crucial requirement for white-light photography of the sun is a suitable photographic material. Ordinary films designed for pictorial photography have not nearly enough contrast, and usually too much grain, to render solar details satisfactorily. Kodalith or Reprolith can be used with some success, but even these high-contrast copying films are inadequate for solar granulation. Some amateurs have obtained good granulation negatives on Kodak Micro-File film; I have not tried this material.

"The best emulsions I know for solar work in white light are Eastman 548-GH and 549-GH. Of these the 549-GH yields somewhat more contrast and shows less stain; but either is capable of a gamma of 14 or better. These emulsions are very slow. The 548-GH has about a twentieth the speed of Eastman lantern-slide plates, and 549-GH is about three times slower. (Note that I exposed a three-inch solar image from a five-inch objective about 1/250 second on 549-GH!) Thus these materials eliminate the problem of shutter speed *v.* telescope aperture that makes the use of faster emulsions so difficult. Of course this problem

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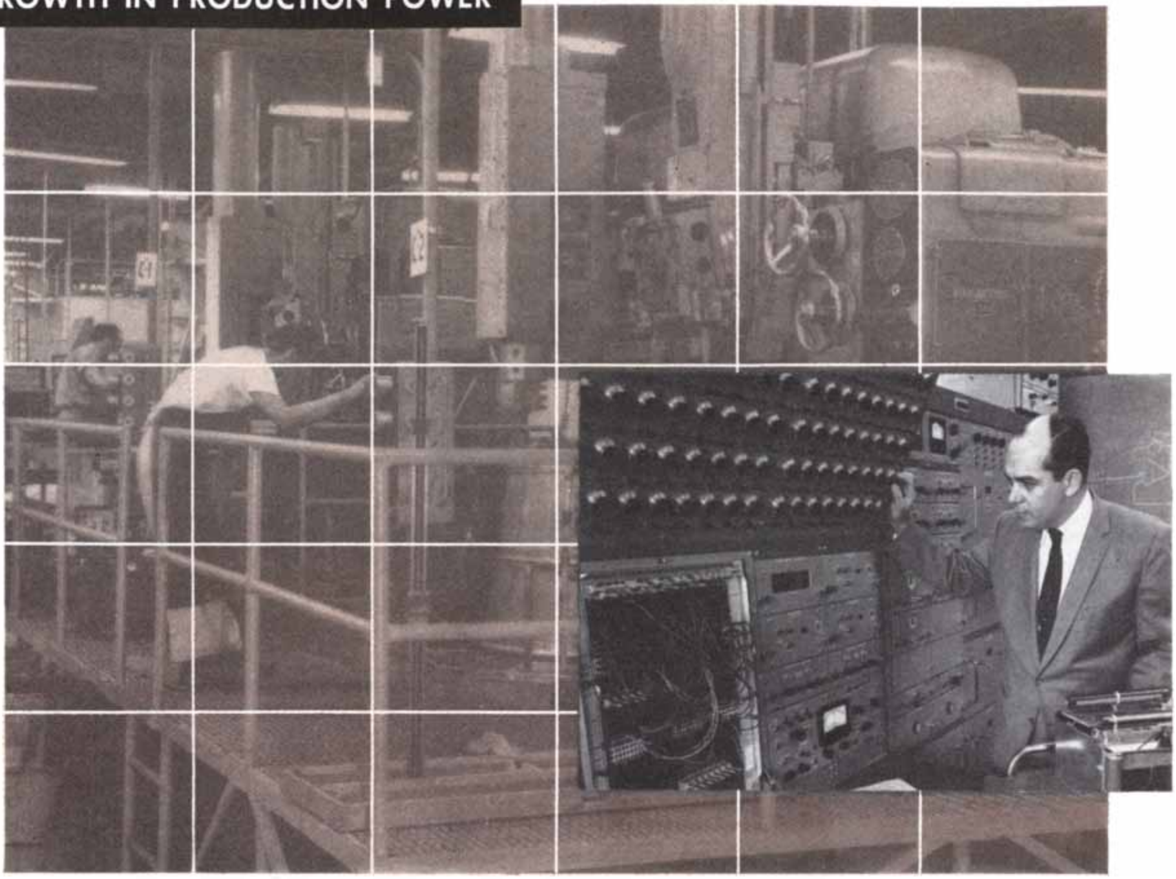

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is still serious if you use an image much smaller than three inches. The resolution of these slow emulsions is extremely high. The manufacturer states that 548-GH will resolve more than 1,000 lines per millimeter, and 549-GH more than 1,500.

"The relative sensitivity of Type GH plates to various colors is important. Granulation photographs in the full white-light spectrum yield less detail than in more restricted regions, and some observers report more detail in yellow-green light than in the blue. The GH color sensitization extends the basic blue sensitivity of the emulsion far into the yellow-green, with maximum response at about 5,400 Angstroms and a cutoff at about 5,650. Thus this sensitization does not require a filter to exclude the red. A yellow or yellow-green filter might provide still better detail by excluding the blue and violet.

"The Eastman Company supplies both 548-GH and 549-GH (as well as other spectroscopic emulsions) in both films and glass plates, in several sizes, and with the antihalation backing that is so important for solar work (backing should be specified in the order).

"The Type 548-GH plates are also sold as a regular commercial product under the name Kodak High Resolution Plates. These are not backed, however, and the price is about twice that of the corresponding spectroscopic 548-GH plates.

"In using these emulsions it is particularly important to remove all dust from the plate or film holders before loading, and to brush the plate lightly before closing the holder. The high contrast and resolution of the emulsions make even the smallest dust spots particularly noticeable. Development is best done in a tray with a deep yellow safelight. The emulsions will stand a great deal of exposure to such a light after they are wet, and with a little experience one can learn to judge the state of development by viewing the wet plate with the light behind it. To assure uniform development, first soak the plate or film in distilled water about one minute. Develop in Eastman D-19; exposure should be such that the desired density is reached in about five minutes, but I have obtained good results in underexposed negatives by developing as long as 40 minutes. Rinse in water, fix in acid fixer and wash thoroughly as usual. Water and solutions should be at about 68 degrees Fahrenheit.

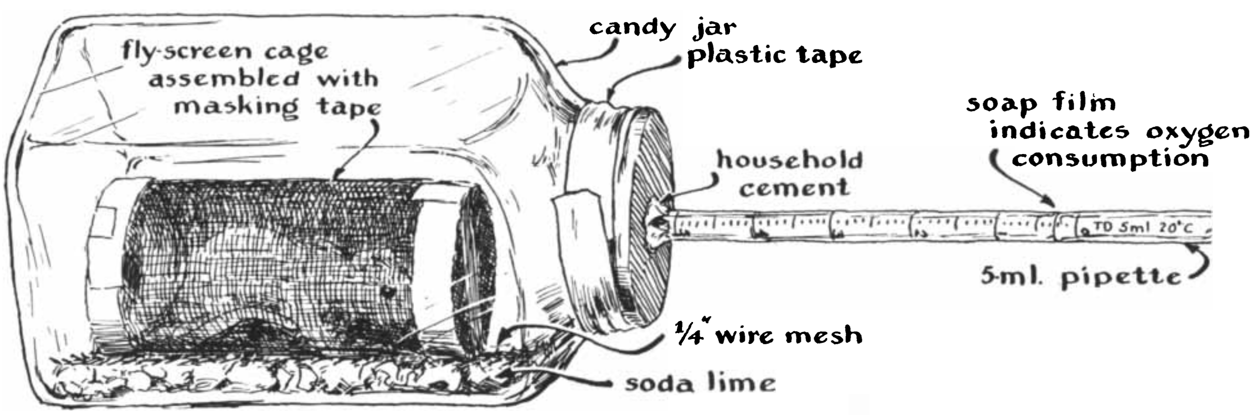
"Solar photography, like all astronomical experimentation, is good fun. But let me close on a note of caution. Nothing could seem quite so harmless as a small telescope, and the instrument always attracts visitors of all ages who are ready to seize on any brief opportunity to peek through the eyepiece. The consequences of such a look at the sun hardly needs emphasizing. I never leave a telescope unattended, even for a minute, when the sun is up. I have found that it makes a healthy impression on an audience to stick a piece of paper into the beam at the exit pupil of the eyepiece and let them see it explode into flame. In this connection it should be noted that the use of a dark filter-glass near the focus for visual observation of the sun is a dangerous procedure. If the glass cracks, the eye is likely to be permanently damaged."

Robert Lawrence and Henry Soloway, students at the State University of New York College of Medicine in Brooklyn, write: "The apparatus for measuring the metabolism of mice described by Nancy Rentschler in your department for August is most interesting. We suggest, however, that comparable results can be achieved with the much simpler apparatus devised by D. T. Watts and D. R. H. Gourley of the University of Virginia Department of Medicine.

"In this apparatus, the rate at which oxygen is consumed by the animal in the test chamber is indicated by the movement of a soap bubble through a calibrated pipette connected to the chamber [*see illustration below*]. Exhaled carbon dioxide is absorbed by a layer of soda lime on the bottom of the chamber.

"The setup consists of a wide-mouthed jar of approximately half-gallon size fitted with a screw cap into which a graduated pipette is sealed with model cement as shown. The calibrated portion of the pipette which extends outside the cap should have a volume of five milliliters. In operation the jar is placed on its side and the bottom covered with half an inch of soda lime. A platform of wire screening is placed inside the jar an inch above the corrosive lime. The experimental animal is first weighed (in grams) and then placed in a small restraining cage of wire screening. The ends of the cage are closed with crosses of adhesive tape. The caged animal is then transferred to the platform, the jar capped and the edge of the cap sealed to the jar with Scotch electrical tape. The animal is permitted to rest for 20 minutes.

"At the end of this interval record the room temperature (in degrees centigrade) and the barometric pressure (in millimeters of mercury). The inside of the pipette is then wetted by means of a test-tube brush dipped in Aladdin's Bubble Set diluted with three parts of water. The soap film (which is to serve as the indicator) is applied by dipping the brush into the soap solution and drawing it across the end of the pipette. The film will move down the pipette slowly, in response to the animal's consumption of



A simple apparatus to perform metabolic experiments of the sort described in this department for August

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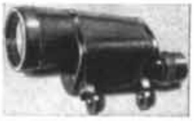

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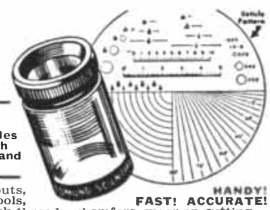

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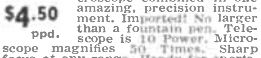

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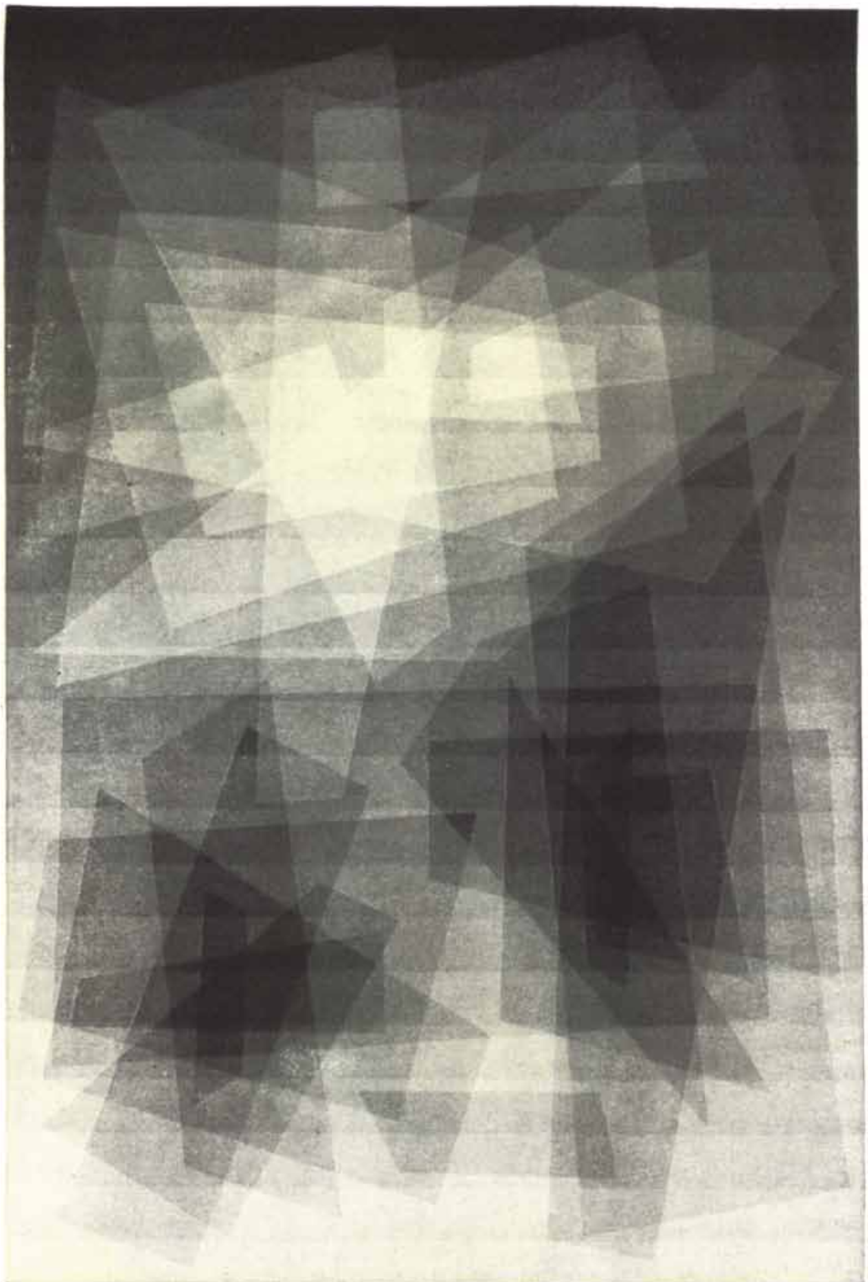
oxygen. Fresh air, to replace the consumed oxygen, flows into the chamber through the pipette and drives the soap film before it. Hence a movement of the film from the zero graduation on the pipette to the five-milliliter graduation indicates that five ml. of oxygen have been consumed by the animal.

"The time required for the soap film to move from the '0' graduation on the pipette to the 'five ml.' is a function of the animal's metabolism. Measure this interval with a stop watch calibrated in 100ths of a minute. Make three such runs, add the three stop-watch readings, divide the sum by three and record the quotient. This is the average time (in minutes) required by the animal to consume five ml. of oxygen. Divide .3 by the average time. This converts the consumption to liters of oxygen per hour. Now multiply the consumption in liters per hour by 273 and divide the product by 273 plus the room temperature expressed in degrees C. This converts the volume of oxygen actually consumed to what would have been consumed at standard temperature (zero degrees C.). Next, a similar conversion must be made to what the consumption would have been at standard barometric pressure. If the barometric pressure of the room is higher than 760 millimeters (standard pressure), multiply the consumption (corrected for standard temperature) by the measured barometric pressure and divide the product by 760. If the measured pressure is lower than 760 mm., then multiply the consumption corrected for temperature by 760 and divide the product by the measured pressure. The consumption is now adjusted to both standard temperature and standard barometric pressure.

"The remaining calculations are equally simple. Look up the logarithm (to the base 10) of the adjusted consumption. Square the recorded weight of the animal, find the cube root of the result and divide it by 1,000. This gives you the surface area (approximately) of the animal in square meters. Look up the logarithm of the surface area, subtract it from the logarithm of the oxygen consumption and, finally, look up the antilogarithm of the difference. This quantity is equal to the liters of oxygen consumed per hour per square meter of surface area at standard temperature and pressure—the measure of the animal's metabolism.

"We hope this procedure, which is much simpler to perform than to describe, will encourage more amateurs—particularly those of high-school age—to undertake metabolic studies."



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BOOKS

Three works about the transition from ancient to modern astronomy

by James R. Newman

THE COPERNICAN REVOLUTION, by Thomas S. Kuhn. Harvard University Press ($5.50). FROM THE CLOSED WORLD TO THE INFINITE UNIVERSE, by Alexandre Koyré. The Johns Hopkins Press ($5). DISCOVERIES AND OPINIONS OF GALILEO, translation and introduction by Stillman Drake. Doubleday Anchor Books ($1.25).

It will never be known when man first became convinced that he was of cosmic importance, but the date this pretension was demolished is clear. The *De revolutionibus orbium coelestium* of Nicolaus Copernicus was published in 1543. Its aim was to improve existing methods for computing the motions of the planets. A narrowly technical work, it was addressed to astronomers who could follow its mathematics. Copernicus proposed a sun-centered system in which the earth had a twofold motion: a daily rotation and an annual orbital revolution. He was aware that this theory, flouting accepted opinion, might stir a tempest. The prefatory letter of *De revolutionibus* to "The Most Holy Lord, Pope Paul III" anticipates that for advancing these views the author could expect "at once [to] be hissed off the stage." He was mistaken. There was not much hissing nor, for that matter, much applause. The book made its mark slowly. Astronomers borrowed its data, computations and diagrams; it was obviously more dependable than Ptolemy's *Almagest* regardless of whether one accepted or rejected as lunacy the notion that the earth moves. It was recognized that Copernicus was a great astronomer and a devout Catholic; therefore he was permitted a harebrained idea that could do little harm. The most favorable of the early reactions to his innovation was typified by this comment of the English astronomer Thomas Blundeville: "Copernicus . . . affirmeth that the earth turneth about and that the sun standeth still in the midst of the heavens, by help of which false supposition he hath made truer demonstrations of the motions and revolutions of the celestial spheres, than ever were made before." But in the end it was the "false supposition" that became the marker of modern thought. Copernicus the orthodox had promulgated a heresy more massive and more consequential than any the Church had yet struck down. Nestled in the mathematics and tables and diagrams was a concept that put man in his place in the cosmos, as Charles Darwin's concept was to put him in his place on earth. It was the harebrained idea that started the revolution. By a simple geometric rearrangement man was dethroned.

Looking backward in history it is easy for us to see that a moving earth and a sun-centered universe gravely subverted Christian theology. If man's abode was not at the center of things, how could he be the king? Kings do not reign from provinces. But Copernicus' hypothesis did not work a revolution overnight. The consequences unfolded slowly in theology and other branches of thought. It took 150 years and the combined exertions of Tycho Brahe, Johannes Kepler, Galileo Galilei, Isaac Newton and many lesser men to construct a coherent model of the universe to replace the Aristotelian model that Copernicus had discredited. Not only were a new astronomy and a new cosmology needed, but also a new physics. And it was not enough to humble man; he had also to be encouraged. He had to find a new source of pride in his ability to interpret the world. To be God's favorite was gratifying, but in some ways it was even more gratifying to make one's own way; magic was good, but discovering nature's laws was better. So the outlook of educated men was changed and modern science was made.

That the Copernican revolution was long in coming and even longer in fulfillment may be seen in the three books under review. Stillman Drake presents a selection, consisting partly of his own translations, from certain lesser known writings of Galileo. (Nothing Galileo wrote should be "lesser known"; this little book is a treasure.) Alexandre Koyré's study deals with the change that took place in 16th- and 17-century thought regarding the boundaries of the universe. Thomas S. Kuhn, a young historian of science who taught for a time at Harvard and is now at the University of California, undertakes the most ambitious task, a history of the Copernican revolution: how it came about, what it overthrew, what it accomplished.

It must be said that the subject has been pretty well picked over by specialists. Herbert Butterfield in *The Origins of Modern Science,* which I reviewed in this department some eight years ago, presented a fresh, penetrating appraisal of Copernicanism. (Kuhn acknowledges his indebtedness to Butterfield.) A. C. Crombie's *Augustine to Galileo* and A. R. Hall's *The Scientific Revolution, 1500-1800,* are but two of many scholarly monographs which address themselves to the topics in Kuhn's book. His telling of the story is nonetheless welcome, for he offers the general reader an illuminating account of the intellectual transformation which laid the foundations of modern science and philosophy, and which may therefore be said to have created the modern world.

The intricacies of ancient and medieval astronomy are a sufficient barrier to the average educated man to prevent him from gaining any but the most general notion of what was involved in the overthrow of the Ptolemaic system. Kuhn handles this part of the history with exemplary skill. Antiquity bequeathed to the medieval world the wonderfully coherent and persuasive theory of the two-sphere universe. This consisted of an interior sphere for man and an exterior sphere for the stars. Between the earth, which was a tiny globe somehow fixed in the exact center of the universe, and the immense rotating sphere carrying the stars, moved the sun and the planets. Outside the sphere of the stars there was neither space nor matter—a void of no concern to God or man. The sphere of the stars rotated steadily westward on a fixed axis once every 23 hours and 56 minutes. The sun moved obligingly in daily revolutions and spiraled sedately eastward on its great track, the ecliptic, tilted at 23½ degrees to the celestial equator; a complete circuit took 365¼ days. From our little perch at the center we could see all this; and the variations which observers in different positions on the globe (*e.g.*, in northern or southern latitudes) might expect to encounter if the theory was correct were in fact encountered. This hypothetical arrangement explained the days and the nights, the changing seasons, the nightly procession of the stars. It was a coherent conceptual scheme which provided a compact summary of a huge quantity of observational data. To this day navigation and surveying are taught by means of the two-sphere model.

If the sun and stars were all we could see in the sky, the two-sphere universe might still be acceptable. But the planets (among which the Greeks included the sun and moon) raise difficulties. Planets—the term comes from the Greek word meaning wanderer—have a complex motion. They have a westward diurnal motion with the stars, and they all move gradually eastward among the stars until they return more or less to their original positions. So far so good. But now individual irregularities appear. The moon travels around the ecliptic faster and less steadily than the sun; and while the moon's phases, being easily visible, are the oldest of all calendar units, the simple lunar unit soon turns out to be intractable because successive new moons may be separated by various intervals between 29 and 30 days. The remaining planets of ancient astronomy—Mercury, Venus, Mars, Jupiter, Saturn—all have different periods; moreover, in each case the time required for any single journey may be quite different from the average period. Not only is the rate of motion irregular, but also planets appear to have moments of indecision: their normal direction of motion (except for the sun and moon) is eastward, but occasionally the journey is interrupted by brief intervals of westward or "retrograde" motion. Sometimes when a planet retrogresses it increases in brilliance; Mars, for example, when it is 180 degrees across the sky or "in opposition" to the sun, outshines everything in the night sky except the moon and Venus.

How were these phenomena to be explained? The behavior of the planets was of less interest to ancient peoples than that of the sun and moon; but, as astronomy grew up, more and more attention was directed to the mysterious ways of the wanderers. Indeed, it was this group of problems which formed the principal source of the Copernican revolution.

The Greeks proposed a model of interlocked concentric spheres to explain the several planetary motions. This device, invented by Plato's pupil Eudoxus, was a central feature of Aristotle's astronomical system, the most comprehensive and influential cosmology of the ancient world. In fact, the notion that the planets are embedded in rotating spheres persisted to the 17th century, and the "orbs" of Copernicus' *De revolutionibus orbium coelestium* are none other than Eudoxus' spherical shells. But even in antiquity it was recognized that the model fell short of "saving the appearances." Since the spheres were concentric with the earth, the distances of the planets from the earth could not vary, and it was therefore impossible to account for the variation in planetary brilliance.

Two Greek astronomers and mathematicians, Apollonius and Hipparchus, were the leading proponents of the celebrated epicycle-deferent mechanism which came to replace the concentric spheres. In its simplest form this arrangement envisaged a small circle, the epicycle, which rotates uniformly about a point on the circumference of a second rotating circle, the deferent. The planet rides on the epicycle, and the center of the deferent coincides with the center of the earth.

Both the epicycle and the deferent are imagined to lie in the plane of the ecliptic (the great circular track of the sun), so that the rotation of the stellar sphere carries the entire system, except the central earth, through one rotation per day. Thus the mechanism mirrors the diurnal motion of the planet.

To describe the motions of the planets a separate epicycle-deferent system had to be designed for each. The loops described by the planets varied in size, depending on the relative proportion of epicycle to deferent, and in number, depending on the rate of rotation of the epicycle with respect to the turning speed of the deferent. The Jupiter diagram showed 11 loops for each trip, the Saturn diagram 28, and so on. But by means of these variations the system of compounded circular motions could be made to describe fairly accurately all the vagaries of planetary motions—the retrogressions, the irregularities in time of successive journeys around the ecliptic, and kindred anomalies. The mechanism was a triumph of imagination.

To be sure, improvements in sky-watching brought new problems. As more was observed, more had to be explained. But the system was versatile and by elaboration could be made to satisfy the demand for increased accuracy of prediction. Minor epicycles were added—as many as a dozen in a single system—to account for small irregularities of motion.

Other devices introduced to correct discrepancies included the "eccentric," which was a deferent circle whose center is displaced from the center of the earth, and the "equant." This was an arbitrarily chosen reference point for measuring the rate of rotation of a deferent or other planetary circle. By placing this point at a locus displaced from the geometric center of the deferent, and requiring the rate of rotation to be uniform not with respect to the deferent's own geometric center but with respect to the equant, the planet, observed from the center of its deferent, seems to move at an irregular rate. This feature helped to smooth out wrinkles in the theory. Not all these improvements were Ptolemy's, but his was the chief contribution. The *Almagest*, epitomizing the greatest achievements of ancient astronomy, "was the first systematic mathematical treatise to give a complete, detailed and quantitative account of all the celestial motions."

"For its subtlety, flexibility, complexity and power," writes Kuhn, the epicycle-deferent technique "has no parallel in the history of science." And yet, as he says, it never quite worked. Apollonius' initial conception solved the main problems of planetary irregularities. Hipparchus tightened up the method. Ptolemy advanced it by his brilliantly ingenious orchestration of deferents, eccentrics, epicycles and equants. His successors, by patching and stretching, made further improvements. But always the theory fell a little short of the results of observation, always the promise of a final solution proved a will-o'-the-wisp.

Why, then, did the two-sphere universe and the model of wheels upon and within wheels survive for 1,800 years? Or, to put it differently, why was the Copernican revolution so long delayed, and what finally brought it about? These are the questions to which Kuhn devotes a major portion of his work.

The main line of his analysis runs somewhat as follows. To abandon Ptolemy meant much more than merely to abandon a system of astronomy. The two-sphere universe was a grandiose and beguiling interpretation of nature and of man's place in it. It was a guide to

problems of the earth—the behavior of falling bodies and the flight of an arrow—as well as those of the heavens; it had religious and philosophical as well as scientific meaning. In the Aristotelian theory of motion, matter remained at rest in the absence of a force pushing it; every terrestrial body had a terrestrial home of its own, a "region natural to it," which the body strove to regain whenever it had been displaced. "Place," as Aristotle said in his *Physics*, "exerts a certain influence"; it possesses "distinct potencies." From his terrestrial physics Aristotle derived support for the notion of the earth-centered universe, for the sphericity, stability and central location of the earth. An entirely new theory of motion had to be invented before the theory of a rotating earth could be made plausible. Otherwise, for example, why would a stone thrown straight up in the air hit the ground at the very spot it was thrown from, instead of being left behind by the earth?

The long-accepted Aristotelian concept of space also buttressed the earth-centered scheme. Matter and space, it was said, are inseparable. Nature detests vacuums; every corner of the universe is full. Beyond the last crystalline sphere, carrying the stars, there is no matter, and therefore no space. It follows that the universe is finite. Being finite it must have a central point: here sits the earth. On the other hand, if the universe were infinite, it is "scarcely plausible that all the earth, water, air and fire . . . should have aggregated at one and only one point." In an infinite universe one may assume the existence of other worlds, with plants, men and animals. Thus the earth's uniqueness vanishes. Obviously this cannot be permitted.

There were of course philosophers both in antiquity and the Middle Ages (notably the great poet Lucretius and the 15th-century cardinal, Nicholas of Cusa) who believed that the universe is infinite. But until the 17th century no one who advanced this view was able to back it up with a cosmology that fitted the everyday phenomena of earth and sky as well as Aristotle's. By the 14th century medieval scholars nonetheless began to chip away at the Aristotelian foundations. The meticulous study of his texts exposed inconsistencies. More and more we are coming to recognize how much we owe to the scholastics, not for their ideas but for their venturesomeness and faith in reason. In Paris Nicôle Oresme showed the weakness of the arguments for the uniqueness of the earth and the assertion that it is stationary. His skepticism spread to Oxford and later to Padua, where Copernicus studied and Galileo taught. The impetus theory (*i.e.*, that a moving body is "impressed" with a certain impetus or motive force which keeps it going until the resistance of the air stops it) invented by Oresme's teacher, Jean Buridan, opened a major breach in Aristotelian dynamics. The theory even took care of the puzzle of the falling stone: If the earth rotated, it endowed the stone with impetus, so that it would not be left behind but would land at the point of departure.

Political, economic, social and religious ferment facilitated acceptance of the innovations of Copernicus. The Moslems were again on the rampage. The feudal order was cracking. A new commercial class was entering the lists of society. Luther and Calvin were shaking the Church. There was a hunger for fresh ideas, an impatience with the old. Even humanism, the "dominant learned movement of the age" helped set the stage for the Copernican revolution. The humanists condemned the values of science, which, they said, helped in no way toward a happy life; they bitterly opposed Aristotle as the prophet of all they detested. Yet their "other-worldliness" and mysticism also stimulated scientific thought. For as Kuhn points out, Copernicus, Galileo and Kepler seem to have drawn from Neoplatonism "two decidedly un-Aristotelian ideas: a new belief in the possibility and importance of discovering simple arithmetic and geometric regularities in nature, and a new view of the sun as the source of all vital principles and forces in the universe." All great scientists are poets; many are mystics. Copernicus was both—though not to the same extent as Kepler. It was the mathematical disorder of the Ptolemaic system that deeply distressed him. Esthetic feelings directed his preferences as to the motions of the planets: they had to be circular and uniform. A geometric harmony characterized the sun-centered astronomy. As Bertrand Russell has said, *De revolutionibus* is not a modern book; it is Pythagorean. And yet it broke completely with the past.

Kuhn sketches the content of *De revolutionibus* and explains why its influence grew despite its inaccuracy, complexity and inconsistency. Copernicus' system was neither simpler nor more dependable than Ptolemy's. Its radical hypothesis had no immediate pragmatic value. But it made a start towards a new astronomical and cosmological tradition, which Newton brought to a triumphant culmination. Protestant theologians clawed at Copernicus even before 1543. Martin Luther called him an "up-

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This mockup of the pressurized water reactor for the nation's first full-scale civilian nuclear power station, being built at Shippingport, Pa., rises four stories tall at Bettis Atomic Power Division. The full-size model is shown when it was under construction. The Shippingport Atomic Power Station is being built as a joint venture of the United States Atomic Energy Commission and the Duquesne Light Co. Westinghouse is developing the nuclear components under a contract with the AEC. Duquesne Light Co. will operate the station.

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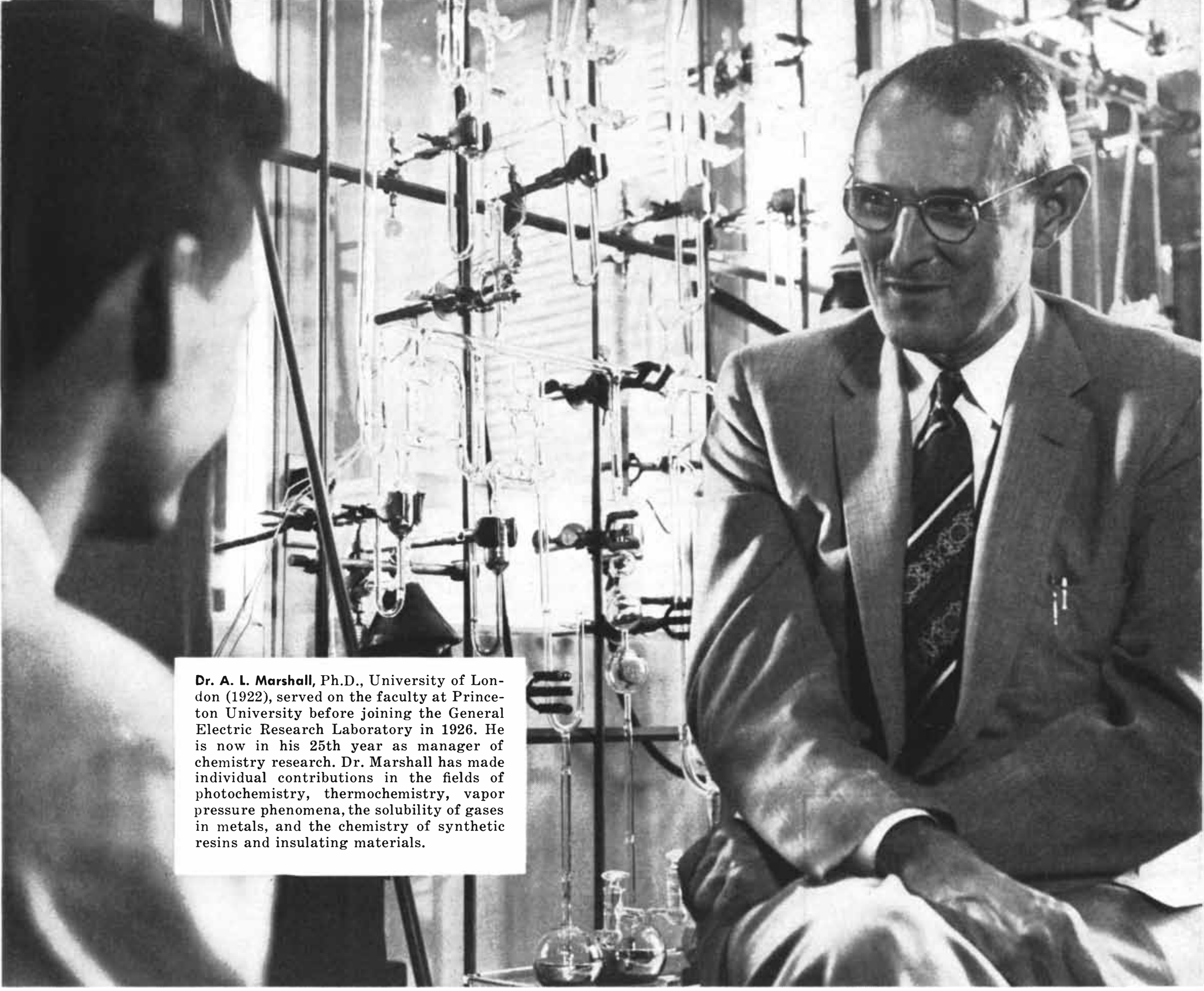
start astrologer" and a "fool"; Melanchthon said he was indecent, dishonest, a charlatan. The Catholic Church was more forbearing; it was not until Galileo began to make fools of those who clung to Aristotle and Ptolemy that *De revolutionibus* was placed on the Index and Copernicanism became formal heresy.

Kuhn's account of these matters, of the gradual assimilation of Copernican astronomy, and the evolution of the new universe is on the whole well-managed. He is a better writer when he sticks to science than when he tackles philosophy. He indulges in the not always happy device of emphasizing his points by casting them as paradoxes. History is not so conveniently dramatic; complex cultural transitions of the 16th century which are most difficult for us to understand today are not necessarily made plain by flights of dialectical virtuosity. One does not come away from Kuhn with a sure sense of why Copernicus' work caused such an enormous upheaval. Yet in Kuhn's approach, apart from its strong expository merits, there is encouraging evidence of a fresh turn in the study of the history of science. He is not afraid to examine his subject in breadth, to trace its connections with other features of society. This is surely the way to teach the history of science, if it is to take its place in the educational curriculum as more than either a graduate-school specialty or an agreeable alternate to courses in music appreciation.

Koyré's study is an example of the orthodox approach—the history of science in the same case as the study of Coptic texts. The subject matter of his book is far from trivial. Nothing, one might suppose, would be more engrossing than the story of how men came to believe in an infinite universe. And Koyré has the learning and experience required to trace this evolution in thought. Unfortunately what he lays before us is little more than a wordy examination of texts. What did Giordano Bruno think of the principle of plenitude? What was Henry More's second argument against the Cartesian concept of reciprocity of motion? Why did he regard Spirit as a "substance penetrable and indiscernible"? How was Joseph Raphson influenced by Spinoza without ever becoming Spinozist? The sight of the heavens, Plato has Timaeus say, made men wonder about the universe and themselves, created number and the concept of time, and was the source of all philosophy, "than which no greater good ever was or will be given by the gods to mortal man." But the men portrayed by Koyré—though Newton, Kepler, Galileo, Berkeley, Leibniz are in the company—appear mainly as logic choppers. They do not wonder; they make nests of word boxes which they crawl into and cannot get out of; they duel with quibbles. The extracts from the lovely writings of Galileo, the quotations from Newton's famous *Queries* attached to his *Optics* are not improved by Koyré's paraphrases and underscorings. Koyré's exegetic text runs to 256 pages, gravid with footnotes. It touches upon few of the rich aspects of science as a human struggle.

A final word about Drake's delightful volume. He has included translations of *The Starry Messenger, Letters on Sunspots, Letter to the Grand Duchess Christina* and excerpts from *The Assayer.* Two of these short works have never before appeared in English; the other two have been translated but are very hard to find. The translations are "free," and since the book is pointed to the general reader, mathematical sections have been omitted. Drake has prefaced each translation with a helpful introduction. Galileo was an incomparable expositor and polemicist. In these pieces he tells us what he saw through his telescope—the features of the moon, sunspots, the satellites of Jupiter; he announces the principle of inertia; he defends Copernicus and demolishes his detractors; he issues his famous manifesto for scientific method. The reader will, I think, be left in a happy frame of mind if I conclude this review by a specimen of Galileo's wit:

"If Sarsi wants me to believe with Suidas [a Greek lexicographer of the 10th century] that the Babylonians cooked their eggs by whirling them in slings, I shall do so; but I must say that the cause of this effect was very different from what he suggests. To discover the true cause I reason as follows: 'If we do not achieve an effect which others formerly achieved, then it must be that in our operations we lack something that produced their success. And if there is just one single thing we lack, then that alone can be the true cause. Now we do not lack eggs, nor slings, nor sturdy fellows to whirl them; yet our eggs do not cook, but merely cool down faster if they happen to be hot. And since nothing is lacking to us except being Babylonians, then being Babylonians is the cause of the hardening of eggs, and not friction of the air.' And this is what I wished to discover. Is it possible that Sarsi has never observed the coolness produced on his face by the continual change of air when he is



Dr. A. L. Marshall, Ph.D., University of London (1922), served on the faculty at Princeton University before joining the General Electric Research Laboratory in 1926. He is now in his 25th year as manager of chemistry research. Dr. Marshall has made individual contributions in the fields of photochemistry, thermochemistry, vapor pressure phenomena, the solubility of gases in metals, and the chemistry of synthetic resins and insulating materials.

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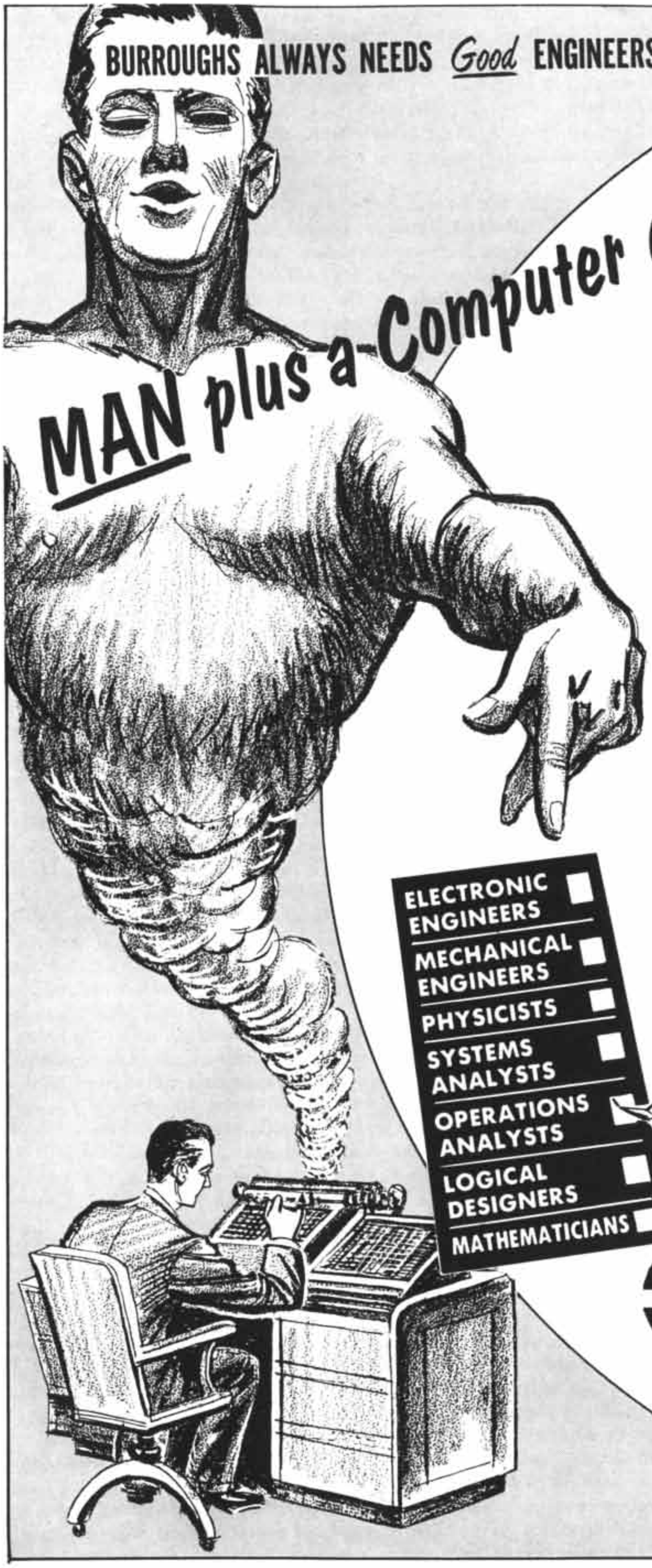
riding post? If he has, then how can he prefer to believe things related by other men as having happened two thousand years ago in Babylon rather than present events which he himself experiences?"

Short Reviews

ATLAS OF THE BIBLE, by L. H. Grollenberg, O.P. Thomas Nelson and Sons ($15). Father Grollenberg's atlas is a book of great worth. He uses three media to impart an immense amount of information about the Bible: maps, photographs and an attractive historical text. The colored maps, of which there are 35, illustrate the different periods of Biblical history, and show all the Biblical places which can be identified with any degree of certainty, from Abel-beth-maacah to Zorah. The maps are uncluttered and, thanks to an excellent system of symbols and overprinted legends, convey a clear sense of Biblical geography not to be gained from any other source. The photographs, which are linked with the maps, are taken from the air and the ground and give a vivid panorama of Palestine and the other lands of the Fertile Crescent. Many things in this fabled region have remained unchanged through 2,000 years; by means of these pictures the reader is carried back in time and the ancient setting is recreated. The text carries the story along and answers the countless questions that arise in the minds of readers of the Bible–questions that usually remain unsolved because they require searching through innumerable reference works, many of contradictory tendency. Father Grollenberg's book embodies the results of the most up-to-date researches of archaeology, linguistics and cartography. He is a responsible guide who, while recognizing the diversity of views on many points, does not overburden his work with academic minutiae. For all who are interested in the Bible and its history this atlas will give many hours of pleasure and instruction.

THE QUATERNARY ERA, by J. K. Charlesworth. Edward Arnold Ltd. and St. Martin's Press, Incorporated ($50). This massive work, to which Professor Charlesworth of Queen's University, Belfast, devoted 35 years, is a survey of all existing knowledge concerning the latest and shortest but, from man's standpoint, the most dramatic and important of the geological periods. The Quaternary was marked by a great glacial period when Europe and America lay under ice, by erosion which shaped mountains and valleys, by changes in the earth's crust and violent earthquakes and volcanoes, by the formation of the earth's soil. During the Quaternary today's climate and the present boundaries between land and sea were established and man himself made his bow. The study of Quaternary geology is only 100 years old, but its literature is huge. The author has gone through it and presents the present position, assessments and conflicts of opinion on a vast array of topics, including snow, glaciers, land ice, ice motion, sea ice, glacial erosion, the formation of cirques, U-shaped valleys, fjords and föhrdes, glacial deposition, glacial effect on scenery, volcanic and tectonic activity, Pleistocene meteorology and climatology, Pleistocene life, early man, Pleistocene stratigraphy, effect of the glacial period on life, postglacial climatic changes, cause of the glacial period, Quaternary chronology. Among the most valuable features of this admirable monograph are a 100-page index and a bibliography which contains thousands of items.

RADIATION: WHAT IT IS AND HOW IT AFFECTS YOU, by Jack Schubert and Ralph E. Lapp. The Viking Press ($3.95). It is unlikely that the average reader has the patience required to go through this entire book, and yet it is hard to imagine a study the general content of which is more necessary for the making of intelligent decisions affecting not only the welfare of the individual but also the very survival of the human species. Schubert is a biologist and chemist who has specialized in the subject of radioactive poisons; Lapp is a nuclear physicist and publicist who has written and lectured on various aspects of atomic energy. The product of the collaboration is a careful survey of radioactivity: the discovery of the phenomenon, the invention and development of devices to detect radiation, the misuse of radiation, how it affects the cells of living organisms and disturbs the mechanism of heredity, the hazards of fallout from atom bomb tests, the safeguards which will have to be established in research, in clinical medicine, in industry and in other spheres if we are ever to gain the benefits of atomic energy without endangering the human population. The book requires no specialized knowledge, but it contains information of which many specialists are apparently ignorant, or at least find it expedient to brush under the rug. This book is too long to serve its popular educational purposes ideally; its profuse de-



Teamwork is an essential ingredient of all successful activity, be it between man and man, man and beast or man and the machinery which his mind creates. The man-computer team is the latest of modern industry's unbeatable combinations. Separately, each is restricted in scope of activity and accomplishment. Together, as a working team, they add up to nothing less than a giant.

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tail and copious quotations from sundry investigators are at times likely to bewilder the reader. But it is an honest, comprehensive and searching report, whose main points, if more widely disseminated and understood, might avert much suffering and save countless lives.

THE TESTIMONY OF THE SPADE, by Geoffrey Bibby. Alfred A. Knopf ($6.75). So many popularizations of archaeology have been published in the last few years that reviewers' heads begin to spin, and general readers exhibit symptoms of shard shock. It would be a pity if Geoffrey Bibby's book fell victim to these reactions, because it is one of the best surveys of its kind. Planned and written as a companion to *Gods, Graves and Scholars* (put out by the same publisher), *The Testimony of the Spade* covers the reconstruction by renowned diggers and interpreters of the early history and prehistory of Europe. The first toolmakers, cave painters, mammoth and reindeer hunters are part of the story; also Swiss lake villages, the kitchen-midden people, the first farmers, Skara Brae (the Pompeii of North Britain), Stonehenge, Maiden Castle, the Sun Chariot of Trundholm, Sutton Hoo, the Polish Iron Age town of Biskupin, and the "bodies in the bogs"—"better preserved than any Egyptian Pharaoh." A practicing archaeologist on the staff of the Prehistoric Museum at Aarhus in Denmark, Bibby knows how to guide his audience through the subject. He has good taste and writes with humor. His book stands well above the crowd.

SPACE, TIME AND CREATION, by Milton K. Munitz. The Free Press ($3.75). THEORIES OF THE UNIVERSE, edited by Milton K. Munitz. The Free Press ($6.50). These two volumes survey the history of cosmology, from the *Enuma elish*, the Babylonian epic of creation in which the ingenious and indefatigable Marduk vanquishes chaos and establishes an ordered universe, to the cheerful system of Fred Hoyle, who assures us that by virtue of continuous creation the universe will last forever. Four main stages may be distinguished in the development of man's wonderings about the nature of the cosmos: the pre-Socratic and Pythagorean notions; the classic views of a geocentric, finite universe; the grand cumulative Copernicus-Galileo-Kepler-Newton-Kant-Herschel conception; the intricate contemporary models spun from the news gathered by the great telescopes and the fantasies of mathematical physicists. Each stage is represented in the second of these books by selections from the writings of noted contributors to cosmological thought. In *Space, Time and Creation* Dr. Munitz, associate professor of philosophy at New York University, presents an unpretentious, admirably clear exposition of the philosophical aspects of scientific cosmology. He considers questions of logic (*e.g.*, does it make sense to say that the universe had a beginning, or is finite or infinite in its dimensions?); he examines the nature of concept formation and of scientific theory; he discusses the meanings of the term "the universe" and the relation of cosmological models to the data of observation. Concepts of physical space and different views of world geometry are analyzed. Critical assessments are made of various methods and principles of cosmological inquiry, and of the world theories of Albert Einstein, Hermann Bondi, E. A. Milne, Edwin P. Hubble, W. H. McCrea and others. Dr. Munitz's essay succeeds in breaking down a forbidding subject into a group of live, engrossing questions intelligible to the educated nonspecialist. Together his two books should be a treat for a wide circle of readers.

THE BIRDS OF THE BRITISH ISLES: VOL. VI, by David Armitage Bannerman. Oliver and Boyd (63 shillings). The sixth volume of this fine natural history deals with two orders: the Ciconiiformes (storks, spoonbills, ibises, herons, egrets, bitterns, flamingos) and with some of the Anseriformes (swans, geese, shelducks, surface-feeding and diving ducks). Readers acquainted with the earlier volumes will know what excellent fare to expect: Dr. Bannerman's authoritative treatment of appearance, occurrences, migrations, distribution, habits, all very leisurely and readably presented, with an abundance of firsthand field detail and diverting anecdotes and attractive reproductions (26 in this volume) of paintings by the late George E. Lodge. There are few bird books so eagerly awaited, so pleasurable and so informative as the installments of Bannerman.

THE VALIDATION OF SCIENTIFIC THEORIES, edited by Philipp G. Frank. The Beacon Press ($5). In this volume are collected a number of papers presented at a conference entitled "The Validation of Scientific Theories," held in 1953 as part of the annual meeting of the American Association for the Advancement of Science. One of the major topics which the participants considered is the present state of operationalism—a concept emphasizing the need of recourse, wherever

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Here members of the Aerothermodynamics Staff discuss heating of jet control surfaces. Left to right: W. E. Brandt, thermodynamic analysis; M. Tucker, Aerothermodynamics Department head; R. L. Nelson, project aerodynamics; B. W. Marsh, aerodynamics; J. I. Osborne (back to camera), aerodynamics.

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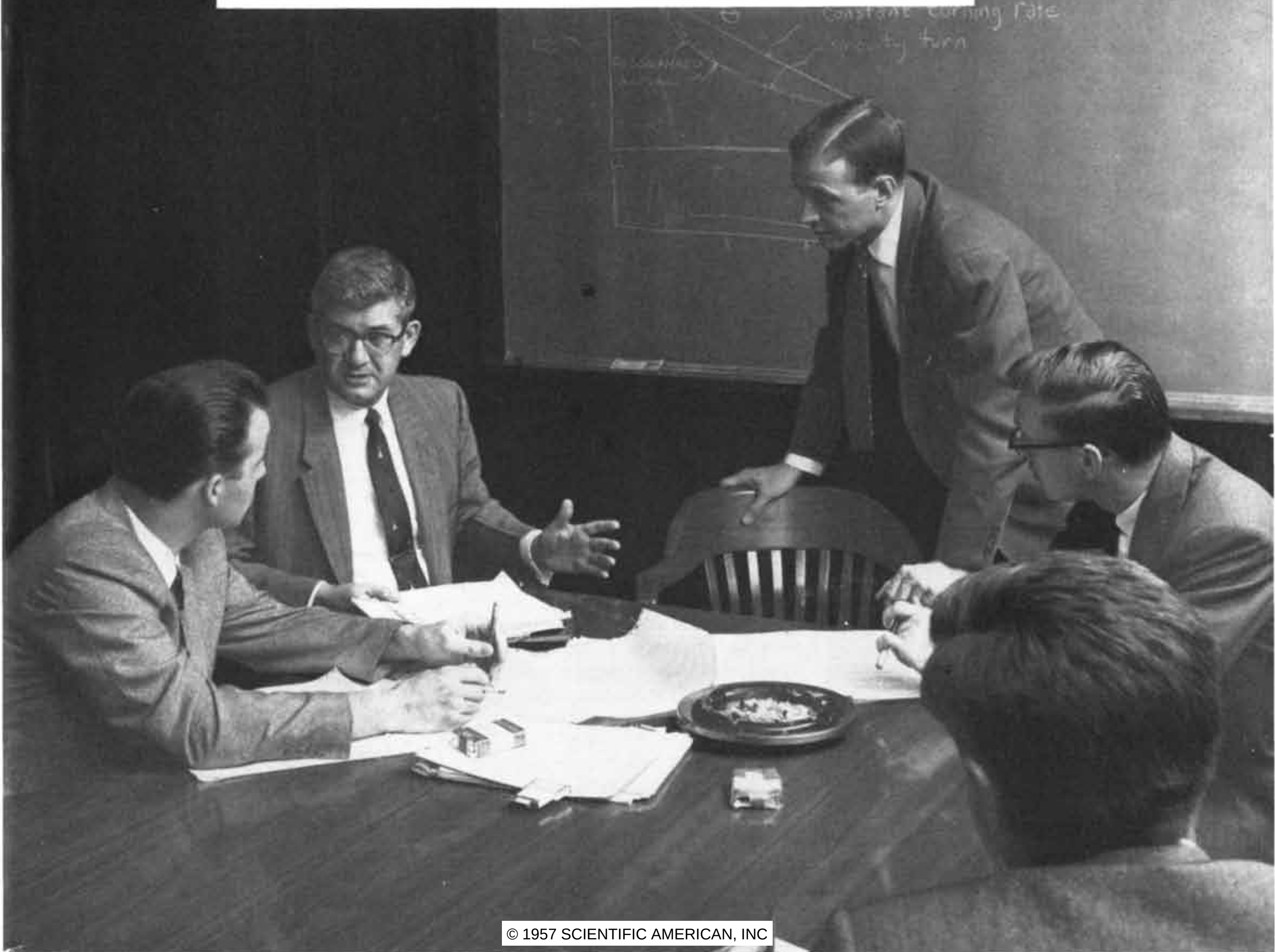

feasible, to "instrumental procedures" when meanings are to be established. This concept was introduced, at least in its modern form, in Percy Bridgman's celebrated manifesto *The Logic of Modern Physics.* Other subjects include the scientific status of psychoanalysis, organism and machine, and science as a social and historical phenomenon. Several of the papers on the methodology of science sparkle and excite reflection; the majority are competent examinations of fundamental questions to which neither the general reader nor the professional scientist can be indifferent.

Notes

Thermodynamic Properties of the Elements, edited by the Staff of *Industrial and Engineering Chemistry.* American Chemical Society ($5). A collection of tables of thermodynamic data: heat capacity, heat content, entropy and free energy function of the several states of the first 92 elements.

Die Theorie der Gruppen von Endlicher Ordnung, by Andreas Speiser. Birkhäuser Verlag (26 Swiss francs). The fourth edition of this standard mathematical monograph on the theory of groups of finite order has been corrected and contains new material on the visual presentation of groups.

Non-Stable Stars, edited by George H. Herbig. Cambridge University Press ($5.50). Twenty-three papers on non-stable stars presented at a symposium held in connection with the 1955 assembly of the International Astronomical Union in Dublin.

Neutron Transport Theory, by B. Davison, with the collaboration of J. B. Sykes. Oxford University Press ($12). A comprehensive account of the principal mathematical methods used in the theory concerned with the migration of neutrons through bulk media.

Alcoholism, arranged and edited by Harold E. Himwich. American Association for the Advancement of Science ($5.75). Some 20 papers on basic aspects and treatment of alcoholism are presented in this symposium held under the auspices of the American Association for the Advancement of Science in cooperation with the American Psychiatric Association and the American Physiological Society. The essays discuss, in addition to medical topics, psychiatric and sociological questions of this important and complex disorder.

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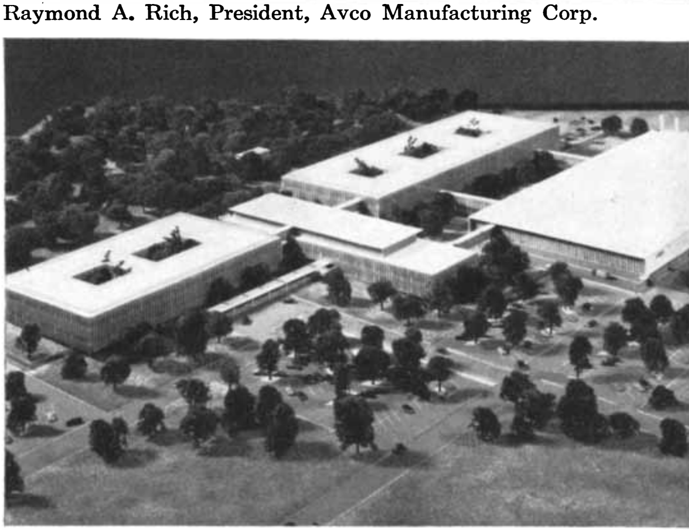

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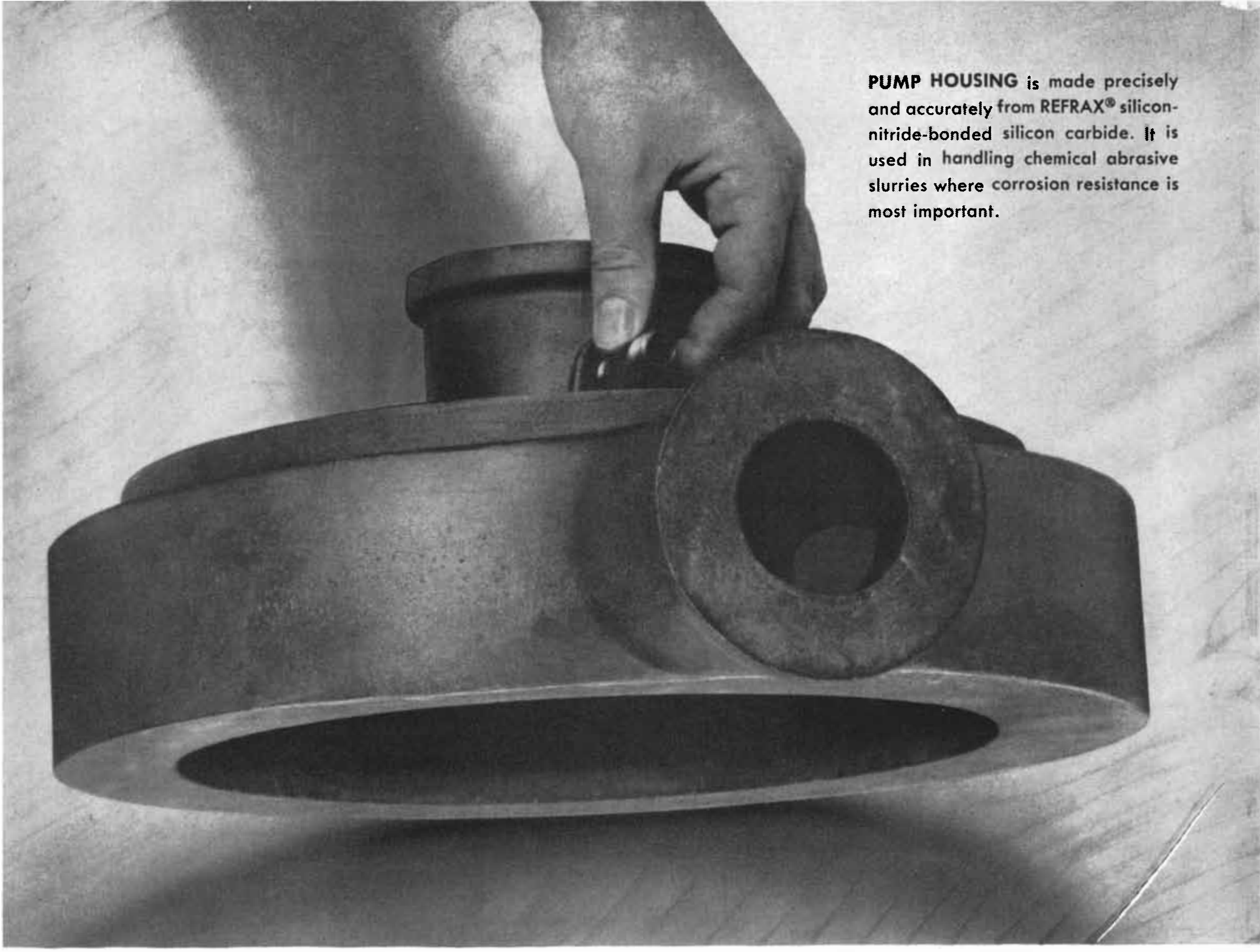

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