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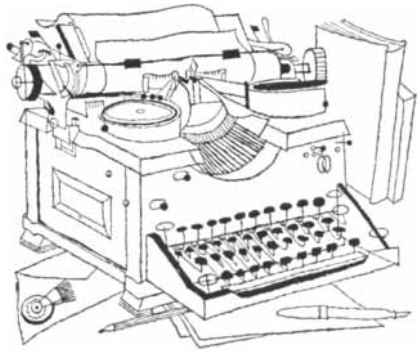

LETTERS

Sirs:

I greatly enjoyed John E. Pfeiffer's article "Symbolic Logic" in your December issue. The article nonetheless possesses one irritating feature. It presents a long logical problem involving a mathematician, a bus, whisky, and Mozart, and then leaves the reader with the exasperating statement that he "is advised not to try to work out the solution." Surely you cannot get away with this. What is the answer?

ROBERT S. HAHN

New York, N. Y.

Sirs:

By now you are no doubt snowed under with requests for the solution to the Pitts conundrum. . . .

This article brought about my first collision with symbolic logic and due to the clarity with which Mr. Pfeiffer expressed his ideas I was able to unriddle the conundrum in an hour and a half, the first hour of which was spent in experimenting with the symbols and transformations. . . .

Verbally, if a mathematician likes whisky at night he must wait 20 minutes for a bus. . . .

O. F. KRAUSE

Menlo Park, Calif.

Sirs:

. . . The solution which I have arrived at is this: A mathematician must wait 20 minutes for a bus if he likes neither Mozart in the morning nor whisky at night.

CHARLES BOMGREN

Albuquerque, N. M.

Sirs:

Your article "Symbolic Logic" was most interesting to me. . . . Using the few rules set forth in the article, I have attempted a solution to the "mathematician and bus" problem, and have arrived at a solution which I believe to be the only one possible. Not knowing the rules of substitution and transposition of this algebra, I had to resort to a "punch card" method, and set up each "statement" on a separate card. Since I am a revenue agent, I found it easier to substitute someone of that profession for the mathematician. Only one card makes reference to a revenue agent (mathematician) who has to wait 20 minutes for the bus, and this card carries the parallel information that he likes Mozart in the morning. . . .

When must a revenue agent wait 20 minutes for a bus?

If a revenue agent does not have to wait 20 minutes for a bus, then he either likes Mozart in the morning or whisky at night, but not both.

If a man likes whisky at night, then he either likes Mozart in the morning and does not have to wait 20 minutes for a bus, or he does not like Mozart in the morning and has to wait 20 minutes for a bus, or else he is no revenue agent.

If a man likes Mozart in the morning and does not have to wait 20 minutes for a bus, then he likes whisky at night.

If a revenue agent likes Mozart in the morning, he either likes whisky at night or has to wait 20 minutes for a bus; conversely, if he likes whisky at night and has to wait 20 minutes for a bus, he is a revenue agent–if he likes Mozart in the morning.

When must a revenue agent wait 20 minutes for a bus? (The obvious answer, "Every day if he lives in San Antonio," is not the correct one to this problem.) My solution is: A revenue

Scientific American, February, 1951, Vol. 184, No. 2. Published monthly by Scientific American, Inc., 24 West 40th Street, New York 18, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

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agent must wait 20 minutes for a bus if he likes Mozart in the morning. [*The answer to the problem is given in a letter by Mr. Pfeiffer below.—Ed.*]

ALEXANDER B. MORRIS

San Antonio, Tex.

Sirs:

In your article "Symbolic Logic," the proposition $a \supset b$ is transformed into $\overline{\bar{a} \cdot b}$. Should it not be $\overline{a \cdot b}$? Assuming, as proposed, that "if you love cats, then you are a true American," it does not follow that "you cannot be indifferent or hostile to cats and also be a true American." This *would* follow from the assumption proposed in the *next* column, that "*only* cat-lovers are true Americans."

The transformation of $a \supset b$ into $\bar{a} \vee b$ is correct, but its verbal translation "*you do not love cats or you are a true American*" must be understood to mean that either one (or both) of the clauses is (are) true.

J. C. BROWN

Wheeling, W. Va.

Sirs:

I was startled to read the following statement in John E. Pfeiffer's article "Symbolic Logic": "Modern logic has abandoned one of Aristotle's most basic principles: the law of the excluded middle, meaning that a statement must be either true or false." This statement gives the unfortunate impression that modern logic has dispensed entirely with the law of excluded middle. While multivalued logics have been formulated, every example cited by Pfeiffer uses a two-valued logic.

CHARLES E. BURES

California Institute of Technology
Pasadena, Calif.

Sirs:

. . . Mr. Pfeiffer carefully draws our attention to the fact that "The operations of symbolic logic can only show that, given certain premises, certain conclusions are valid and others invalid. . . . The establishment of factually accurate premises is outside the province of logic; its concern is with the validity of the conclusions drawn from a given set of facts or assumptions." Yet on the next page we are told: "Mathematicians are applying symbolic logic to examine some of the basic assumptions upon which mathematical theories have been built—assumptions that have long been taken for granted as 'obvious' but have never been subjected to rigorous anal-

ysis." Surely mathematical assumptions are no more subject to logical analysis than any other assumptions? If we show their derivation from other propositions, they are no longer assumptions; if we do not, logic has nothing to criticize. Mr. Pfeiffer might profitably recall the story of the young Bertrand Russell refusing to study Euclidean geometry because he could not accept the *a priori* definition of a "point"; he wanted even his premises to be deduced from—something.

MARK I. HALPERN

New York, N. Y.

Sirs:

It is good to learn that some readers found the problem of the whisky-drinking mathematician (or revenue agent) as tantalizing as I did.

The answer I obtained is that a mathematician has to wait 20 minutes for a bus when he likes Mozart in the morning.

Mr. Brown is correct in noting that $a \supset b$ is equivalent, not to $\bar{a} \cdot b$, but to $\bar{a} \cdot \bar{b}$.

Dr. Bures' remarks are also well taken. Aristotelian, two-valued logic has by no means been discarded. It is one of an infinity of possible logics, just as Euclid's geometry is one of an infinity of possible geometries.

In stating that symbolic logic is being used "to examine some of the basic assumptions upon which mathematical theories have been built" I did not intend to give the impression that one can demonstrate the truth or falsity of an assumption—an obvious contradiction, as Mr. Halpern points out. All systems rest on assertions that cannot be proved and, among other things, logic examines new assumptions to create new and consistent systems.

JOHN E. PFEIFFER

New York, N. Y.

Sirs:

I should like to correct a rather confusing error in my article "Simple Simon," which appeared in your November issue. In the article appears the sentence: "Selection: Choose the number *a* if there is an indication that *p* and *p* is 1, and choose the number *b* if there is an indication that *p* and *p* is 0."

This sentence should read: "Selection: Choose the number *a* if there is an indication *p*, and *p* is 1, and choose the number *b* if there is an indication *p*, and *p* is 0."

EDMUND C. BERKELEY

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50 AND 100 YEARS AGO

FEBRUARY 1901. "Prof. Pickering of Harvard College Observatory again refers to the need of a large telescope in the Southern Hemisphere to carry on work which cannot be done in the Northern Hemisphere. It is of the highest importance to provide for special work on the extreme Southern stars, and a great telescope installed in some elevated station in the Southern Hemisphere, at Arequipa, Peru, for example, is necessary."

"A fire in the pathological museum of the University of Berlin on January 16 damaged Prof. Virchow's collection of skeletons and other objects."

"Prof. Dewar, in a recent lecture before the Royal Institution, expressed his disappointment that the experiments in the laboratory of the institution had failed to produce pure helium. He said that he longed to find a rich man generous enough to supply funds necessary for the discovery of pure helium; the expenditure would be very great. It is said that his discovery would enable the realization of Lord Kelvin's idea that a temperature within five degrees of absolute zero can be reached."

"The center of the population in the United States is now at a point in southern Indiana about seven miles southeast of the city of Columbus. Since the last census of 1890, the center of population has moved westward about fourteen miles and south about three miles."

"A short while ago an exacting test was made in the open sea of the English Channel, in which the inventor was able to manipulate by means of ether waves and with conspicuous success the movements of a torpedo in any desired direction while it was traveling below the surface. The invention has been inspected by several military and naval experts from all countries, who have expressed the opinion that it is by means of wireless telegraphy that torpedoes will be controlled in the future."

"Long distance wireless telegraphy is about to take an enormous stride both in its reach and rapidity, for we are shortly to be in possession of a means of wireless telegraphic communication across the Atlantic. The feat is to be accomplished by the assistance of that 'oscillator' with which the name of Nikola Tesla is so well identified."

"The United States is now the world's greatest producer of iron and steel and coal, as well as of copper, cotton, breadstuffs, provisions and many other articles entering into the daily requirements of man. In a comparative survey of the world's iron ore situation, the remarkable fact is brought out that the United States in 1899 produced 30 per cent of the world's ore, or 25 million tons out of a total of 85 million tons."

"The discovery of krypton and neon was announced to the Royal Society in the early summer of 1898; and subsequently atmospheric air was found to contain a heavier gas to which the name of xenon was applied. These elements exhibit gradations in properties such as refractive index, atomic volume, melting-point and boiling-point, which find a fitting place on diagrams showing such periodic relations. Since this regularity is similar to that which is found in other elements, we had entertained hopes that the simple nature of the molecules of the inactive gases might have thrown light on the puzzling incongruities of the periodic table. That hope has been disappointed. We have not been able to predict accurately any one of the properties of one of these gases from a knowledge of those of the others; an approximate guess is all that can be made. The conundrum of the periodic table has yet to be solved."

FEBRUARY 1851. "Five years ago, California had a white population of less than 5,000 inhabitants. She is now a state that boasts of a population that numbers almost a half million. Five years since, Monterey, her capital, had only 300 inhabitants. San Francisco today has a population four times as large as the whole state could boast of in 1845. Five years since, California was but little better than a wilderness, while her population confined their ambition almost entirely to the pleasures that spring from scratching and praying. Fifty millions of dollars have already been exported, and millions are monthly sent to different parts of the world."

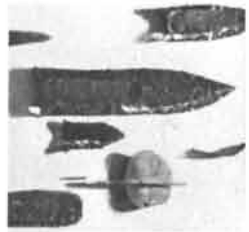
"The British are beginning to awake to the importance of fast sailing ships, to compete with America. It is well known that American ships have taken the trade out of the hands of English houses and that all the fine packet ships running between New York and Liverpool are built in America. The Liverpool *Albion* states that clipper ships are beginning to be built and to supersede all others there."

"The great refracting telescope at Harvard continues to justify the sanguine anticipations originally formed of its superior power and admirable construction. The nebulae, which appear as dim patches of light through ordinary instruments, are separated by the great refractor into brilliant clusters of stars. The measurement of double stars, and the close inspection of the planets, and of comets, when in positions not to be reached by common instruments, have likewise called into use the powers of the great telescope. The great telescope has also revealed to the searching eye of the observer a third ring of Saturn, which had escaped the power of all other instruments."

"In no country in the world is there such a recklessness of life on steamboats as there is in ours. During the past year 67 steamboats were lost on our Western waters, the majority of these losses being caused by explosions. Four hundred and sixty-seven lives were lost, and a great number of people severely injured. The chief quarter for the explosions of steamboat boilers is the Mississippi and its tributaries. On the 13th of last September, the *Anglo Norman* blew up, and two days after that the steamer *Knoxville* exploded at the same place."

"Our moustached friends will be glad to learn that the London *National and Military Gazette* has made the discovery that the wearing of moustaches is conducive to health. It affirms that the moustaches, acting as a part of the breathing apparatus, absorb the cold of the air before it enters the nostrils, and are consequently a preservative against consumption."

"A Parisian inventor thinks he has at last devised a machine for setting type. He has been at work upon it for 15 years, and having completed it, has entered it for exhibition at the World's Fair."



THE COVER

The painting on the cover shows a number of objects associated with early prehistoric inhabitants of the Western Hemisphere (*see page 15*). At the upper right is a fluted projectile point characteristic of the famous Folsom remains. The larger projectile point below it and the smaller one at left center were also made by "Folsom Man." At the upper left is the tip of a projectile point of the Yuma type, contemporary with the Folsom. At the lower left is a fluted Folsom knife. The round object to the right of it was probably used as a gaming piece. Resting on the round object is a bone needle. Near the left end of the needle is the eye end of another. To indicate the scale, at right center is an artifact of modern man.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

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ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

FEBRUARY 1951 VOL. 184, NO. 2

THE EARLY AMERICANS

The pattern of their movements some 10,000 years ago has been outlined by widely scattered clues and new determinations of their age. The second of two articles

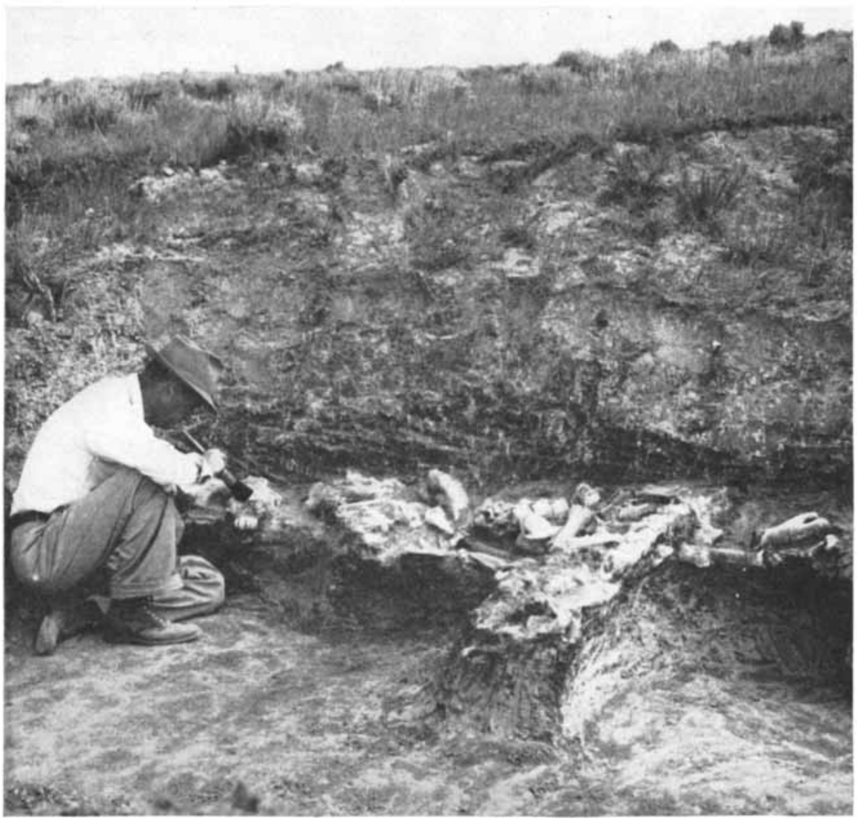
by Frank H. H. Roberts

SINCE there are no great apes in America, and no traces of primitive types of men, it is generally accepted that man did not originate in this hemisphere but arrived as an immigrant from some other part of the world. The homeland of these early immigrants has been the subject of ingenious speculations ever since Columbus and his successors found the New World and its Indian inhabitants. Various scholars proposed that the American Indians were descendants of the lost tribes of Israel, of the Carthaginians, of the Phoenicians or of other ancient peoples of the Old World. Today most investigators agree that the American aborigines must have originated in Asia, for they were markedly similar to some of the eastern Asiatics in certain physical and cultural characteristics. As Ralph Solecki showed in his article in SCIENTIFIC AMERICAN last month, there is now good evidence that America was first populated by wandering groups of Asiatic hunters who arrived by way of Alaska.

So far archaeologists have found re-

ORIGINAL FOLSOM SITE was near Folsom, N. M. There the projectile point at the lower right was found between the ribs of an extinct bison. Many points with the same fluted shape have been found at other sites.

LINDENMEIER SITE near Fort Collins, Col., is one of several where archaeologists found not only projectile points but also tools of stone and bone.



AGATE BASIN SITE in Wyoming yielded artifacts of a culture similar to the Folsom. Here an archaeologist brushes dirt from the bones of a bison.

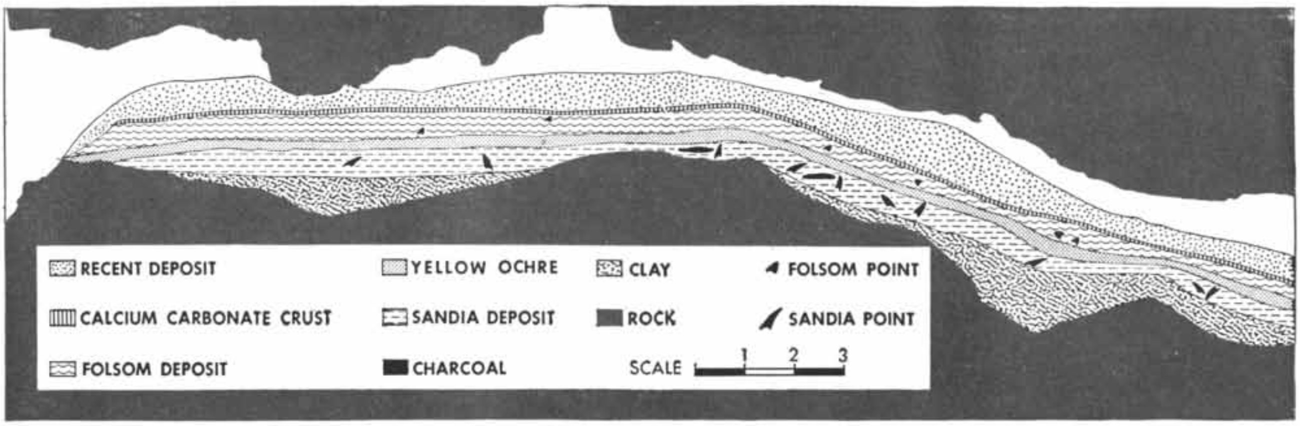
markably little record of these early Americans, or Paleo-Indians. We have no bones to tell us what they were like physically, and very few relics that throw light on their culture. All we have are a few tools and other remains that suggest what they ate and where they found shelter. But the growing accumulations of such finds are beginning to outline at least the pattern of life and the migrations of those early pioneers who settled North America more than 10 millennia ago.

Even before any archaeological remains were discovered, it was evident that man had occupied this continent for a very long time. The variety of physical types among the Indian tribes who lived here when the white man came, their language differences, their various forms of social organization and worship, their domestication of crop plants, their development of arts and industries, their almost perfect adjustment to a wide variety of environments—all this indicated a long period of social evolution and separation from their ancestral origins in the Old World.

THE first generally accepted archaeological evidence of the antiquity of the American Indian was found just 25 years ago. In the summer of 1926 a party from the Denver Museum of Natural History led by Jesse Dade Figgins was digging in northeastern New Mexico. Near the small town of Folsom they uncovered a few stone fragments of some peculiar man-made tools. The tools were evidently very ancient, because they were associated in the same stratum with skeletons of an extinct species of bison. The discovery at once aroused the excited interest of archaeologists. The following summer, at the same quarry, a complete stone projectile point was found. It was lodged between the ribs of an extinct bison. The point had a peculiar and interesting fluted shape. Several fragments of similar fluted stone points were uncovered nearby. By the third summer Barnum Brown, curator of the department of paleontology at the American Museum of Natural History, was busily engaged at the site. He made further finds: more bison skeletons, fluted points and other tools. It was clear that the site on which the Denver party had chanced had once been a bog or water hole where men had hunted game.

These human relics, the earliest that had been found in America, were named Folsom, after the town near which they were discovered. What made them particularly exciting was that geologists identified the deposits in which they lay as belonging to the closing days of the Pleistocene or the beginning of the Recent geologic period—roughly 10,000 to 25,000 years ago.

As often happens in science, this discovery soon led to others of the same



SANDIA SITE near Albuquerque, N. M., is a cave containing both Folsom artifacts and those of an older culture. This cross section shows the levels at which the artifacts were found. The scale is given in feet.

kind. About 170 miles south of Folsom, in an area known as the Black-Water Draw, a party from the University of Pennsylvania Museum unearthed a prehistoric camp site that proved much richer in Folsom material than the original find. Then a Smithsonian Institution party excavated another Folsom camp site at the Lindenmeier Horse Ranch north of Fort Collins, Col., near the Wyoming border. At these two sites and others the investigators discovered not only the characteristic Folsom points but a whole series of other implements, some made of stone, some of bone. They also found evidence that the early Americans had hunted other animals besides bison: the mammoth, the American camel, wild pig, horse, musk ox, extinct antelope and the giant sloth.

Year by year parties of diggers found more and more old stone tools in many parts of North America, not only of the Folsom type but of others apparently related to them. There could be no doubt of the antiquity of these finds. In many cases they were associated with fossils of invertebrates and with charcoal from trees that must have lived in a moister, colder climate than exists at these sites today. The indicated geologic change of climate of course suggested the lapse of considerable time. At the Black-Water Draw and Lindenmeier sites there was evidence that the tools dated back to the closing days of the Pleistocene.

As to the tools themselves, the outstanding feature is a certain peculiarity of workmanship in the projectile points. Most of them have flutings, or shallow channels, chipped lengthwise along their surfaces—a feature which thus far has been found only in North America. In the classic Folsom type many of the points have a fine secondary chipping along the edges; they apparently reflect improved techniques in stone-chipping which reached their peak in the area of the High Plains. The particular group of tools that has been given the name "Folsom complex" consists of a number of projectile points and two kinds of knives, one fluted and the other made of long thin flakes chipped from the fluted forms.

Other types of projectile points, given different names to distinguish them from the Folsom complex, are also fluted but tend to be larger, less carefully made and lack the peripheral retouch. It appears that these larger points primarily were intended for killing larger animals, such as the mammoth. They probably represent an early stage in the development of this type of tool, but this does not necessarily mean that the samples found are older than the Folsom implements. The large crude types may well have persisted for a long time after the more skillful Folsom techniques were developed. As a matter of fact, such tools probably served their purpose so well that their forms continued unchanged through many thousands of years.

The main concentration of the Folsom type of points is in the Western plains, from Alberta and Saskatchewan on the north to southern New Mexico in the south. The larger forms occur mainly in Texas, Oklahoma, Ohio, western Pennsylvania and New York, Virginia, North Carolina, Kentucky, Tennessee and Georgia—that is, chiefly in the eastern half of the continent. One of the principal problems, of course, is to try to work out the relationship between the eastern and western forms, with a view to establishing a sequence of development and migration for early man in North America. There are three sites in Virginia, now being explored, which give promise of yielding some much-needed information on these questions.

Not long after the Folsom discoveries there came a series of equally significant finds in the county of Yuma in northeastern Colorado. Projectile points found there at first were believed to be linked to the Folsom. But further study suggested that they probably belonged to a different complex (culture would be too inclusive a term for the fragmentary remains we have) which lasted much longer than the Folsom. The various Yuma finds, which differ in types among themselves, have now been named for the localities where each was found: Eden, Wyo.; Scottsbluff, Neb.; San Jon, N. M.; Agate Basin in Wyoming; Plainview, Tex.; and Browns Valley in Minnesota. The Yuma types are particularly significant because of their wide distribution. Furthermore, a few of them seem to be at least as old as the Folsom, if not older; the San Jon and Plainview points were found in beds identified as late Pleistocene.

In 1935 a group of Boy Scouts happened on another extremely important site. In a cave in the Sandia Mountains east of Albuquerque, N. M., they found some signs of ancient human habitation. Excavated by parties from the University of New Mexico, the cave yielded not only some Folsom artifacts but evidences of an even older culture. There were three distinct levels of deposits in the cave. The upper contained comparatively recent objects probably predating Columbus. The middle level, sealed off from the top one by a hard crust of calcium carbonate, contained Folsom artifacts and some Plainview points in association with bones of mammoth, bison, giant sloth, camel, native horse and wolf. And in the bottom layer, separated from the Folsom level by a sterile stratum of yellow clay, were found some stone implements and hearths, along with bones of animals. The projectile points in this oldest layer have a notch on the base at one side, like the well-known Solutrean points in the Old World. There are no geologic clues by which to date the deposits in this cave, so it is difficult to say how old the bottom layer may be, but on its face it seems to go back to a culture older than the Folsom.

Of the many other caves that have contributed valuable data, one of the most important is Ventana Cave in the Castle Mountains of southern Arizona.

Excavating parties from the University of Arizona have found there some 15 feet of deposits left by successive waves of inhabitants over a period of several thousand years. In the bottom level, in association with bones of extinct species of horse, bison, giant sloth, tapir, jaguar and wolf, were stone implements very like the Folsom types at the Lindenmeier Ranch, except that the points were not fluted. The upper layers show an evolution from a hunting and food-gathering economy through the acquisition of pottery and agriculture and subsequent agricultural stages to a late pre-Columbian culture. From geologic studies and the fossil evidence it appears that the bottom level dates from late Pleistocene times.

In 1926, the same year as the first Folsom find, Byron Cummings of the University of Arizona discovered some stone implements with the skull of a mammoth in Cochise County in southeastern Arizona. At the time little attention was paid to his find. But about 10 years later the staff of the Gila Pueblo museum at Globe, Ariz., returned to the site and began a systematic study of the area. Eventually they collected a great deal of material, constituting the remains of a culture which they named Cochise. It consisted of three successive stages. The oldest remains were in sand-gravel deposits believed to date back to the end of the Pleistocene. Most of the man-made objects in this layer were grinding or hammering stones, which indicates that the basic economy was food-gathering rather than hunting. There were no projectile points and few knives or scrapers such as hunters use. But in the second and third stages, which followed this, there emerged a number of flaked stone implements and other evidence that hunting had become more important, perhaps as a result of changing climatic conditions. The artifacts in these last two Cochise stages appear to be related to those in the upper levels in Ventana Cave. For that reason it has been suggested that the Cochise and Ventana Cave remains together depict the entire range of artifacts manufactured by the inhabitants of southern Arizona from the earliest stage of the Paleo-Indian to late pre-Columbian times.

SCATTERED across the length and breadth of the country are various other sites which have contributed evidence about the early Americans. Each is an important paragraph or page in the story of the Paleo-Indian, and all of them together give us something of a panoramic view of the human settlement of the continent.

Toward the end of the last Ice Age peoples began to drift into North America from Asia and to overrun the continent through glacier-free corridors in Alaska and Canada. Most of these early migrants lived mainly by hunting. Some time after the end of the Pleistocene Period many of the animals they hunted rather suddenly became extinct. The causes of that extinction are still unknown. Some have suggested that the Paleo-Indian may have had a part in killing them off, both by slaughtering them for food and by introducing Old World diseases to which the animals were susceptible.

We know virtually nothing about the social customs or beliefs of the Paleo-Indians, and very little about their material culture beyond their tools and weapons. We do not even know what they wore as clothing, though sandals found in Oregon show that they did not go barefoot. As hunters they probably made garments, moccasins and even tents of animal skins; bone needles and awls have been found among their tools, and stone knives, scrapers and rubbing stones that could have served for dressing hides are fairly abundant. There is no evidence of any form of Paleo-Indian art, except for some simple scratched designs on a few bits of bone and on fragments of wooden shafts of spears or javelins. The early Americans did have some appreciation of "the finer things of life," however, as evidenced by stone and bone beads and pendants with which they apparently bedecked themselves and by pieces of rubbed hematite and red and yellow ochres, which suggest the use of paint to ornament their bodies and various articles they made.

We have already noted that thus far no human remains have been found in association with the earliest complexes such as the Folsom. One fragmentary human skeleton was recovered from the oldest level of the Cochise, and portions of one skeleton and a single bone from another were partially embedded in the floor of one of the Oregon caves. In both cases the physical type is considered similar to that of the southwestern Basket Makers, who were the first agricultural-pottery-making peoples in the Pueblo area in the period from the beginning of the Christian Era to A.D. 600. There have also been the discoveries of a series of skeletons in Texas, "Homo Novusmundus" in New Mexico, three skeletons in Minnesota, four skeletons in a cave in Wyoming, the Vero and Melbourne skulls in Florida, and Tepexpán Man in Mexico. Many of these are not generally accepted as being as old as their finders claim, but they probably are fairly representative of an early period. Counterparts of these early skulls may be found here and there in individuals of various tribes of recent Indians. Although in most cases the "ancient" skeletons exhibit some primitive features, essentially they were modern Indians. It seems likely that the early migrants from Asia to America may have been relatively well-developed specimens of *Homo sapiens,* for virtually modern forms of man have been found in Pleistocene deposits in eastern Asia.

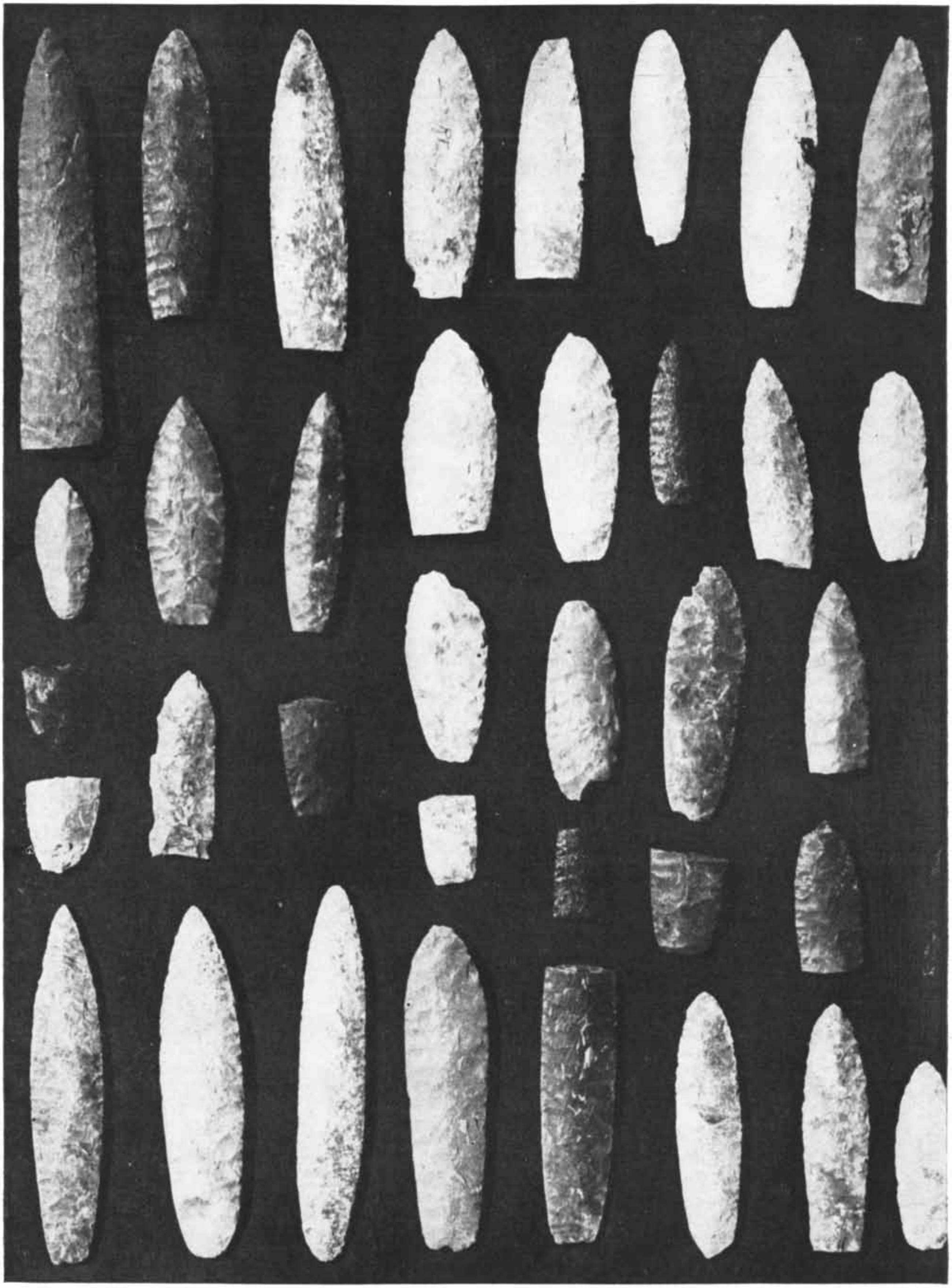
WITHIN the past year or two a new method of dating archaeological remains has made it possible to estimate the age of the Paleo-Indian artifacts more precisely than by the standard geological techniques. This is the radiocarbon analysis developed by W. F. Libby, J. R. Arnold and E. C. Anderson at the University of Chicago. It is based on measurement of the amount of radioactive carbon 14 left in the ancient materials, particularly in charcoal. Libby and Arnold recently analyzed samples from a number of the sites of the Paleo-Indians and gave tentative estimates of their ages. The oldest stage of the Cochise was estimated to be about 7,750 years old, the middle stage about 4,000 years and the last phase about 2,500 years. The age of the Oregon sandals was calculated to be about 9,000 years. Three analyses of sites where Yuma-type projectile points were found gave their ages as about 7,700, 6,900 and 9,500 years, respectively. The same type of analysis on material from old sites in the eastern U. S. showed that early migrants had reached Kentucky and New York at least 5,000 years ago.

Thus far no dates have been established for the deposits at Folsom or in the Sandia and Ventana Caves. A good indication of the age of the Folsom complex has been obtained, however, from analysis of material found in what has been identified as a Folsom horizon at a site near Lubbock, Tex. The carbon-14 measurements show these remains to be about 9,800 years old.

In general the geological estimates and the new carbon-14 dates are not greatly out of line with each other. For instance, geologists had estimated the Folsom artifacts to be 10,000 to 12,000 years old, the oldest level at Cochise 10,000 and certain of the Yuma points from 5,000 to 6,000.

We have considered here only the finds in North America. Similar discoveries have also been made in Middle and South America. One cave almost at the southernmost tip of South America shows evidence that man had arrived there, according to radiocarbon measurements, about 8,600 years ago. Considering that it must have taken some thousands of years for the early men to travel the length of two continents from their original point of entry in Alaska, it seems safe to conclude that man must have come to the New World at least 10,000 years ago.

Frank H. H. Roberts is Associate Director of the Bureau of American Ethnology of the Smithsonian Institution.



PROJECTILE POINTS were found at the Agate Basin site (*see photograph at bottom of page 16*). They resemble Folsom projectile points but were produced by a culture that lasted longer and that may have been older.

THE BEVATRON

It is one of three great machines now being built to accelerate protons to energies of more than a billion electron volts. With such accelerators physicists hope to learn more of the nucleus

by Lloyd Smith

ONE Monday evening in February, 1948, the members of the University of California's Radiation Laboratory gathered for a staff meeting in an unusually intense state of excitement. Even those who had been away for the week end knew *via* the grapevine that something big had happened. Eugene Gardner (the brilliant physicist who died a few weeks ago of beryllium poisoning) was to report on a critical experiment that a group consisting of himself, Giulio Lattes and several others had performed during the week end. They had demonstrated beyond question that alpha particles accelerated to 380 million electron volts in the big California cyclotron had created mesons. For the first time man had seen produced in the laboratory those strange, short-lived particles that are constantly being showered on the earth as part of the cosmic radiation and are strongly suspected of being an essential ingredient of the cement that holds the atomic nucleus together.

As Gardner started to talk, the lights in the lecture room suddenly went out. Someone found his way to the wall switch and jiggled them on again. In those seconds in the dark a few of us were taken with the thought that Nature was protesting a penetration to an entirely new level of knowledge.

Since then information concerning mesons and nuclear particles has been accumulating at a great rate, and physicists are eager to press forward with new and more effective tools. Many of the new facts are bewildering and apparently contradictory, and the goal of this work—to establish laws for the behavior of microscopic bodies as general as the laws of Newton and Maxwell for macroscopic bodies—is certainly not yet in sight. But the general picture has improved so greatly that we are encouraged to spend a great deal of effort in building still bigger accelerators than the 300-million-volt machine at Berkeley.

This article will describe the proton synchrotron, in particular the one called the Bevatron (for billion electron volts) now under construction at the University of California.

WHY SHOULD the nuclear physicist expect to gain so much more from one of these immense machines than from the dozens of accelerators he already has? To answer this question we must take a close look at his methods of research. A physicist of this century, interested in the basic structure of matter, deals with radiation he cannot see, forces he cannot feel, particles he cannot touch.

One of the few relatively effective means the physicist has found for feeling his way into the nucleus is to whip some of the simpler nuclei up to high speeds, throw them at various materials and observe what, if anything, happens. His position is precisely that of a blind man who finds a pile of strong boxes and wants to know what is in them. The scheme of investigation he has hit upon, in effect, is to set a ladder in the center of the pile, climb up with one of the boxes, drop it on the others and come down to grope for something that feels different, in the hope that one of the boxes has split open. Just as a box-dropper's chance of smashing a box gets better as he climbs higher, so the physicist's chance is improved if he puts more energy into his projectiles.

For some 30 years physicists have been studying the atom-smashing activities of nature's energetic cosmic rays. This radiation consists principally of nuclei of hydrogen atoms, accelerated in outer space to tremendous energies. When the cosmic particles approach the earth, most of them strike nuclei of oxygen or nitrogen in the air near the top of the atmosphere, giving rise to secondary radiations, including mesons, some of which reach the surface of the earth and penetrate far below it.

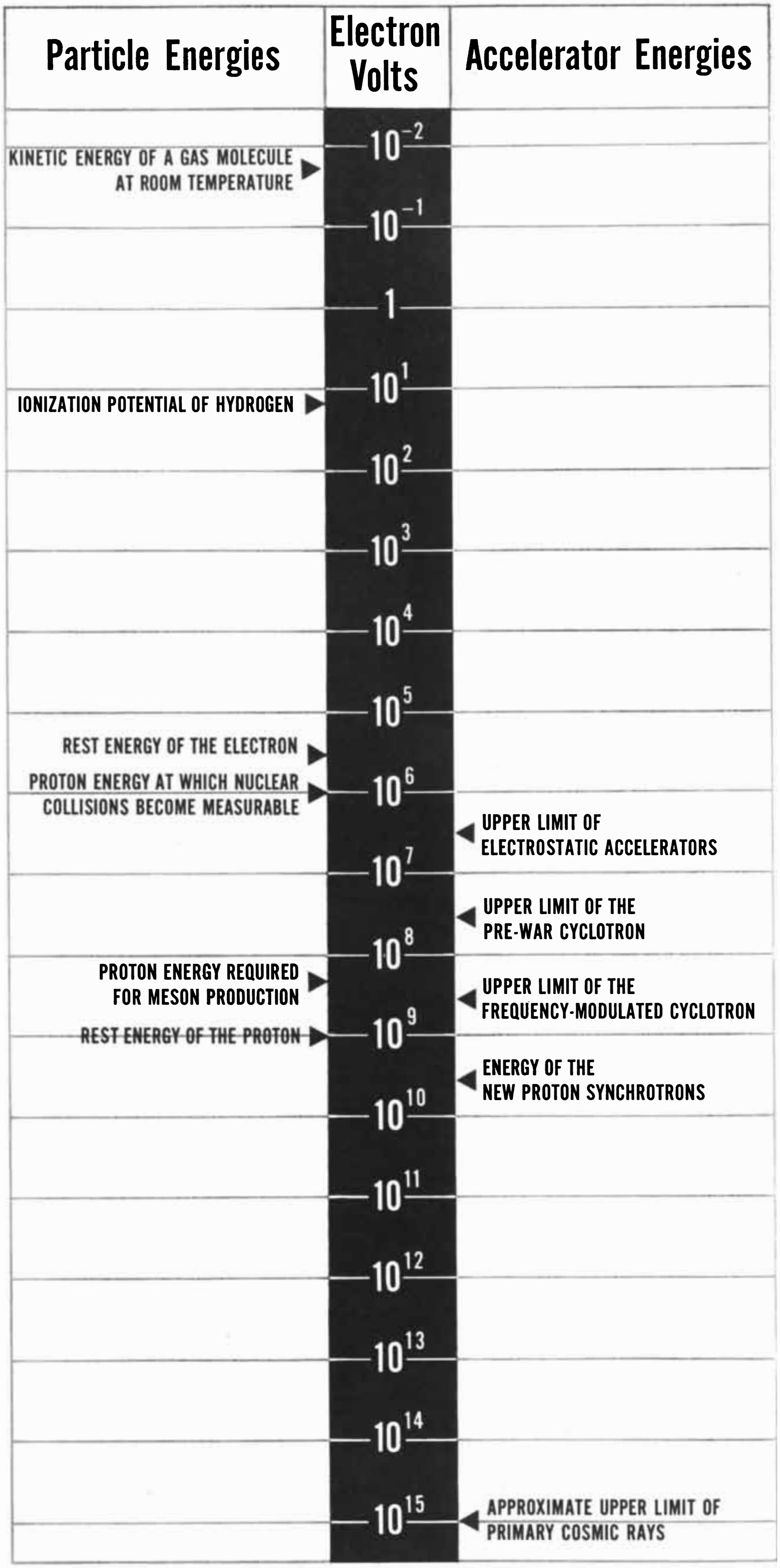
Valuable information has been obtained from studies of the effects of these collisions between the cosmic projectiles and atoms, but cosmic radiation is completely out of control; there is no way to turn it off to get comparative measurements. More important is the fact that its intensity is exasperatingly low. A cosmic-ray worker must wait for months before he has observed enough events of the type he is investigating to draw a valid conclusion. Besides, to use the primary radiation the laboratory must be transferred to the top of the atmosphere by means of balloons or rockets, which are seriously limited in the type and amount of equipment they can carry, and the secondary radiation that reaches us at ground level is a chaotic mixture of different particles of widely varying energies. Consequently the physicist would also like to have a concentrated, manageable source of high-energy nuclear projectiles which he can handle under laboratory conditions.

The most convenient particle to use as a projectile in the laboratory is the nucleus of the hydrogen atom. It is the simplest nucleus, consisting of a single proton, so our interpretation of the results of an experiment will be subject to a minimum of complicating factors. Furthermore, the hydrogen atom can easily be stripped of its single electron; a hydrogen arc discharge provides an abundance of bare protons. The proton's positive electric charge serves as the handle by which we can accelerate and guide it with appropriate electromagnetic forces.

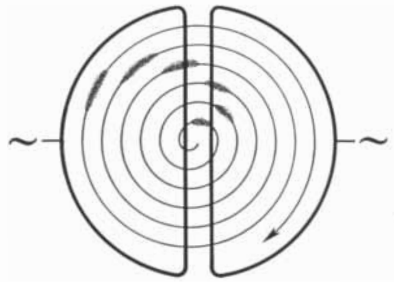
WHAT energy are we shooting for? The largest accelerators now in operation have a maximum energy of less than 500 million electron volts (always abbreviated to Mev). To make a significant advance we must multiply this energy by a factor of at least 2, and perhaps 10. Current cosmic-ray experiments indicate that another kind of meson exists which we might possibly be able to create in the laboratory if we could accelerate protons to an energy of about one billion electron volts (Bev). With six Bev we could start to look for a proton of negative charge, which present theory predicts but which has never been observed. These are examples of the spectacular discoveries that would be announced in the newspapers; there are many other aspects of nuclear physics which stand to gain by the use of projectiles in the billion-volt range.

To see how such energies might be reached, let us consider how a proton is accelerated. Basically the procedure is to turn a proton loose in an evacuated space with a positive electrode at one end and a negative electrode at the other. The proton runs from the positive electrode to the negative, picking up speed as it goes. Its final energy is proportional to the potential difference between the electrodes. Now to accelerate a proton to several billion electron volts in one stage, by letting it run through a potential difference of the necessary magnitude, would require a tube several times taller than the Empire State Building, to say nothing of the fantastic electrical system that would be needed to produce such a voltage. It is clear that energy must be given to the protons in small steps, preferably using the same energy source over and over again. Another requirement that seriously restricts the design of the machine is that the protons must be constrained to follow the intended course without straying off, and they must arrive at the place where they are to be accelerated at the exact moment when they are expected. Since we shall have to accelerate the protons many times, and since they must travel great distances, this requirement must be strictly met if we are to obtain a measurable number of protons at the business end of the accelerator.

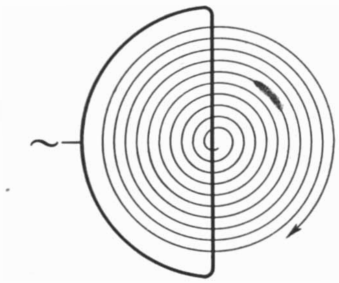
WE CANNOT get billion-volt protons simply by building an enlarged version of the conventional prewar cyclotron which has served physics so well for many years. The cyclotron accelerates particles by means of an oscillating electric field applied in a gap between the halves of a split metal pillbox. A magnetic field keeps the protons moving in a circle so they return again and again to the gap, and at each crossing they are speeded up by the oscillating electric field, if the latter's frequency is tuned to match the rotation period of the protons. But as the proton's energy increases its mass also increases, in accordance with the special theory of relativity. Because of this the proton takes longer and longer to make its semicircular trip between accelerations and arrives at the gap successively later than it should, for the electric field always takes the same time to reverse direction. Thus the proton gets more and more out of step with the field that is supposed to push it along. Eventually it arrives so late that the electric field is completely



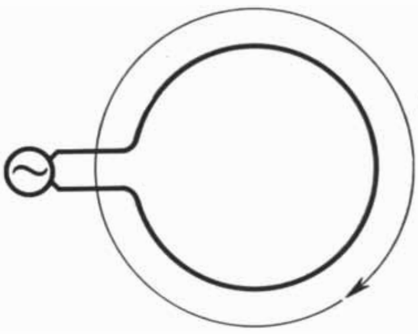
LOGARITHMIC SCALE shows the relative energy of accelerating machines. The upper limit of primary cosmic-ray energies is given with those of the accelerators for direct comparison with the efforts to achieve such energies.



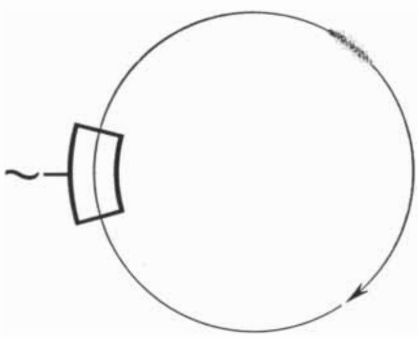
CYCLOTRON can accelerate protons to about 30 Mev. At higher energies the particles fall out of step with the oscillations of the accelerator (~).



SYNCHRO-CYCLOTRON can accelerate protons to about 450 Mev. Particles are kept in step by modulating frequency of oscillations.



BETATRON accelerates electrons in a single orbit and continuous stream. At higher energies they are bent by an increasing magnetic field.



SYNCHROTRON accelerates protons in a single orbit and in bunches. At left is a segment of the chamber in which they are accelerated.

in the wrong direction. From then on the proton is slowed down instead of accelerated. As a consequence 30 Mev seems to be about the maximum energy attainable with a cyclotron of the conventional type.

In the effort to reach higher energies much serious thought was expended on the linear accelerator. In this, as in the cyclotron, an alternating electric field kicks the protons along at successive gaps, but instead of traveling in a circle the protons move through a series of tubes laid end to end. This stratagem defeats the relativity effect, for the successive tubes can be adjusted in length to take account of the protons' increasing weight so they will arrive at each gap when the electric field is in the right direction. The chain of tubes may need to be as much as a mile long, but it can be laid on its side, so this is not an absolute objection. Besides the loss of compactness, however, there is a more basic difficulty in the linear accelerator. As the particles cross the gaps, they are subjected to sidewise electrical forces which are bound to throw them into the walls of the tubes long before they reach the end of the machine. The diversionary electric forces may be eliminated by placing a very thin metal foil over the entrance of each tube to distort the electric field, but the foil itself retards and deflects the protons to some extent. To make a billion-volt linear accelerator the designers would have to solve three difficult problems: 1) developing an adequate focusing system to keep the protons in a stable path; 2) maintaining an evacuated chamber something like a mile in length, and 3) keeping the dozens of high-power oscillators that supply voltage to the tubes synchronized with one another.

So we are left with the synchrotron, the one machine among all those yet designed that can take us into the billion-volt range. There is a variation of the synchrotron that answers all the objections to the accelerators we have considered and raises no new ones.

THE principle of the synchrotron occurred independently to E. M. McMillan of the University of California and the Russian physicist V. Veksler just at the end of the war. These two took a critical look at the operation of the cyclotron and discovered a way to get around the relativity effect. Suppose, they suggested, that when the accelerated proton gets seriously out of step with the accelerating field and is in danger of being decelerated, we suddenly change the oscillation period of the electric accelerating field or the strength of the guiding magnetic field or both, so that the period of the electric field again matches the rotation period of the proton. This is a fairly obvious means of trying to circumvent the difficulties of the cyclotron, but McMillan and Veksler went further and demonstrated that such changes in the applied forces would so stabilize the timing relations that the protons would be forced to follow more or less arbitrary variations in the magnetic field and oscillator frequency.

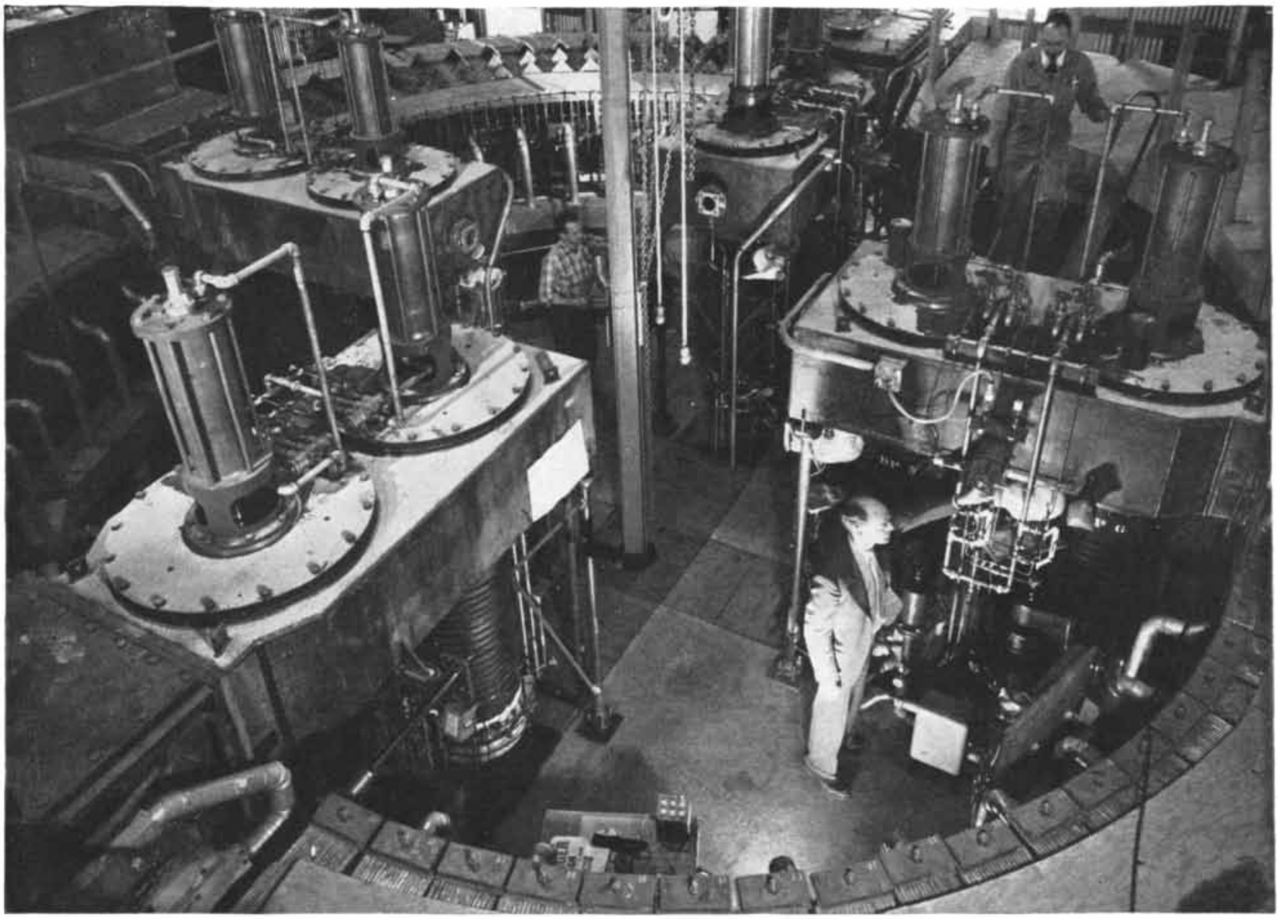
To see how this stability comes about, consider a proton that happens to be crossing the gap just at the moment when the accelerating field is reversing direction. Because the electric field is zero at this moment, there will be no change in the proton's speed, energy or mass. And since the oscillation period has been adjusted to match the proton's rotation period, the proton will continue to travel in the same circle indefinitely, neither losing nor gaining energy. Other protons, arriving at the gap earlier or later, will gain or lose energy and mass, and in just such a way that they will try to fall in line with the well-behaved one.

This tendency to get together on the equilibrium orbit is so strong that if the oscillator frequency or the magnetic field is changed again, creating a new equilibrium circle corresponding to a higher particle energy, the protons will scramble for it, absorbing energy from the electric field to help them get there. This process can be continued as slowly or rapidly as the designer wishes, until the protons are boosted to the desired energy.

The name "synchrotron" is suggested by the analogy with a synchronous motor: a phonograph turntable, for instance, will settle down to a speed determined only by the frequency of the voltage supply, no matter how it is pushed or held back during starting. If the frequency of the line voltage wavers while the turntable is running, it will slow down or speed up accordingly.

All the big postwar cyclotrons operate on this principle. The magnetic field is kept constant, but as the protons gain in energy the period of the accelerating field is slowly lengthened. By such modification cyclotrons have been boosted to an energy of about 450 Mev. In principle there is no immediate limit to the energy that can be attained by this procedure; all we need to do is to increase the size of the magnet and extend the range of frequency modulation. But in practice there is an actual physical and financial limit. To build a cyclotron with an energy of, say, five Bev we would need for a magnet a solid chunk of iron far outweighing the largest battleship.

Consequently the proton synchrotron needs one more modification. We can avoid the need for so bulky a magnet if we change the magnetic field as well as the frequency. Instead of letting the protons spiral out from a center, let us rather pick the size of the final circle and keep the accelerating protons on this circle by continuously adjusting the magnetic field. Thus the central part of



WORKING MODEL was constructed in preparation for building the Bevatron. The model is a quarter the size of the full-scale machine. At the bottom is a segment of the magnet; at left and right are vacuum pumps.

the magnet becomes superfluous; it is only necessary to provide a magnetic field over a narrow ring-shaped region surrounding the prescribed circle. We use a doughnut-shaped magnet, with a great saving in money, weight and space.

THIS stage in planning, implemented by blueprints and engineers' estimates of how much steel would be needed, how much the machine would cost and how long it should take to build, was reached at the University of California's Radiation Laboratory and at the Atomic Energy Commission's Brookhaven National Laboratory in the winter of 1947-48. The British, under the leadership of a group headed by the physicist Marcus L. E. Oliphant, had arrived at this point more than a year earlier and were already at work on a 1.3 Bev proton synchrotron at the University of Birmingham. Unfortunately they have been held up so much by lack of material and manpower that the American machines may well be in operation as soon as theirs.

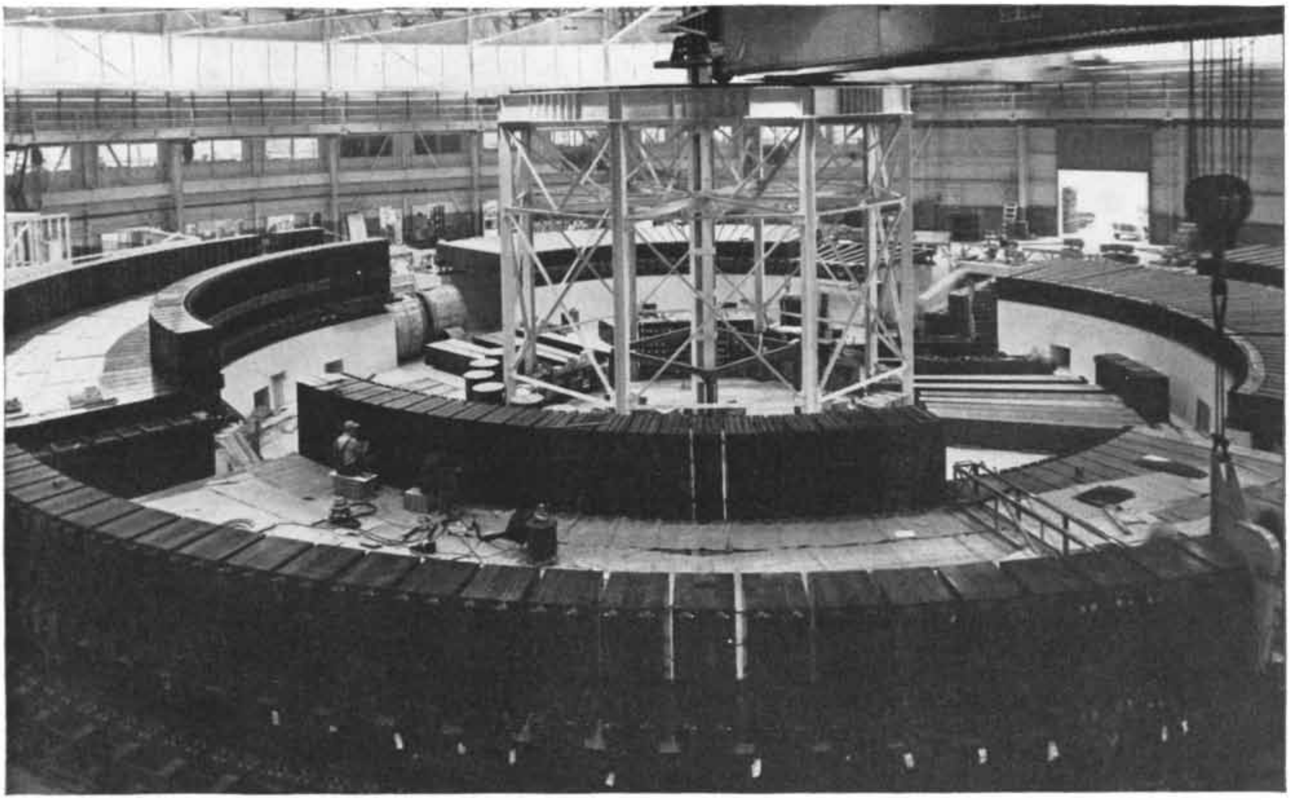
The Atomic Energy Commission, which is financing the two U. S. synchrotrons, gave Brookhaven the go-ahead to build one of 2.8 Bev, to be completed some time in 1951, and California to construct a larger model which by the end of 1951 should be operating at 3 Bev and later would be stepped up by alterations to 6 Bev. As preparation for this big job California was authorized to build a smaller test model one quarter this size.

Why should it take three years or more for a laboratory with the most generous resources to assemble a magnet and some auxiliary equipment? Anyone who has puttered about in a scientific laboratory trying to do something new has discovered the maxim that it always takes much longer than anticipated. The proton synchrotron is perhaps the most intricate machine that has been attempted. Let us take a look at some of the problems, completely new in engineering or physics, that have to be solved. For illustration we shall concentrate on the construction of the machine at our laboratory at the University of California.

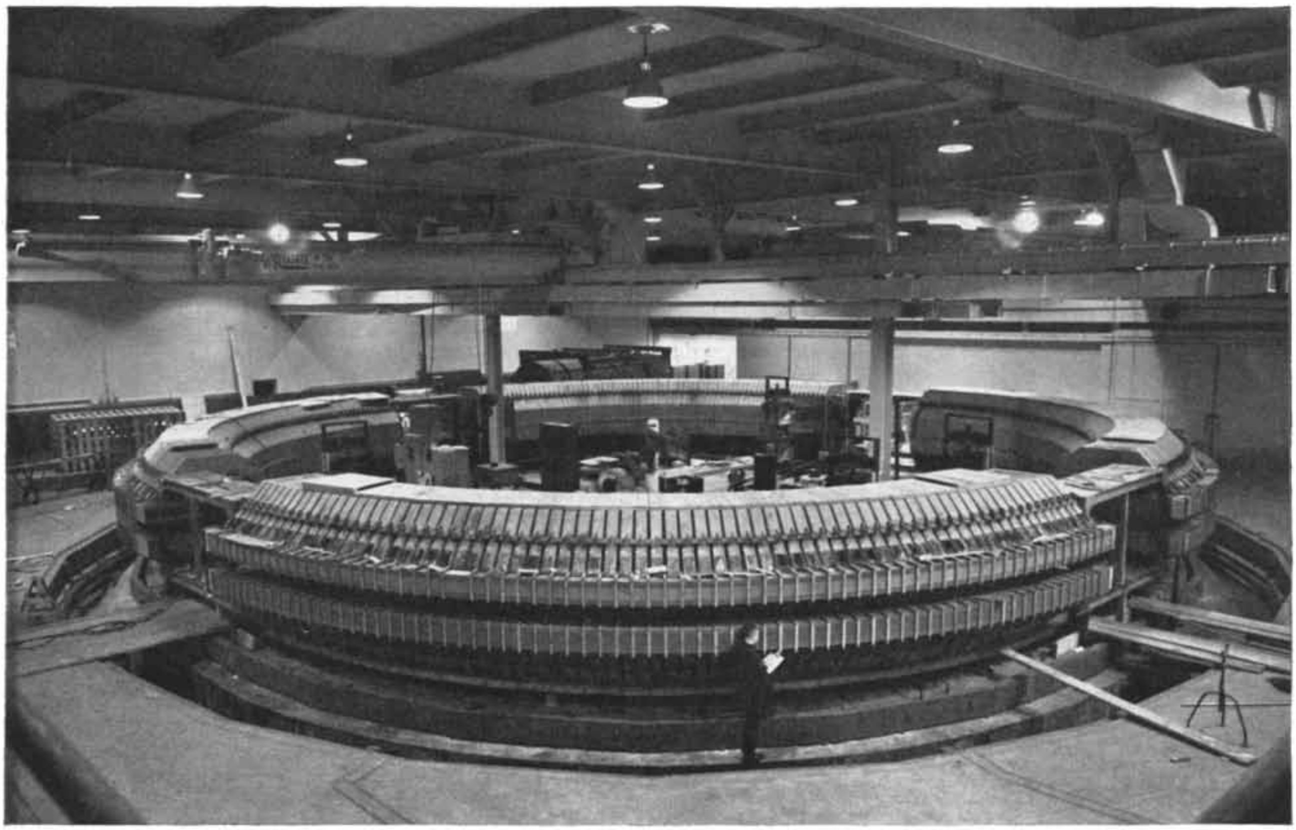
Consider first the problem of modulating the frequency of the electric field. Standard frequency-modulation devices, used in radio or other communication systems, involve frequency changes of only a few per cent. In the proton synchrotron the frequency must be changed by a factor of 10, as the protons are accelerated from practically a standing start to something approaching the speed of light. A new system of frequency modulation has to be devised and tested and retested. Alternate schemes must be investigated and compared.

Then there is the question of electric power supply. To increase the magnetic field from zero to maximum every few seconds, as planned, will require 100,000 kilowatts—the amount of power used by a city of 100,000 population. We cannot take any such drain of power; hence means must be found to use the same energy over and over, instead of demanding a new supply from the power lines for each acceleration. We adopt the device of storing the energy between accelerations in a huge rotating flywheel, but the loss still amounts to 5,000 kilowatts. More tests become necessary. The Pacific Gas and Electric Company must determine whether it can supply even that much power without causing all the lights in Berkeley and Oakland to flicker each time a bunch of protons is accelerated.

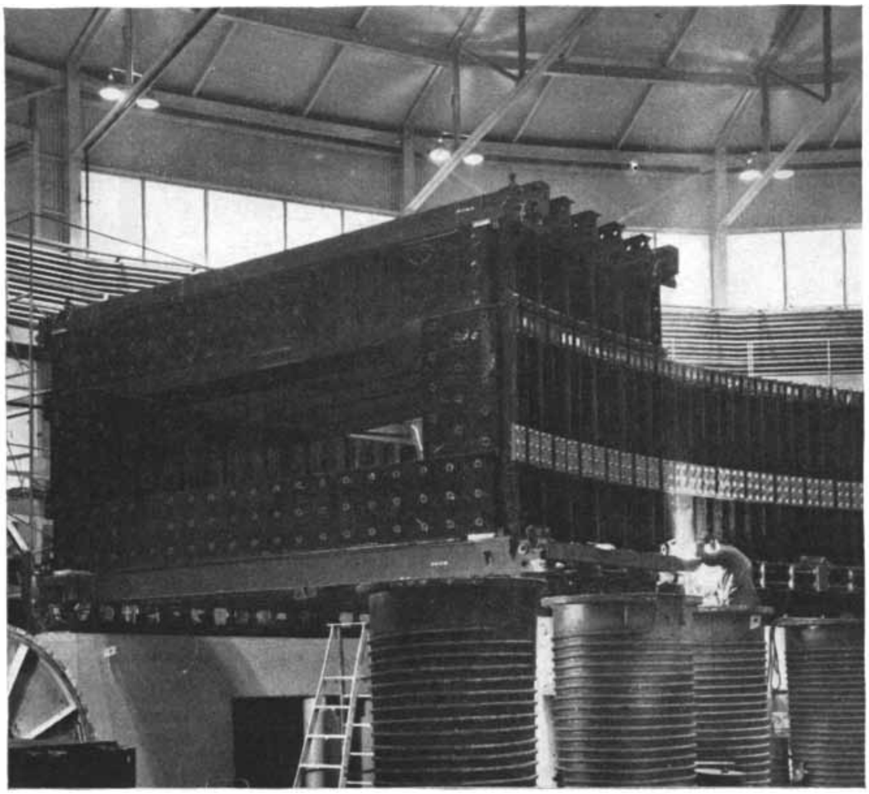
Further, a new type of accelerating electrode has to be invented for our peculiar doughnut-shaped chamber, and in order to be able to get at the electrode



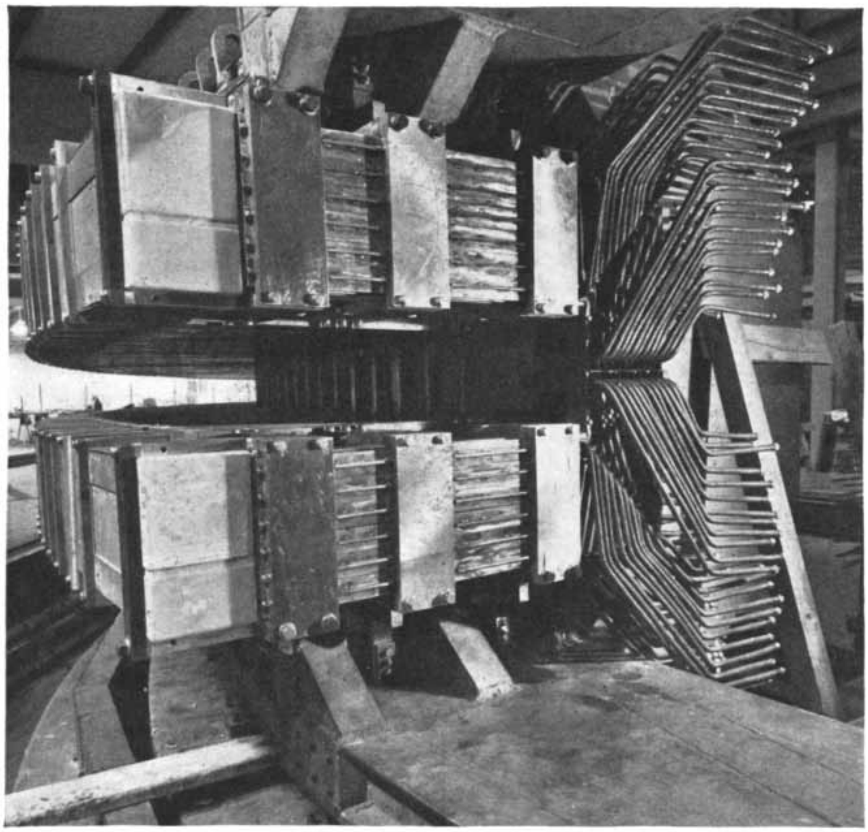
THE BEVATRON is presently under construction at the University of California in Berkeley, Calif. Shown in this photograph is the great ring of its partly completed magnet. When the Bevatron is finished, it is expected to accelerate protons to energies of 3.5 billion electron volts. Later it will be stepped up to 6 Bev.



THE COSMOTRON is presently under construction at Brookhaven National Laboratories in Patchogue, N. Y. Shown in this photograph, as in the photograph of the Bevatron, is the ring of its magnet. When the Cosmotron is finished, it is expected to accelerate protons to energies between two and three billion electron volts.



THE BEVATRON MAGNET is a tunnel-shaped structure. It weighs 10,000 tons and is wound with 140,000 feet of two-inch copper cable. The dimensions of the magnet may be judged by the size of the welder at lower right.



THE COSMOTRON MAGNET has an open cross section. It weighs 2,000 tons. The outside diameter of the ring is 73 feet. In both the Bevatron and the Cosmotron the protons will first be launched by a linear accelerator.

and to connect vacuum pumps to the chamber we must break the magnet into several sectors, with spaces between them. We must also be concerned about the problem of holding the protons strictly to their path through the center of the chamber. During acceleration the protons travel a distance equivalent to 10 trips around the world, and they must stay clear of the walls of a chamber a few square feet in cross section. What if the magnetic field is a little stronger on one side of the magnet than on the other? What is the chance of a proton being deflected into the wall by striking one of the few air molecules left in the chamber? What if the magnetic field or accelerating frequency fluctuates in such a way that the equilibrium orbit moves away from the center of the chamber? Some sort of structure must be placed in the chamber to introduce the protons to be accelerated. Won't the protons run into this structure during one of the millions of circuits they make through the chamber?

IT was the purpose of the quarter-scale model to make sure that all these problems could be handled. By the middle of 1949 the model had been completed and was behaving as we had hoped. The questions of principle had been answered well enough so we could proceed to concentrate on assembling the full-scale machine. The decision marked a real turning point for the Laboratory, for it meant that the scientific staff could turn its main efforts again to actual research, leaving to the engineers the responsibility for bringing the paper machine to life, and to contracting companies the chores of leveling one of Berkeley's canyons as the site for the machine and hauling endless loads of magnet steel up the hill to the Bevatron's home.

When finally completed it will have a magnet of 10,000 tons, and the ring-shaped chamber, or doughnut, will be 110 feet in diameter. It will be housed in a circular structure 215 feet in diameter, with an attached rectangular section housing electrical and other equipment. A linear accelerator will feed protons at about 10 Mev into the Bevatron itself.

By the end of this year, or perhaps in 1952, all the pieces should be in place, and the time to unloose the greatest punching power man has yet created will have come. To atomic physics the Bevatron will bring an extension of the horizon such as the 200-inch telescope on Palomar Mountain has brought to astronomy.

Lloyd Smith worked from 1947 to 1950 on the theoretical aspects of the Bevatron. He is now a research physicist at the Carnegie Institute of Technology.

People in Groups

Are there patterns of behavior common to every human organization? An account of studies in three aspects of the problem: communication, leadership and interaction

by David B. Hertz and Sandra Lloyd Lesser

IN most of our daily activities we operate not simply as individuals but as members of groups. When you sit down to breakfast with the family, arrive at the office for the day's work, go to the theatre, play a game of bridge, board a train, or even stop a passer-by in the street to ask directions, you become a member of a more or less formal human organization. Philosophers and social scientists have given a great deal of study to specific forms of group organization—the family, the state, the church, commerce, industry and so forth. But what about the basic dynamics of organization itself? Are there laws that apply to the behavior of human groups in general, regardless of the particular activity?

In recent years a number of social investigators have begun to examine these questions at the elementary level. The problem of course cuts across the various social sciences, and its investigators include psychologists, anthropologists, sociologists, economists. The Department of Industrial Engineering at Columbia University, under the chairmanship of R. T. Livingston, has undertaken to act as a coordination center to collect and dispense information about all the work being done by the various investigators in organization. This article will review some of the interesting researches being conducted in this new field.

ONE basic factor affecting all human organization is communication. At the Massachusetts Institute of Technology Alex Bavelas and two students, H. J. Leavitt and Sidney Smith, carried out some simple experiments designed to determine how various patterns of communication would affect a group's behavior. They gathered a group of five people and gave them certain problems to solve jointly. The five did not discuss the problem as a group but sat in separate cubicles, communicating with one another only by written messages. In a typical task each of the five was given a card with certain symbols. The problem was to identify one symbol that appeared on all five of the cards. Each member of the group was allowed to exchange any number of written messages with the others, telling what the symbols on his card were and passing along information he received. The group's efficiency was measured by the number of errors made and the number of messages and the time required to identify the common symbol.

Several patterns of communication were tested (*see diagrams on opposite page*). In the first the five cubicles were arranged in a circle. Each member could communicate directly with two others: his neighbors on his left and on his right. To reach the two remaining group members he had to transmit his notes by way of one or the other of his immediate neighbors. The significant feature of this arrangement is that each of the five is exactly on a par with the others in ease of communication with his four colleagues. In the second pattern the five members were placed in a straight line. Now one member of the group had a marked advantage over the others. The person in the middle position in the line could communicate directly with his two neighbors and could reach each of the remaining two by one relay. For all the others intercourse was more complicated; the member at either end of the line, for example, could exchange messages directly with only one neighbor, and to reach the person at the other end of the line he had to pass it through the hands of three intermediaries. The third arrangement, which represents a pattern of communication that occurs commonly in business organizations, placed the members in an inverted-Y pattern. Here one person, at the fork of the Y, could communicate directly with three others, while three members enjoyed free communication with only one other person.

The second and third of these arrangements are obviously less democratic than the first. The two drawings at the right in the bottom panel on the opposite page depict another possible arrangement which represents the ultimate in centralization. Here one person, at the hub of the group, controls all the others, because they can communicate only through him.

NOW what is the relative efficiency of these patterns of communication? It turns out, as might be expected, that the less democratic arrangements result in a faster solution of the problem. In both the straight-line and the inverted-Y patterns the person in the central position invariably becomes the leader. Along with the emergence of a leader comes organization and direction of the group. The leader correlates the data reaching him; he sees a trend and sends out messages asking for specific information, telling the others what he has found. The result is that the task is completed in a shorter time and with fewer errors than in the case of the circular pattern, where no one correlates the data or gives directions.

Yet after a while the gain from high centralization of authority in these experiments was offset by another factor: the outlook of the group members. The investigators asked individuals in the groups how they enjoyed working on the problem and whether they were satisfied with the results. In general, all persons in the circular pattern were happy at the task, although as a group they made the most errors. On the other hand, in the less democratic groups only the central member expressed comparable satisfaction. The other four on his team became dissatisfied, and their work performance dropped. The moral seems obvious: a satisfied worker is one who feels that he is contributing to the group goal and who knows about the efforts of the others associated with him in working for the goal.

Bavelas' work raises the very interesting question: Is leadership primarily a function of one's position in a communications pattern or of inherent personal characteristics? What factors affect the *quality* of leadership? This is surely a subject that needs further study.

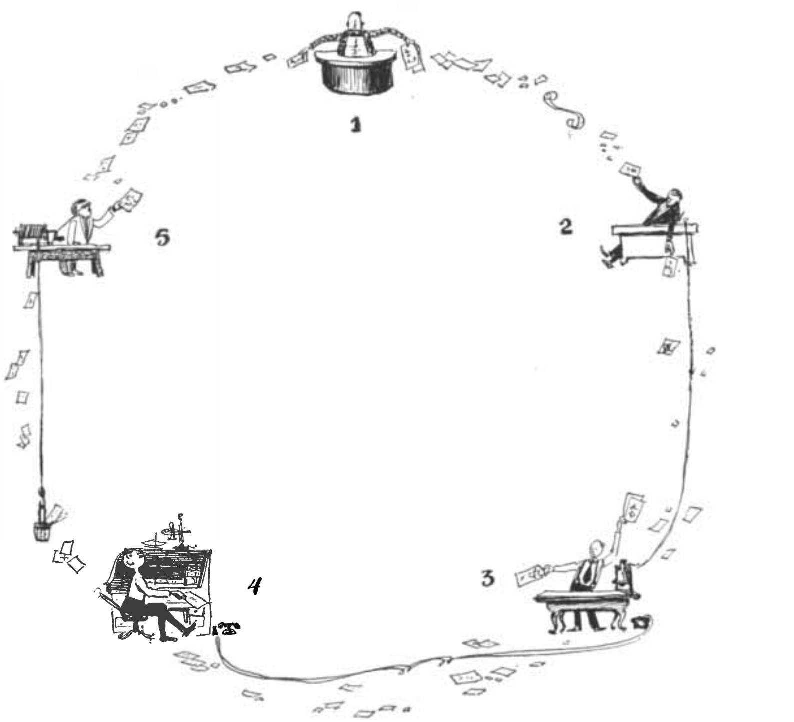
At Ohio State University a group of sociologists, economists, engineers, anthropologists and psychologists under the direction of Carroll Shartle have been studying what a leader does and how he does it. They assume that the leaders in an organization will be those who occupy certain policy-making positions. In industry these people are company executives; in a university they are departmental chairmen and administration officials.

In an industrial study of a particular company the Shartle group first learn as much as possible about the organization from company manuals and laws and from financial reports. They spend about four weeks making observations within the company. The executives to be studied are interviewed; their written and oral communications are examined; their subordinates are questioned. The executives are asked to estimate the amount of time they spend in planning, research, public relations, personnel, inspection, and so on. From this information the investigators construct "Work Patterns Profiles," which show what a specific leader does.

For example, the president of one company was found to spend the greatest proportion of his working hours in public relations and planning. The Work Patterns Profiles of other executives in the company differed from the president's. Thus the director of research rated low in public relations, high in planning and research; the treasurer spent most of his time evaluating reports and correspondence and in cost accounting, and so on. Another typical finding was that the profile of a top executive differs from those of his assistants; usually none of the assistants rates high in the same categories as the executive does. It appears that an executive tends to select men whose work patterns supplement his own.

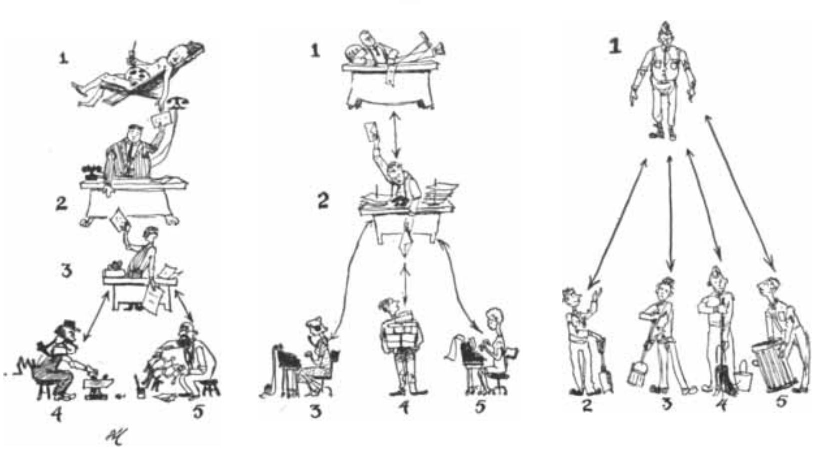
The Shartle investigators believe that Work Patterns Profiles have an important place in executive placement. If a company wishes to change executives, the profiles of the men being considered for the job should be compared with that of the man who holds the job. Replacing an executive who rates high in planning and public relations with a man who also rates high in these categories will cause little or no hitch in the smooth operation of the company. On the other hand, if a shake-up is desired the replacement should have a different profile.

One phase of the Ohio State Leadership Studies is to test the practical effectiveness of the organizational charts used by companies to show the chain of com-



CIRCULAR PATTERN of communication allows each member of a group to communicate directly with two others and places all members on a par. The arrangement is not efficient, but all participants are happy at their work.

LINEAR PATTERN gives the member in the center an advantage over the others and he becomes the leader. This improves efficiency in solving a problem, but the others become dissatisfied and after a time lose interest.



INVERTED-Y PATTERN at left, a typical business setup, makes Member 3 the active leader. The two patterns at the right, both essentially the same, center authority in one man, through whom all others communicate.

mand and channels of communication. Executives and subordinates are asked to list the people with whom they spend the most time during business hours. An informal communications chart is constructed from the lists. When it is superimposed on the organizational chart diagrammed in company manuals and laws, differences are always found between the two. In some cases the deviations are considerable. The formal organization, important as it is for the maintenance of authority and control, may become inefficient for getting work done. Informal communications then evolve. Individual contacts are concentrated with those who are actively engaged in carrying out the same work, regardless of level in the organization and of the formal communications pattern.

AT Harvard University the sociologist Robert Bales is conducting an elaborate and subtle study of the interactions of people in groups. Whenever a group attempts to perform a task, tensions are likely to arise among the members. The tensions may become so acute that the members are sidetracked into an attempt to solve their social-emotional problems instead of proceeding with the task in hand. Group projects frequently alternate between such social-emotional and task types of activity. Bales has classified the interactions of group members trying to solve a problem into four general types: questions, attempted answers, positive reactions, negative reactions. These four are subdivided into 12 specific categories, such as requests for information or an opinion and replies to such requests, agreement and disagreement, displays of tension and release of tension, support and antagonism.

This is the way the interactions of members of a group might be categorized in a given situation:

It is a hot day. A motorist is drinking a cool beer at a roadside stand and talking to the counterman. A car pulls up with a second traveler. He gets out and also orders a beer.

"So you want to go to Bass Lake?" the counterman is asking the first traveler.

"Yep," he replies, "I figure the best way to get there is to continue on Route 9 to the other side of Central City, and then take 135." (*Gives opinion.*)

"You'll never get there that way," the second traveler breaks in. (*Disagrees.*)

"Oh? Know a better way?" (*Asks for suggestions.*)

"Go into Central City. Take a left at the third traffic light on Main Street. Follow Oak Avenue to the sign." (*Gives information.*)

"Besides," continues the second traveler, "135 joins 9 *this* side of Central City." (*Disagrees.*)

"You must be mistaken," replies the first traveler, "I'm sure . . ." (*Defends self.*)

"I just came down from there." (*Asserts self.*)

"Your car's going toward it." (*Shows antagonism.*)

"I just came down from there," repeats the second traveler, "two weeks ago, I was going to say." (*Defends self.*)

"Plenty of time to forget which side of Central City 135 is on." (*Shows antagonism.*)

"I can remember a thing like where 135 joins 9." (*Defends self.*)

"You probably wouldn't know that this is 9 if I hadn't told you." (*Shows antagonism.*)

"Now listen here . . ." (*Shows antagonism.*)

"Hey!" The counterman speaks. "If you two are as good at baiting hooks as you are at baiting each other, you must be first-class fishermen." (*Jokes; releases tension.*)

The two men stop arguing and grin. One drains his beer glass. The other takes some change from his pocket. (*Show tension release.*)

"You want to go to Bass Lake," the counterman points to the first traveler. "Well, taking 135 is OK. And Oak Avenue is a good road, too.

"But let's get out the map and check," he continues. (*Gives opinion, implying autonomy for the others.*)

Such an analysis clearly brings out the patterns, including emotional factors, that characterize group activity. At Bales' Harvard laboratory a standard procedure is used to observe these social processes. A group of people are given a problem to solve. A trained observer in a separate room watches the group through one-way mirrors which prevent the group from seeing him. He listens to the participants' conversation by means of an amplifying system. He records the group members' interactions with the help of a machine which has a moving paper strip running past a list of the 12 categories. The observer notes on the paper strip the category into which he decides each item of behavior falls. From this record is constructed an interaction profile which shows graphically the amount of group interaction in each of the 12 categories.

In one experiment a husband and wife were asked to fill out separate questionnaires on how three couples they knew managed their households. The husband and wife were then to compare their answers and discuss their points of disagreement with the object of reaching a joint decision on these disputed points. The interaction profiles of a number of husband-and-wife teams that worked on this problem brought out two particularly interesting points. The first was that during the discussion the husband and wife gave information and facts about the situations rather than opinions and analyses. Apparently the efficiency of communication between them was such that a word or sentence of information was sufficient to make a point clearly, without the need for lengthy analysis. A second feature was the relatively high rate of activity in the category of antagonistic behavior. Husband and wife spent seven per cent of their interaction showing open antagonism toward each other. This is appreciably higher than for other adult groups studied by Bales. One explanation of this result may be the fact that the amount of antagonism in marriage is greater than in more temporary relations. Bales believes that the marital relationship allows displays of antagonism to occur without threatening its stability. Another possible explanation of the results of the experiment is that the couples did not know that they were being watched by the observers, whereas other adult groups usually were informed that they were under scrutiny.

Bales is carrying out investigations to show that the interaction of small groups is a key to what may be expected of larger similar groups. In one such study a group of people who have never played chess are given a standard chess problem which must be solved with the use of only four different pieces. They get a simple briefing on enough of the rudiments of the game to solve the problem. A test is given to see how well the briefing has been mastered. From 2 to 10 persons, who have not previously met, play as a group against a member of the research team who has one piece, the black king. A certain amount of time is allotted for checkmating the king. Bales hopes that such a study will lead to the first empirical norms for a standard problem situation. By the use of standard techniques in the various social sciences the Harvard investigator is attempting to apply his findings to the analysis of full-scale social systems.

THE studies of communication, leadership and group interaction reviewed in this article are only a part of the experimental work being done in group organization. Other aspects of the subject also are under investigation. The development of methods of measuring and of understanding group behavior, as differentiated from individual behavior, requires intensive research along the frontiers of social psychology and human organization. From all the research will come a deeper understanding of the factors which enable social groups to devote themselves to common purposes and goals.

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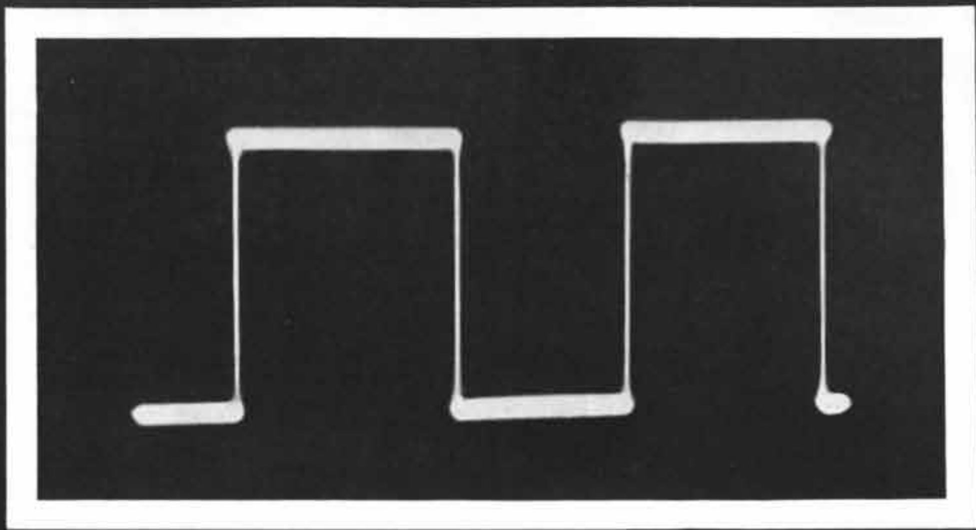
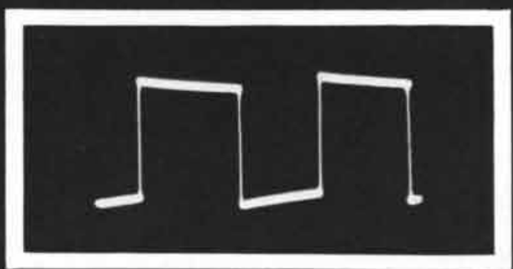
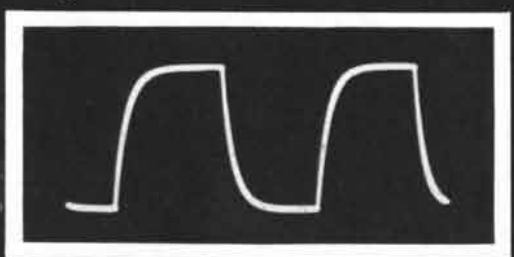


A perfect square wave, photographed by engineers of Allen B. Du-Mont Laboratories, Inc., at the output of a high-frequency amplifier. This is the result of repeated adjustment and readjustment of a compensated attenuator and peaking coils.

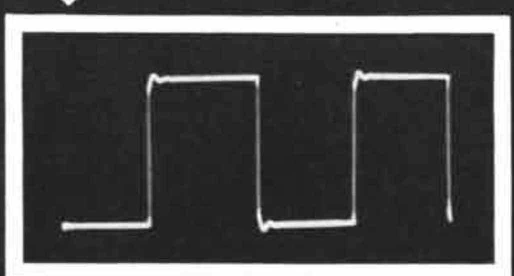
Improper adjustment results in poor low-frequency response. Note tilt in top and bottom flats. Percentage of tilt is a measure of low-frequency response and low-frequency phase shift.



Effect of "under peaking" of high-frequency compensating inductances. Note that rise time of square wave has been distorted so that the leading edge is rounded instead of sharp.



"Over peaking" with extremely fast rise. This produces "ringing" in the leading edge of the square wave.



PHOTOGRAPHY

helps adjust an amplifier

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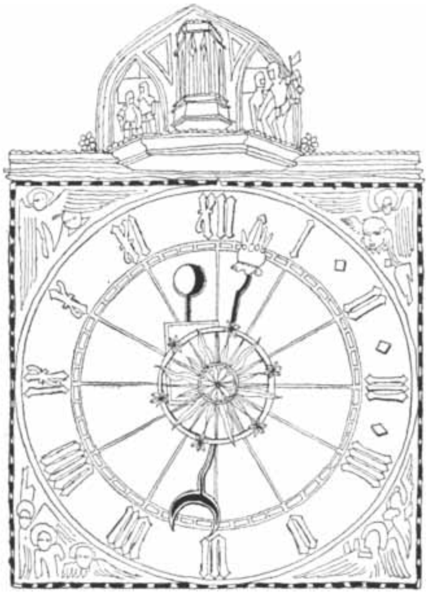

A.A.A.S. Meeting

THE 117th annual meeting of the American Association for the Advancement of Science in Cleveland during Christmas week was marked by a drop in attendance and in the number of reports from the high level of recent years. The major keynote of the meeting was a talk called "The Stockpiling and Rationing of Scientific Manpower" by Atomic Energy Commissioner Henry D. Smyth, who proposed a plan for mobilizing scientists to meet the national emergency proclaimed by President Truman.

The A.A.A.S. council chose Detlev W. Bronk, president of the Johns Hopkins University and of the National Academy of Sciences, as association president-elect, to take office January 1, 1952. The president for 1951 is the geologist Kirtley F. Mather of Harvard University, who succeeds Roger Adams, head of the chemistry department at the University of Illinois.

The proposals outlined by Smyth are indicated to be under active consideration by the Government. In recent months many scientific and professional societies have urged that scientists and scientific students be deferred from the draft, in order to provide the scientific manpower the nation needs. On the other hand, Harvard University President James B. Conant and others have urged that all young men of 18 without exception be drafted for two years of military service. Without opposing universal military service for youngsters, Smyth proposed the formation of a civilian Scientific Service Corps, directed by a Scientific Manpower Board and responsible directly to the President. This Board would determine the use made of all scientists of military age. "It should have power to return men from military to civilian service or *vice versa,* or to shift them from one project to another, or to return them to universities." Scientists over military age would not be required to join the Scientific Service Corps, but the Manpower Board would advise them as to where their services were needed. Scientific students would be enrolled, presumably after their two years of military training, in a Student Science Corps beginning in the freshman year and continuing through graduate training. "The requirements of native intelligence and industry in such a student corps would be high and the requirements of sustained performance higher still. Students who did not keep up would be continually weeded out. Men of excellent technical competence but lacking in imagination and originality would be carried only through their undergraduate training and then released to the armed services or to industry."

Smyth suggested this system as a long-range program for a "20-year period of tension" which he said the U. S. must be assumed to face.

The $1,000 A.A.A.S. prize for the most noteworthy scientific paper presented at the meeting went to the zoologist Carroll M. Williams for his studies with a group of co-workers at Harvard of the metamorphosis of the silkworm (see "The Metamorphosis of Insects," by Carroll M. Williams; SCIENTIFIC AMERICAN, April, 1950). They have shown that the cellular and molecular changes in metamorphosis are controlled by an important hormone which works through the enzyme system known as the cytochromes.

Karl T. Compton, former president of Massachusetts Institute of Technology, won the first award of the new $1,000 William Procter Prize for Scientific Achievement, awarded by the Scientific Research Society of America.

The annual $1,000 A.A.A.S.-Westinghouse prizes for science writing went to Rachel L. Carson, of the U. S. Fish and Wildlife Service, for the best science article in a magazine and to Norman M. Howden of the Rochester, N. Y. *Democrat and Chronicle* for the best article in a newspaper. Miss Carson's winning work was "The Birth of an Island," published in *The Yale Review,* and Mr. Howden's a story on cancer research in his newspaper. Eugene Kinkead of *The New Yorker* received honorable mention in the magazine division and Robert Goldman of the New York *Post* and Robert K. Plumb of the New York *Times* in the newspaper contest.

Some other highlights of the meeting:

J. N. Stannard of the Atomic Energy Project at the University of Rochester

THE CITIZEN

dealt with a question that has aroused considerable recent interest among workers in the atomic energy field: Are the safety precautions against radioactivity unnecessarily high? He pointed out that the Atomic Energy Commission had found in a comparative study that a plant using radioactive materials cost 12 times as much to build ($12 million to $1 million) as a plant performing similar operations and handling the same amount of material without radioactivity. Current safety standards in handling "hot" material also multiply by about five the time normally required for some operations. Noting that these standards, established by biologists, allow a safety factor of at least 10 and often as much as 100, he remarked that the addition of a further safety factor by engineers can raise the cost of shielding far beyond the needed level. Stannard suggested that further study of the permissible dosage levels and closer cooperation among those concerned with the design and operation of nuclear energy installations might well reduce their cost considerably.

J. A. Swartout of the Oak Ridge National Laboratory, in a comprehensive paper on the chemistry connected with nuclear reactors, revealed that this research had opened a whole new field of "high-temperature chemistry." Most chemical research in the past, he pointed out, has been conducted at room temperatures, and relatively little study has been given to chemical reactions above 100 degrees Centigrade. In the program looking toward the development of reactors for power, chemists must study how chemicals react at temperatures far above this level, Swartout noted.

Max Tishler of Merck and Company announced that chemists of that company had succeeded in synthesizing Compound F, a hormone of the adrenal cortex similar to cortisone. This synthesis, starting from animal bile, requires two more chemical steps than that of cortisone. It will make the hormone available for clinical testing, however, to determine whether the new material has any advantages over cortisone for treatment of arthritis and other diseases.

Pauline Berry Mack of Pennsylvania State College reported a study which indicated that because of poor dietary habits about three out of four children in the U. S. are below par in health. The sample she studied—2,654 Pennsylvania children—averaged higher in economic status than the general population. Yet only one fourth of the children were eating the amounts of essential nutrients recommended by the National Research Council. A large majority of the children showed skeletal deformities of some kind, undue fatigue, poor reflexes, nervous habits, excessive tooth decay and other signs of poor health, most of which were quickly overcome when the diet was improved. Girls of 13 to 15 had the poorest eating habits.

Frances Krasnow, research director of the Guggenheim Dental Clinic in New York, reported the discovery of a method by which tooth decay can be anticipated and prevented. The test is measurement of the protein content of the saliva, which gives an indication of incipient tooth decay and of the general condition of the body. Persons with high-protein saliva are advised to drink more milk, take cod liver oil, eat vegetables, eggs and dark bread and get plenty of rest and fresh air. By these measures the Clinic succeeded in reducing tooth decay.

Loh Seng Tsai, psychologist at Tulane University, reported some dramatic experiments with cats and rats. Loh was a university colleague in Shanghai of Z. Y. Kuo, who reared cats and rats to live together without fighting ("Social Instincts," by Ashley Montagu; SCIENTIFIC AMERICAN, April, 1950). At Tulane Loh carried these experiments further and succeeded in teaching cats and rats to cooperate: both learned to touch buttons simultaneously in order to get food. Even alley cats accustomed to hunting rats were trained to cooperate with their erstwhile enemies. At the A.A.A.S. meeting Loh exhibited films of his animals, and he sent photographs of them as Christmas greetings to the United Nations delegates in New York, with the caption: "If cats and rats cooperate, why not nations?"

A National Water Policy

WHEN New York City's water shortage attracted nationwide attention a year ago, President Truman appointed a seven-man commission to develop a national policy on water resources. The Commission, headed by the engineer Morris L. Cooke, has now issued its three-volume report, under the title "A Water Policy for the American People." Its main recommendation is that the river basins of the U. S. be developed under a comprehensive, unified plan which would provide for adequate water supplies, irrigation and drainage, navigation, hydroelectric power, flood and erosion control, control of stream pollution, protection of recreational areas and of wildlife and fish resources.

The Commission notes that the nation's water and land resources are now being exploited in piecemeal fashion under a variety of statutes and agencies. It proposes that no new river-basin projects be started until "they are clearly shown to be in conformity with revised and approved basin plans." It urges that a survey to supply full geological and hydro-

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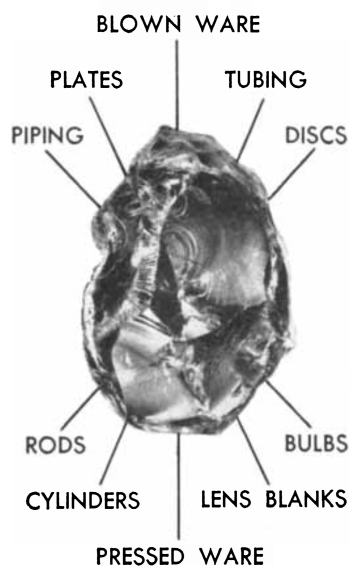

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logical knowledge of the nation's surface and ground water be started immediately (see "Ground Water," by A. N. Sayre; SCIENTIFIC AMERICAN, November, 1950). The Commission recommends a 10-year deadline for cleaning up the nation's polluted waters. It also suggests that the Federal government institute research programs on ground-water resources, artificial rain-making and the conversion of sea water to fresh water. "In terms of the nation's future, such research may well be found to rank with the development of atomic energy," says the Commission.

The entire program, advises the Commission, should "be incorporated in a single statute stating both principles and policies, with provisions requiring their application to all Federal water-resources activities irrespective of the agency or agencies concerned."

Cutting Out Calories

WEBSTER'S *New International Dictionary* gives four definitions of the word calorie: 1) the amount of heat required to raise the temperature of one gram of water from 0 to 1 degree Centigrade, from 4 to 5 degrees or from 15 to 16 degrees—three different values, because of variations in the specific heat of water at different temperatures; 2) the heat required to raise a kilogram of water one degree (the dietitian's calorie); 3) the heat needed to raise one gram of water from 0 to 100 degrees; 4) one hundredth of the amount of heat needed to raise a gram of water from 0 to 100 degrees. Now Britain's Royal Society for the Advancement of Science has understandably proposed the abolition of the calorie.

In a report entitled "The Unit of Heat," the physicist Sir Charles Darwin, chairman of the Society's Symbols Committee, points out that since heat is a form of energy, it is both logical and desirable to measure it in terms of the unit of energy, that is, the joule. Using the most common scientific definition of the calorie, namely, the heat necessary to raise a gram of water from 15 to 16 degrees, one joule equals .239 calorie. For the time being the Royal Society proposes that heat be given in both joules and calories.

AEC in Kentucky

TO expand its production of fissionable material the Atomic Energy Commission will build another huge gaseous diffusion plant for separation of uranium 235 on a 5,000-acre site near Paducah, Ky. The plant will be constructed by F. H. McGraw and Company of Hartford, Conn., at an estimated cost of $350 million. It will be operated by the Union Carbide and Carbon Corporation, which also runs the gaseous diffusion plant at Oak Ridge. The neces-

What GENERAL ELECTRIC People Are Saying

W. R. G. BAKER

Vice President, Electronics Department

CIVIL DEFENSE: No longer do oceans and distance protect us from any determined and ruthless enemy who possesses atomic weapons. Are we then tilting at windmills if we take precautions to eliminate surprise, confine the damage, and alleviate sufferings of the wounded? I sincerely think not.

We maintain police and fire departments, and do not rebel at the expense because there are no holdups or fires. Can anyone who has lived through the years after the war and watched the march of Communism in Europe and Asia say that we are not in real danger? The communities . . . should seize the initiative in planning on a local level for . . . protection of their citizens against not only the threat of atomic weapons but other disasters resulting from sabotage, fire, flood, or pestilence.

We should accept this responsibility, not through fear, but because we are men enough, American enough, to recognize and face grim reality, and deal with the problem of safeguarding our families and our neighbors.

Utica, New York
November 13, 1950

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M. A. EDWARDS

General Engineering & Consulting Laboratory

FIELD PLOTTER: Direct solution of many theoretical and practical problems in the electrical, mechanical, thermal, hydrodynamic and aerodynamic fields, has been simplified by a field plotter recently developed.

Consisting basically of a thin sheet of graphite-impregnated paper, 6-volt d-c power source, voltage divider, sensitive microammeter, and potential-exploring stylus, the instrument offers graphic solutions by simple analogy methods. Patterns to be established can be controlled by metallic electrodes, silver conducting paint, or cut-out areas on the paper with boundary conditions in accordance with the problem. Equipotential lines on the paper are located with the stylus by a series of punch marks at zero readings of the microammeter, and can later be intensified with white ink. This instrument has proved highly satisfactory for making studies of intricate or irregular boundary shapes which would otherwise have required tedious, point-by-point mathematical calculations.

American Association for the Advancement of Science
Cleveland, Ohio
December 26, 1950

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J. W. RAYNOLDS

Chemical Department

SILICONES: The first silicone rubbers were useful because of the high and low temperature stability, together with good oil resistance, ozone resistance, and considerable chemical resistance. From a rubber man's viewpoint, silicone rubber was miserable to handle. It would not band on the mill. Pigments and fillers were difficult to combine. Curing temperatures ranged up to 400° F with time cycles up to 72 hours . . .

During the past year, our research and development engineers have been making steady progress in perfecting some new silicone rubber polymers and compounds. These new materials look, feel, and handle more like the natural rubber products. They also possess the excellent high and low temperature characteristics for which silicone rubbers are especially noted.

The new silicone rubber has over twice the elongation and tensile strength of the old product. It handles easily on a cool rubber mill. It can be calendered, extruded, or molded by compression, transfer, or injection processes, and has curing cycles as short as one minute at 300° F.

American Chemical Society
Los Angeles, California
November 7, 1950

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K. C. SEEGER

J. H. OLIVER

Apparatus Department

RADIANT CHICKEN BROODING: Repeated tests in the midwest, in New York State, and at the University of Delaware have proved that high air temperatures are not necessary for the successful brooding of chicks, provided they receive sufficient radiant energy to keep them warm. These conclusive tests were carried to the extreme of brooding baby chicks in air temperature of 15°F below zero. In this extreme test, 30 chicks were placed in a cold storage plant where air temperatures are maintained at 5° to 15° F below zero. At the end of two weeks, the 30 chicks, all alive, were larger, 1.9 pounds per 100 heavier, and better feathered than others of the same hatch, which were brooded in the conventional manner in a warm room under coal stove brooders.

Four 250-watt infrared lamps . . . 18 inches above the litter . . . supplied the radiant energy that kept them comfortable at all times. Radiant energy at chick level measured 2.62 btu per square inch. This heated the chicks but contributed little heat to the jars of water, so that half of the water in the jars was frozen.

American Society of Agricultural Engineers
Chicago, Illinois
December 18, 1950

You can put your confidence in—

GENERAL ELECTRIC

sary power will be supplied by new facilities of the Tennessee Valley Authority and by a coal-burning generating plant of half a million kilowatts to be built by a private syndicate. The new gaseous diffusion installation, employing some 1,600 workers, will be directed by Kenneth A. Dunbar, head of the AEC's new Kentucky Area Office.

How to Go Crazy

A NEW machine developed at the University of Illinois takes only five minutes to give a calm person a nervous breakdown. The device takes advantage of a phenomenon well known to radio engineers but hitherto neglected by psychologists. The subject simply talks into a microphone and hears his own voice over earphones—but with a slight delay. A recording and playback device between the microphone and the earphones arranges the lag between speaking and hearing. The confused victim soon begins to have trouble in talking. The longer the test continues, the more frustrated and excited he grows. He talks louder and louder, stammers, repeats himself, eventually becomes a gibbering, trembling wreck.

The machine was designed by Grant Fairbanks, director of Illinois' Speech Research Laboratory. He has suggested that subjects may defeat the machine either by adjusting the rate of their speech to that of the playback or by ignoring the playback, but no one has yet succeeded in doing either. Fairbanks expects the device to be useful in research on stuttering.

The Dangerous Bedpan

FOR many patients the most trying hardship to bear in a hospital is the traditional bedpan. Some physicians complain it is downright dangerous, particularly for patients with heart disease. Three New York University doctors working at Bellevue Hospital have recently made a scientific test of the device and condemned it heartily.

The physicians—Joseph G. Benton, Henry Brown and Howard A. Rusk—measured the energy expenditure, in terms of oxygen consumption, of 38 patients (including 15 with heart disease) during use of the bedpan. They found that it takes 50 per cent more energy to use the bedpan than the bedside commode, on which a patient can sit comfortably. Moreover, they pointed out in their report in *The Journal* of the American Medical Association, "it is obvious that the use of the bedpan causes psychological trauma, irritation and often resentment," and occasionally patients even die while using it. The N. Y. U. physicians strongly urged that the bedpan be discarded in favor of the commode, "radical" as this procedure may seem to most doctors.

The Common Cold

It is a subject fraught with folklore and a remarkable paucity of proved facts. Here is a summary of the four years of work at the famous Salisbury colds laboratory

by Christopher Howard Andrewes

THERE are many good reasons for attempting serious scientific study of the common cold. First of all there is the great discomfort this universal nuisance inflicts on the human race. Then again, this is a time when manpower is particularly valuable, and the common cold causes much wastage of it. Although we have no reliable estimates of the man-hours lost to colds, we can be certain that the toll of people's time and efficiency is very great. Besides this, the common cold tempts the investigator as a particularly knotty scientific problem. The causation of colds is not simple. Unlike the situation in many other diseases, for a cold to occur we need not only a germ and a person but a person ripe for infection and conditions suitable for the transfer of the cold virus to that person. To determine what makes an individual a ripe and fit pasture-ground for the virus and what conditions are necessary for transmission of the virus from one person to another—this is a big and difficult problem. It has baffled so many people for so many years that any investigator must needs feel it a challenge—something worth getting his teeth into.

Why has the solution of the common cold problem so long eluded us? Perhaps the fact that it is not a dangerous disease has detracted from the pressure to solve the problem. There are, however, more important reasons. Virus diseases are studied mainly by observing the effects produced in experimental animals or plants, for viruses cannot be grown on artificial culture media. Unfortunately there is no convenient experimental animal for investigating the cold virus. Neither the mouse, the guinea pig nor any other readily available species can be infected with colds. The only animal, besides man, that will catch a true cold is the chimpanzee, and chimpanzees are so hard to come by and to handle and so expensive as to be almost useless.

Furthermore, the whole subject of colds is overlaid by stratum upon stratum of folklore, superstition and pseudo science. Colds touch each of us personally, and it is a human failing that where our own afflictions are concerned our scientific judgment becomes faulty. We are apt, when we unexpectedly catch a cold—or avoid catching one—to attribute this to some unwise or wise act on our part. He who would solve the cold problem would do well to consider only scientifically checked facts and to keep a very critical attitude toward the folklore and toward what his friends tell him about how they catch or avoid colds.

The Known Facts

What do we know about colds? There is ample evidence that colds are "catching": we know that an infected person can pass on infection to another person, and that chimpanzees can catch colds from human beings. Yet it is also true that often an individual intimately associated with a cold-sufferer fails to catch a cold at all. Another very well attested fact is that among a group of people isolated on a remote island, particularly if the community is small, colds tend to die out. But when such a cold-free community re-establishes contact with civilization, as by the visit of a ship from outside, its inhabitants are found to be abnormally susceptible and are pretty sure to catch a real "snorter."

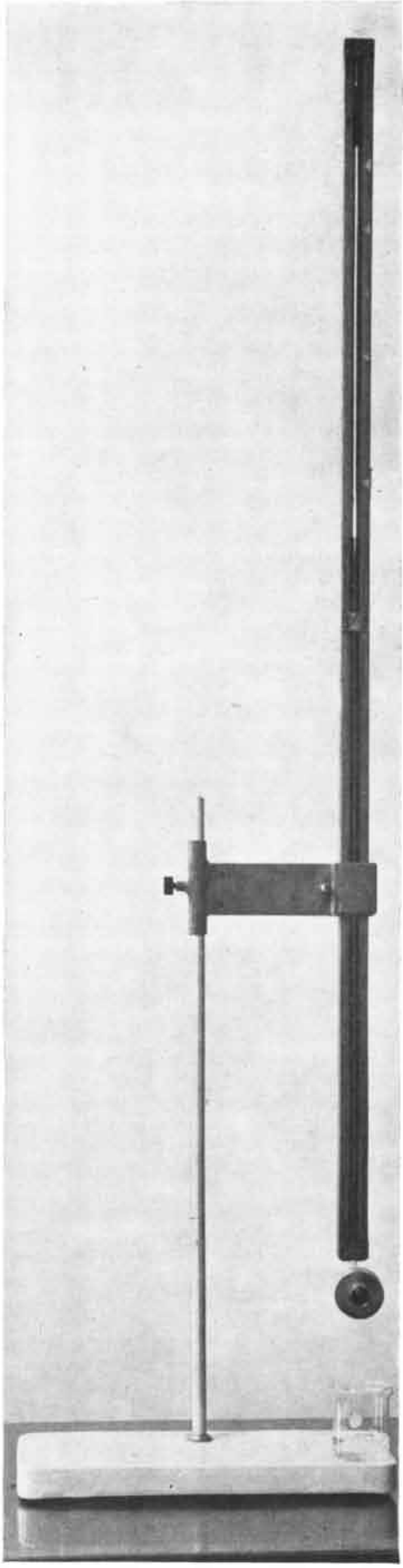
In the ordinary way, the immunity acquired after a cold apparently is of brief duration. It is fairly clear that the freedom from colds of isolated groups is dependent not on increased resistance but on disappearance of the cold germ during their isolation. Their fate when they do meet cold germs shows that their resistance has waned with their freedom from attack. The temporary resistance developed by people in ordinary communities seemingly is maintained by frequent and repeated contact with cold virus.

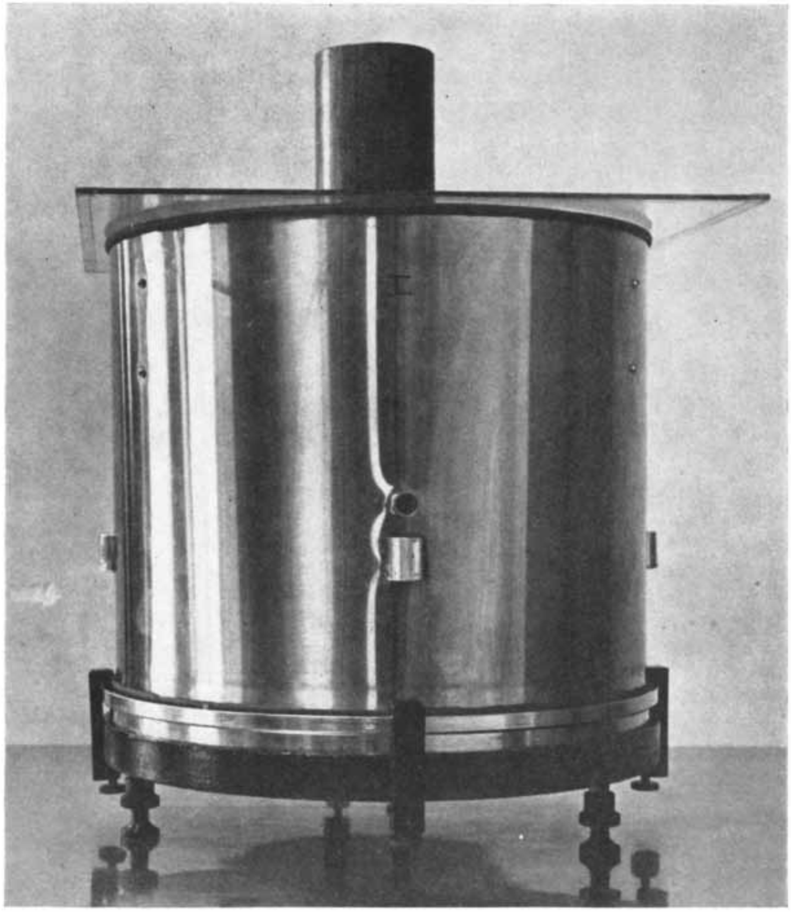
Attempts to transmit colds artificially from one person to another are successful in about 50 per cent of the trials: a number of people at any one time prove resistant. The technique used has been to wash the noses of people who have colds with a salt solution and to drop some of this mucus-containing solution in the noses of normal people. Careful study of these solutions by the standard bacteriological methods has failed to show that any of the cultivable bacteria can be incriminated as the cause of colds. Indeed, during the early stages of colds the nasal secretions often have a subnormal content of bacteria. Several investigators have shown that after nasal secretions from people with colds have been passed through filters so fine that they hold back ordinary bacteria, the filtered material is still infective; it can pass in series from one person to another and continue to produce colds. This indicates that the infective agent is something which can multiply and is smaller than bacteria: *i.e.*, a virus. It is now generally agreed that the criminal responsible for the common cold is indeed a virus.

Such are the main facts about colds of which we can feel fairly sure. About 1946 several groups on both sides of the Atlantic decided that the time was ripe to attempt a carefully controlled investigation of the causes of colds. Many new techniques for studying viruses had been developed. In particular, it had been discovered that fertile hens' eggs were a suitable medium for growing them; the viruses of influenza, mumps and yellow fever had been cultivated in this way. Also, it had been found that ferrets could be infected with influenza virus, and this had led to laboratory studies which had developed an enormous amount of information about influenza.

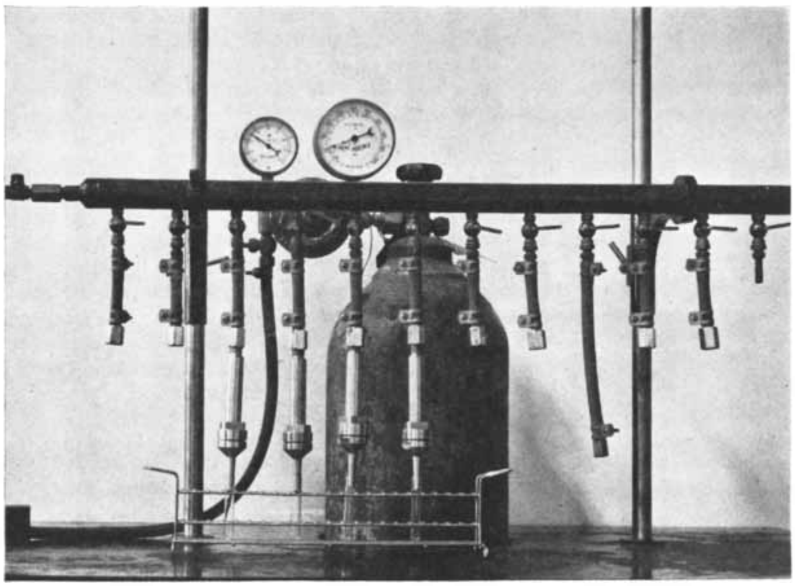
The Salisbury "Laboratory"

I propose to describe here the attack on the cold problem that has been carried out since 1946 in the Common Cold Research Unit of the Medical Research Council at Salisbury, England. Naturally the first objective of a study of this kind is to find a reliable, simple test, if possible, for the presence or absence of the virus. With such a test we could determine whether the virus is present in nasal secretions at various stages of the





COLLODION FILTER TECHNIQUE for measuring the size of viruses is described by the author. The apparatus shown here is at the International Health Division Laboratories of the Rockefeller Foundation. At the bottom of the cylindrical chamber above is a very flat surface over which a thin film of collodion is poured. The atmosphere in the chamber is maintained so that the collodion dries at a controlled rate; this roughly determines the size of the tiny pores in it. At the left is a glass tube in the bottom of which is a cell containing a small collodion filter. When water is poured into the top of the tube, the rate at which it falls indicates the size of the filter pores. Below are four cells in which solutions containing virus can be forced through such filters.



disease, whether it can be killed by various disinfectants, and so on. The only test we have at present, a very expensive and rather unreliable one, is to drop material in people's noses and see if it produces a cold. As a first step toward attaining our objective of finding a simpler and better test, we had, perforce, to resort to this method, and to set up a very complicated organization to carry it out.

Our "laboratory" is the Harvard Hospital at Salisbury, consisting of a number of prefabricated huts which during the war were used as an American hospital with a staff from the Harvard Medical School and at the end of the war were generously handed over to the British Ministry of Health. As now set up, the unit has six rather luxurious huts, each divided into two separate flats. The 12 flats house 12 pairs of volunteers. We decided to take the subjects in pairs because it seemed obvious that people would be more likely to volunteer if they could have a friend with them. Each pair is kept in isolation and studied for 10 days; a fresh lot of about 24 volunteers comes along every fortnight. During university vacations we have no difficulty in getting students to come; at other times we have managed to keep pretty full with other people coming along in response to appeals on the radio or in the press. Since we started, four years ago, more than 2,000 volunteers have passed through our hands.

Patient Smith

Let us follow what happens to a typical volunteer. John Smith, who lives in the north of England, reads about us in the paper and writes in for particulars. He is sent a form to fill in, and this tells him when there will be vacancies. He chooses a period that suits him and is then sent a railway travel warrant. He arrives, with others, at noon on a Wednesday, and is met at the Salisbury station. He is examined at once to see that he has not got a cold on him already and that he is otherwise suitable. Because Smith could not arrange to come with a friend, he is paired with another chap of similar age and tastes, Tom Brown. Smith and Brown and the 22 other new arrivals meet for lunch in the staff messroom. The doctor in charge explains the routine of the experiment and the rules that must be observed. All now go off to their own flats.

Thenceforth Smith meets no one but his own partner and the gowned and masked doctor and matron who visit them daily. He is allowed out for walks, so long as he keeps away from other people, vehicles and buildings. He is provided with facilities for table tennis and other games with his partner. Thrice daily meals are left in hot thermos containers at the entrance to the flat. The apartment has a living room with radio and telephone, a dining room, two bedrooms and a "medical room" for examination and inoculation.

During the first three days Smith and Brown are left uninoculated, in order to allow time for any cold they may have caught beforehand to show itself. On the first or second day they are given a routine physical examination and an X-ray of chest and sinuses. They are examined daily, even before inoculation, and are asked to make daily notes on any symptoms of illness that may appear. During the early examinations the doctor notes the normal amount of mucous secretion by each man, so he will have a "base line" to help him detect the abnormal secretions that mark a cold.

Then comes Saturday and the inoculation. Each volunteer is given, at random, one of three types of inoculation. Some receive "positive control" material—nasal secretions expected from past experience to produce a cold. Others get a harmless broth or salt solution. The third group receives an inoculation of material of unknown properties, perhaps the fruits of an attempt at cultivating virus. The bacteriologist who has prepared these materials makes the inoculations from numbered bottles taken at random. Neither Smith nor his doctor knows what preparation Smith has received; that will be made known only at the end of the trial, when the clinician has committed himself in writing as to the result. It is not easy to tell just when a person has a mild cold and when he hasn't, and with the best will in the world an observer cannot make an unbiased judgment in borderline cases if he has a preconceived idea as to whether the patient ought to be getting a cold or not.

Thereafter the doctor keeps a careful watch of Smith for signs of a cold. In this Smith's daily notes on symptoms and the doctor's own clinical examinations help, but the most valuable evidence on whether Smith has a cold or not comes from daily inspection of his handkerchief to see how much mucus has been expelled.

Findings

What have been the over-all results of our tests with the 2,000 volunteers? The first thing to be said is that those who received the harmless control inoculations remained satisfactorily free from colds during their 10-day stay. This is an indication that our quarantine and other precautionary measures are adequate. Of those who received the active secretions taken from people with colds, some 50 per cent, as I have mentioned, caught colds. An interesting point is that many of those who were inoculated with active materials seemed to be starting a cold on the second or third day after inoculation but next day had lost all their symptoms: the cold had aborted. Possibly most colds abort naturally. If this is true, it is easy to see why remedies purporting to cure the common cold so often gain a wholly unmerited reputation.

Women, according to our observations, are definitely more susceptible to colds than men; the comparative scores were 55 per cent to 43 per cent. Age has very little effect on vulnerability, within the age group of 18 to 40 from which our volunteers come. The incubation period of a cold is usually two to three days. In about two thirds of the cases it begins with soreness or roughness of the throat, and in almost every case the predominant symptom that develops is an increased flow of nasal mucus. Fever is rare. On the whole the colds have been milder than we expected. Perhaps in ordinary life it is only the severe colds that attract one's attention; we remember the virus' offensive triumphs rather than our own defensive successes. The colds of our volunteers have usually cleared up by the time they go home, several days after the cold's onset. Those departing are given post cards to send back a fortnight later with news of any nasal happenings in the meantime. Not a few relate that the colds, which had cleared up in our sheltered environment, got worse again in the hard outside world.

All this is very interesting, but what about the primary objective, the development of a better technique for studying colds? We cannot yet, unfortunately, report success. Much effort has been devoted to cultivation of the cold virus in fertile hens' eggs, by each of several different techniques that have proved useful with other viruses. No unequivocal success has been attained. A few colds have been produced with such cultures, but unfortunately materials from uninoculated eggs have not given quite such uniformly negative results as our other control materials, so the results are hard to interpret.

Nor have we succeeded in inducing colds in experimental animals. We have tried rabbits, rats, mice, guinea pigs, hamsters, voles, cotton rats, gray squirrels, flying squirrels, hedgehogs, pigs, chickens, kittens, ferrets, baboons, green monkeys, capuchin monkeys, red patas monkeys and a sooty mangabey. People have told us that they have observed that such-and-such an animal develops colds in captivity when in contact with human colds. Such clues we have followed up, but in vain. The "colds" in these animals have either not been reproducible or have seemed to be due to bacteria rather than to a true cold virus.

Four groups of workers in the U. S. have claimed success in growing cold virus in eggs. In such a difficult field no confidence in a result can be felt until it can be repeated at will in other laboratories. We ourselves have tried, and are still trying, to reproduce some of these results at Salisbury.

The Virus

Efforts have been made to determine the properties of the cold virus, for knowledge of these should help us toward our objective of the simple laboratory test. We have, for instance, learned something about the size of the virus. Virus-containing fluids can be filtered through a special type of collodion filter having pores of very uniform and accurately graded diameter. We find that the cold virus passes with but little loss in potency through membranes with pores as small as 120 millimicrons, or 120 millionths of a millimeter. In one experiment patients took colds from material passed through a filter with pores of only 57 millimicrons. If we can believe this single positive result, we can deduce that the cold germ is one of the smaller viruses—about as big as that of yellow fever, which has a diameter of some 25 millimicrons. At most the cold virus seems to be no more than about 60 millimicrons across; that is, decidedly smaller than the influenza virus.

Cold virus is very stable when kept frozen at 76 degrees below zero Centigrade; some of it has retained its potency for as long as two years at this temperature. This knowledge is very useful to us. At any point we can bottle our "pedigree" strain of virus, put it away in dry ice and forget about it till it is next needed.

We have also established several negative facts about the virus: it is not affected by penicillin or streptomycin, nor is it adsorbed, as is influenza virus, on human or fowl red blood cells.

We need to know not only these rather abstract properties but also something of how the virus behaves in man—the relation of the parasite to its host. We have no way of telling how many virus particles our infectious dose of material contains; it may take thousands of particles to overcome a person's normal resistance and produce a good cold. We have found, however, that nasal secretions are infectious even when diluted up to 1,000 times with salt solution. Apparently the saliva secretions in the front of the mouth also contain much virus. This is important in relation to the means of spread, for most of the liquid expelled when you sneeze comes from the front of the mouth.

Nasal secretions contain plenty of virus during the incubation period of a cold, even before symptoms develop. We found this out by washing out the noses of infected subjects 12, 24, 48 and 72 hours after inoculation and testing the washings for infectivity. The 12-hour specimen was negative, all the rest positive. The subject who provided the washings developed symptoms 48 hours after inoculation. Our impression is that secretions from the early stages of a cold are the most potent, but we have had "takes" with washings taken seven days after inoculation. We have occasionally produced mild colds with secretions from normal, symptom-free people; this suggests that some people may be carriers of cold infection without showing symptoms themselves, as in diphtheria, typhoid fever and many other diseases. There is some evidence that children are especially "efficient" in spreading cold infection.

The Chilling Test

We have tried many dodges to increase the rate of successful transmission of colds from 50 per cent to 100 per cent. Obviously if we could produce a cold every time we tried, we could work faster and more certainly, and we might find some clues to the reasons for people's varying susceptibility and resistance. But so far we have not been able to increase or decrease the rate of cold "takes" very much.

For instance, we put to the test the practically universal idea that chilling induces colds, or at least increases one's chances of catching a cold. Three groups of six volunteers each were used in this experiment. One lot received a dose of dilute virus, calculated not to produce many colds. The next lot were given no virus but were put through a severe chilling treatment: that is, they had a hot bath and were then made to stand about in a draughty passage in wet bathing suits for half an hour, by which time they felt pretty chilly and miserable. They were further made to wear wet socks for the rest of the morning. A third group received the dilute virus plus the chilling treatment. On one occasion, in a variation of the experiment, the chilling consisted in a walk in the rain, following which the subjects were not allowed to dry themselves for half an hour and were made to stay in unheated flats.

Now this experiment was performed three times. In not one instance did chilling alone produce a cold. And in two out of the three tests chilling plus inoculation with the virus actually produced fewer colds than inoculation alone; in the other the chilled people who also got virus did have more colds than the "virus only" group. So we failed to convince ourselves that chilling either induces or favors colds. Perhaps under appropriate conditions it does so, but this has never been proved, to our knowledge, by any controlled experiment. It is pertinent that arctic explorers away from civilization do not, as a rule, get colds.

One of the great puzzles about colds is that even repeated attacks do not confer any lasting immunity. We have found some evidence in the blood that the body produces antibodies to cold virus. But in contrast to the antibodies called forth by the virus of a disease such as measles, which guard the body against future attacks, the antibodies that respond to a cold seem almost powerless to help. A person may develop two successive colds within a matter of months. Why are the antibodies so effective against the one disease and so ineffective against the other?

The answer may possibly be that in the latter case the antibodies are not in the right place. In the case of measles the virus always appears in the bloodstream at one stage of the attack, and this is where the antibodies are, ready to intercept and destroy it. On the other hand, the virus of the common cold (and of influenza, in which the antibodies are also relatively ineffectual) attacks the superficial membranes lining the nose and other respiratory passages, without having to pass through the bloodstream and encounter the antibodies. True, some influenzal antibodies apparently can pass from the blood into the mucus covering these membranes, and this doubtless helps to keep infection under control. But there is usually much less antibody there than in the blood.

Consequently a promising approach to the prevention of colds is to try to determine what conditions control the

DAYS	DEFINITE COLDS
1	27
2	103
3	71
4	22
5	7
6	4

SOME RESULTS of the tests at Salisbury are shown in these tables. At the left: the number of persons de-

amount of antibody in the mucus. Perhaps frequently repeated contacts with small doses of virus, doses insufficient to produce a manifest cold, stimulate the body to provide the mucus with enough antibody to protect it. Very probably it is the lack of such stimuli that renders small isolated communities so susceptible to colds. It may be that in the future colds may be kept at bay by repeated doses of an attenuated virus taken as a snuff, rather than by vaccines given in the orthodox ways used in other diseases.

The Germ's Travels

We all expect to catch a cold now and again by immediate contact with a cold-sufferer. If such a one unkindly sneezes in our face, the mode of transmission is obvious. But most people are trained not to be so unneighborly, and the virus must get about in ways less crude than this. Several possibilities have to be considered. Aside from the coarse droplets from a sneeze that may attain a direct hit on your nose, finer infectious particles seem to be more or less constantly present in indoor places during the cold season. William F. Wells of the University of Pennsylvania School of Medicine, an investigator of airborne infection, has shown that these "droplet nuclei" may float about in a room for an hour or more after someone has sneezed in it. Droplets collected by the floor, furniture or clothing, and particularly those on handkerchiefs, may dry up and be redispersed as infected dust when the floor is swept, the beds made or the handkerchief shaken. Again, the hands are easily contaminated with infected mucus and can distribute this around very effectively.

All these are possible routes of transfer of infection, but we cannot yet say which, in practice, are the important ones. Let us look more closely into some of them, bearing in mind that what is the effective route for one respiratory infection may not be so for another.

The evidence is rather good that measles virus can be carried by droplet nuclei and so infect a susceptible child. The importance of this is that the young science of air hygiene has developed new ways of dealing with the infective droplet nuclei in the air. Really good ventilation is, of course, the simplest and best way of disposing of them. Failing this, the air can be disinfected by the use of ultraviolet radiation or by certain germicides sprayed into the air as a very fine mist; triethylene glycol and compounds related to lactic acid are some of those used. But there is as yet no evidence that these measures will control cold infections. It is difficult to apply them 24 hours a day. Further, it is open to question whether droplet nuclei are a primary source of colds, as in order to catch a cold by this means we would have to inhale a considerably larger dose of virus than would suffice to give a susceptible child measles.

As for germs in dust, we can do a great deal to reduce this hazard by rendering the dust particles sticky, so they do not float about in the air to be inhaled. The method, developed during the war by the South African Van der Ende and his colleagues working in London, is to treat floors and other surfaces with oil. When a floor so treated is swept, the dust tends to roll up into balls, instead of being whirled all over the room; blankets given a similar treatment (which by the way does not noticeably alter their appearance or feel) can be shaken without scattering dust. There is some evidence that these methods are useful in controlling the streptococci causing sore throats. But again we do not know whether they will help against colds. Handkerchiefs, on which cold germs probably are especially numerous, cannot conveniently be oiled, but they can be treated with disinfectants such as octyl cresol, and 90 per cent of the germs on them are thus destroyed.

There is not much one can do about his hands, though these, unfortunately, are one of the most effective distributors of cold virus. This was graphically demonstrated in an experiment by some of our workers at Salisbury. They fixed up a volunteer with an artificial running nose by attaching a small container of liquid to his nose and letting the liquid drip through a narrow tube at a slow steady rate—about the rate of secretion that a cold-sufferer might produce. In

DOUBTFUL COLDS
14
15
13
3
7
3

PORE DIAMETER IN MILLIMICRONS	NUMBER TESTED	NO COLDS	DOUBTFUL COLDS	DEFINITE COLDS
410	3	1	0	2
310	15	5	1	9
230-220	8	7	0	1
140-120	20	10	1	9
68-57	22	20	1	1

veloping cold symptoms at various elapsed times after inoculation with virus. This indicates the incubation period of a cold is usually two or three days. Table at right shows results with infectious material passed through filters of various sizes. It suggests the cold virus probably is less than 57 millimicrons in diameter.

this liquid was a fluorescent dye which, when viewed under ultraviolet rays, was visible even in tiny traces. The subject then spent four hours in a room with three colleagues, blowing his nose when he wanted to and otherwise conducting himself in a normal manner. When, after four hours, the lights were turned off and the ultraviolet lamps switched on, the wide distribution of the "tracer" dye was found to be quite amazing. Not only was his handkerchief soaked with it, but there were dots of dye all over his face, hands and clothes and even over the food he was about to eat.

On an Island

Our "laboratory" attempts to study the relative importance of these various modes of transmission of cold infection failed; colds just would not jump from an infected to a normal person as regularly as we wanted them to. So we decided to carry on this investigation with a group of people living in isolation, in the hope that their heightened susceptibility to cold infection would provide a surer means of studying routes of cross-infection. We learned of an island away off the northern coast of Scotland that was ideally suited to our purpose: it was uninhabited but still had on it a number of old stone houses in reasonable repair. Its owner, the Duke of Sutherland, kindly allowed us to use it.

Twelve volunteers, mostly students from Aberdeen, went and lived on this island for the months of July, August and September, 1950, with enough provisions and equipment for their three months' stay. For the first 10 weeks their only contact with the mainland was a portable radio set. The students occupied themselves with cooking and other domestic duties, study, observations on ornithology, fishing and in many other ways.

The results of the experiment were of much interest, though not at all as expected. The 12 persons spent the first 10 weeks together. Then they divided into three separate parties of four, each occupying one third of the island. At this time two scientific observers arrived from the mainland and joined one group, party C, to see whether they would infect the presumably hypersusceptible islanders, assuming that the visitors might possibly be carrying cold virus. No colds, however, appeared. Five days later six people who definitely had colds were sent to the island. The six had been infected with a pedigree strain of cold virus from Salisbury. They joined party C and lived with them for four days in close contact, to make sure that their colds would "jump" to the islanders.

Parties A and B were subjected to two different methods of exposure. The six mainlanders with colds went to one of the rooms used by the members of party A, while the latter were absent, and occupied it for three hours, handling crockery, playing cards and anything else they could find, in order to distribute their infected nasal secretions and contaminate the environment as liberally as possible. After they had withdrawn, party A returned to the room and for three hours used the cards, crockery and so on. Party B, on the other hand, was exposed only to the same air as the cold-sufferers used. Its members spent three hours in a sealed room with the visitors but separated from them by a screen which did not reach floor or ceiling and was designed to allow only the finest airborne particles to pass from one part of the room to the other. The people with colds talked and sneezed freely; party B remained quiet. Tests showed that plenty of bacteria-carrying particles reached party B.

The unexpected upshot of all these tests was that nobody caught cold, not even the members of party C, who lived in close contact with the cold-sufferers! We scratched our heads to account for the result and wondered if, perchance, the artificial passing of our pedigree colds at Salisbury had so attenuated or modified the infective agent that, though it could still produce colds when dropped in the nose, it would no longer "jump." So we got hold of a crofter on the mainland who happened to have a natural cold and brought him to the island for a day. Though his cold was already five days old, it passed naturally to three of the eight people who were in contact with him. A second lot of four pedigree colds arrived at this time and again failed to jump to any of those exposed. Our hunch as to a difference between wild and propagated colds may therefore have been correct. Most of those who did not get colds on the island remained free also when they went back to the mainland. Hence one conclusion from our work was that three months' isolation may not be long enough to induce uniformly high susceptibility. The different behavior of the crofter's and the pedigree colds has given us a number of ideas for further study; consequently the experiment was by no means in vain.

Cold "Cures"

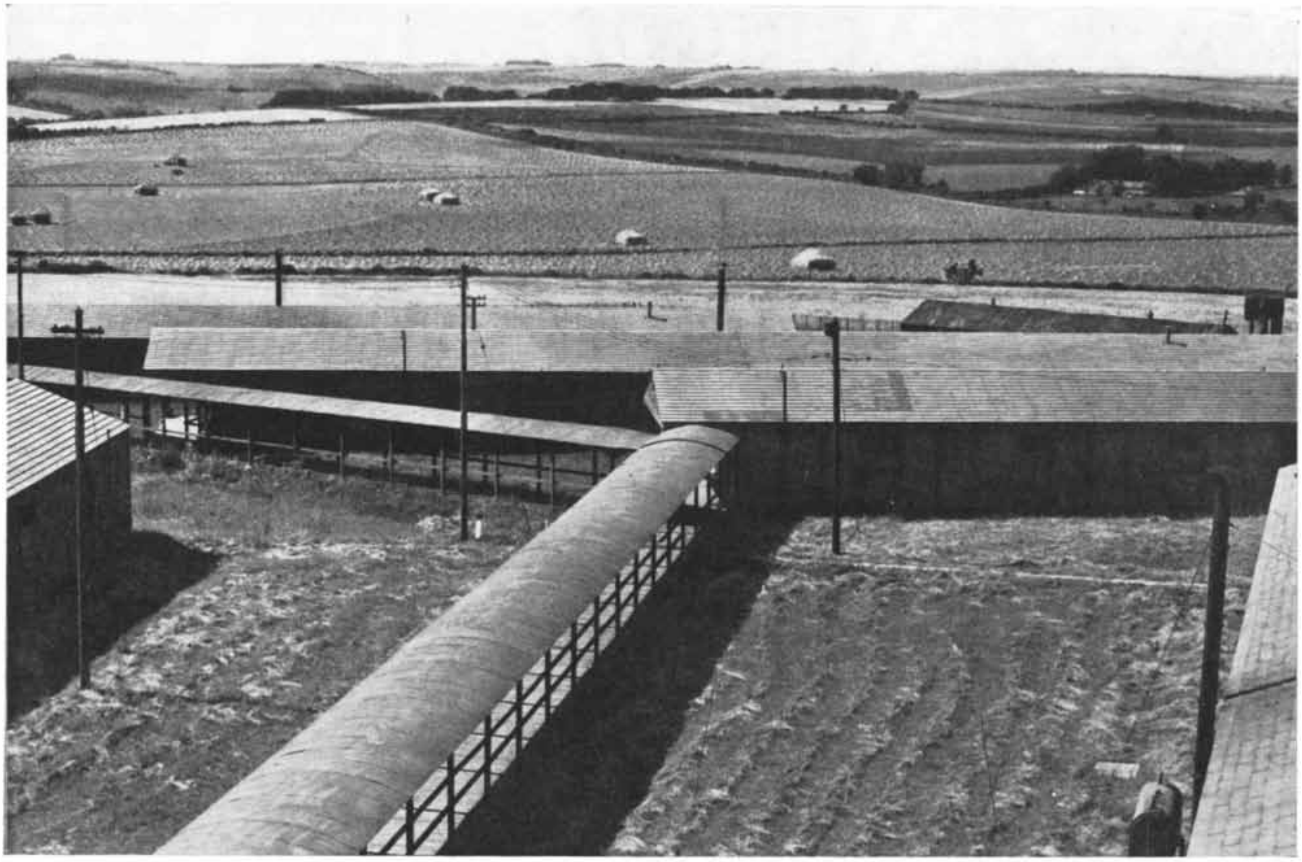
As explained earlier, it is not always easy to decide just when a person has or has not got a cold; often this can be determined only by carefully designed techniques. It is still more difficult to decide when a cold has been prevented or cured. A cold's natural duration is extremely variable, and it is likely that at least as many colds abort in their early stages as go on to be full-blown. Hence people often draw rash conclusions about "cures" on slender evidence, as testified by the correspondence sent to us by over 200 persons with the most helpful intentions. Not only can we place little or no faith in conclusions based on individual experience, but we can be readily deceived by trials carried out on a fairly extensive basis.

Recently a group of drugs called antihistamines has come into prominence. They have considerable effectiveness against unpleasant symptoms due to hypersensitivity or allergy—for instance, in hay fever. Two years ago several groups in the U. S. claimed that the antihistamines were effective in curing colds, especially when administered within a few hours of onset. It was stated that adequately controlled trials carried out on hundreds of subjects had proved this. Antihistamines as cold "cures" immediately caught on, were sold over the counters of drugstores in bucketsful and proved very profitable to many concerned. Those who knew the difficulties of the subject were not, however, convinced that the controls described in the published accounts were by any means adequate. More conservative doctors, including the Council for Pharmacy and Chemistry of the American Medical Association, became alarmed at the indiscriminate use of the drugs, especially as they are not without unpleasant or even dangerous side-effects. Really adequate trials, both in America and Britain, have now failed to show that antihistamines give any appreciable benefit at all: the bubble has been pricked. In trials at Salisbury we found two of these substances to be valueless, even when given for three days before instillation of virus into volunteers' noses and continuously thereafter.

Unfortunately for the poor public, a "cold-cure" is news and is well publicized. Pricking of a bubble is not news and word of it gets around slowly. So antihistamines, useless for curing colds, are still being sold in quantity for that purpose. Claims to prevent colds by means of oral or other vaccines rest on just as shaky foundations as those of the antihistamines: adequately controlled trials have failed to demonstrate their value.

There are things that can be done to relieve the unpleasantness of colds, but up to the present it still remains true that the untreated cold will last about seven days, while with careful treatment it can be cured in a week!

C. H. Andrewes, head of the department of bacteriology and virus research at the National Institute for Medical Research, London, is director of the research on the common cold at Salisbury. He has been assisted there by a team including T. Sommerville, K. R. Dumbell, J. E. Lovelock and J. Porterfield.



SALISBURY LABORATORY consists of a number of long huts divided into apartments and connected by passages. The volunteer subjects are isolated in pairs in separate apartments. Meals are left outside their doors.

DESERTED ISLAND north of Scotland was used for an experiment to see how subjects would react to cold infection after a period of isolation. Unexpectedly, three months' seclusion here did not make them susceptible.

GEORGII AGRICOLAE DE RE METALLICA

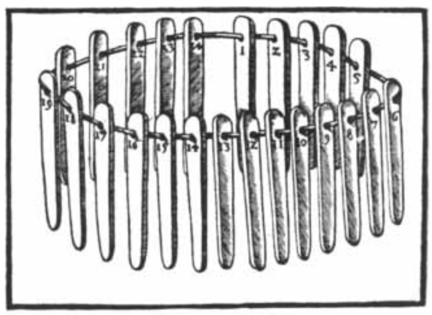
A Renaissance genius was the earliest modern writer on mining and metallurgy

GEORGIUS AGRICOLA was a Renaissance scholar who spent much of his life studying the mining districts of Central Europe. Out of his observations came *De Re Metallica,* the first systematic account of the ancient technologies of mining and metallurgy. Some 40 years ago this great book was translated from the Latin by former President Herbert Clark Hoover and his wife Lou Henry Hoover. Now the translation has been handsomely reprinted by Dover Publications, Inc., of New York. A few of the many original woodcuts from this edition are shown here.

Agricola was born in the Saxon town of Glauchau in 1494; his name is a Latinized form of Georg Bauer. He studied philology in Germany and medicine in Italy. When he came back from Italy he was appointed physician of Joachimsthal, a town in what is now Czechoslovakia. Today Joachimsthal is known as the center of one of the world's richest uranium deposits, and even then it was a booming mining town. Agricola spent his spare time visiting the mines and smelters and reading everything he could find about mining and metallurgy. It was not a great deal. "From all these sources," he wrote, "not one half of the whole body of the science of mining could be pieced together." Agricola was skeptical of earlier writing on the subject, which had been done either by alchemists or ancient Greek philosophers. He said: "I have omitted all those things which I have not myself seen, or have not read or heard of from persons upon whom I can rely." *De Re Metallica* appeared in 1556, the year after Agricola's death.

According to the Hoovers, Agricola was not only the first modern writer on mining and metallurgy; he was also the first modern scientist. They write that ". . . he was the first to found any of the natural sciences upon research and observation." Say the Hoovers: "No comparative study of . . . the modest sober logic and real research and observation of Agricola, can leave a moment's doubt as to [his position] as the pioneer in building the foundation of science by deduction from observed phenomena."

SHAFTS AND TUNNELS were dug by miners. Wrote Agricola: "Now when a miner discovers a *vena profunda* he begins sinking a shaft and above it sets up a windlass, and builds a shed . . . to prevent the rain from falling in."



TOUCHSTONES tested gold or silver content of metals. They were alloys of gold, silver and copper.

TIN ore was washed by diverting a stream into a ditch near the deposit. The miners then threw the ore into the ditch to wash away everything but stones bearing tin.

VENTILATION of mines was a serious problem. Sometimes it was solved by a magnificent arrangement of bellows. These were operated by horse- or manpower.

GOLD was sometimes washed by miners standing in streams. When the ore was placed in the frame, the gold settled near the handles and the waste washed away.

DIVINING was disapproved by Agricola. He wrote that a miner should be a "serious man." He should be "skilled in the natural signs" instead of using a divining rod.

White Blood Cells v. Bacteria

Some new observations have settled an old argument as to whether phagocytes are primary or secondary antagonists of infection. It seems that in acute infection they are the first line of defense

by W. Barry Wood, Jr.

"IF EVER there was a romantic chapter in pathology it has surely been that of the story of phagocytosis." Lord Joseph Lister so remarked to the British Association for the Advancement of Science in his presidential address in 1896.

The story to which he referred began on the Strait of Messina in the year 1882. There the Russian zoologist Élie Metchnikoff had sought refuge from the political strife that had driven him from his native country. Metchnikoff's own words vividly describe the simple biological experiment that was destined to become one of the most important in medical history:

"One day when the whole family had gone to a circus to see some extraordinary performing apes, I remained alone with my microscope observing the life and the mobile cells of the transparent starfish larva, when a new thought suddenly flashed across my brain. It struck me that similar cells might serve as the defense of the organism against intruders. Feeling that there was in this something of surpassing interest, I felt so excited that I began striding up and down the room and even went to the seashore, in order to collect my thoughts.

"I said to myself that if my supposition was true, a splinter introduced into the body of the starfish larva, devoid of blood vessels or of a nervous system, should soon be surrounded by mobile cells, as is to be observed in a man who runs a splinter into his finger. This was no sooner said than done. There was a small garden to our dwelling, in which we had a few days previously organized a Christmas tree for the children on a tangerine tree. I fetched from it a few rose thorns and introduced them at once under the skin of the beautiful starfish larva, transparent as water.

"I was too excited to sleep that night at the expectation of the result of my experiment, and very early the next morning I ascertained that it had fully succeeded. That experiment formed the basis of the phagocytic theory, to the development of which I devoted the next 25 years of my life."

In later experiments Metchnikoff observed that the mobile cells were able to ingest and destroy small particles, including bacteria, that were foreign to the host. The cells were therefore named "phagocytes," from the Greek words meaning eating and cells. From his own observations and from earlier ones by the German pathologist Julius Cohnheim, who had demonstrated that white blood cells migrated from tissue capillaries to form pus at a site of injury, Metchnikoff concluded that inflammation constituted an important defense reaction of the body and played a major part in bringing about recovery from bacterial infection. He wrote: "Inflammation . . . is a curative reaction in the organism, and morbid symptoms are no other than the signs of the struggle between the mesodermic cells and the microbes."

METCHNIKOFF'S theory that bacteria were destroyed by the phagocytic cells met with immediate opposition among pathologists. They had often found bacteria within the white blood cells of patients who had died of bacterial infections, but they interpreted this to mean that the cells merely provided transportation for the microbes, carrying them to new areas and thus promoting the spread of infection. Pasteur's immunization against rabies, and the detection of bactericidal substances in blood serum by the German bacteriologist Hans Buchner, had convinced students of infectious disease that recovery from bacterial infection depended upon the presence of antibodies in the circulating blood, rather than upon cellular reactions in the tissues. This view that chemical properties of the blood were solely responsible for immunity was given further support by the discovery of antitoxin in blood serum by the German bacteriologist Emil von Behring.

So during the closing decades of the 19th century a spirited controversy developed between the great majority of pathologists, who adhered to the doctrine of "humoral" immunity, and a few followers of Metchnikoff, who championed the theory of cellular immunity. At the turn of the century, however, there came a discovery that threw new light on the situation. In 1903 two British bacteriologists, Almroth Wright and Stewart Douglas, found that the serum of immunized animals contained substances that greatly accelerated the destruction of bacteria by phagocytes. The substances were antibodies which appeared to prepare bacteria for ingestion by the white blood cells; they were therefore named opsonins, from the Greek verb meaning "to prepare food." The discovery of opsonins partly reconciled the two conflicting theories of bacterial immunity by suggesting that the antibodies and the phagocytes played a joint role. Nevertheless, the controversy continued. In time the antibody theory gained the upper hand, for antibodies were easily measured in the laboratory. Furthermore it was shown that bacteria possessing protective capsules could not be phagocyted unless first opsonized with specific antibody. The phagocytes, it was held, played only a secondary part; immunity depended mainly on the antibodies.

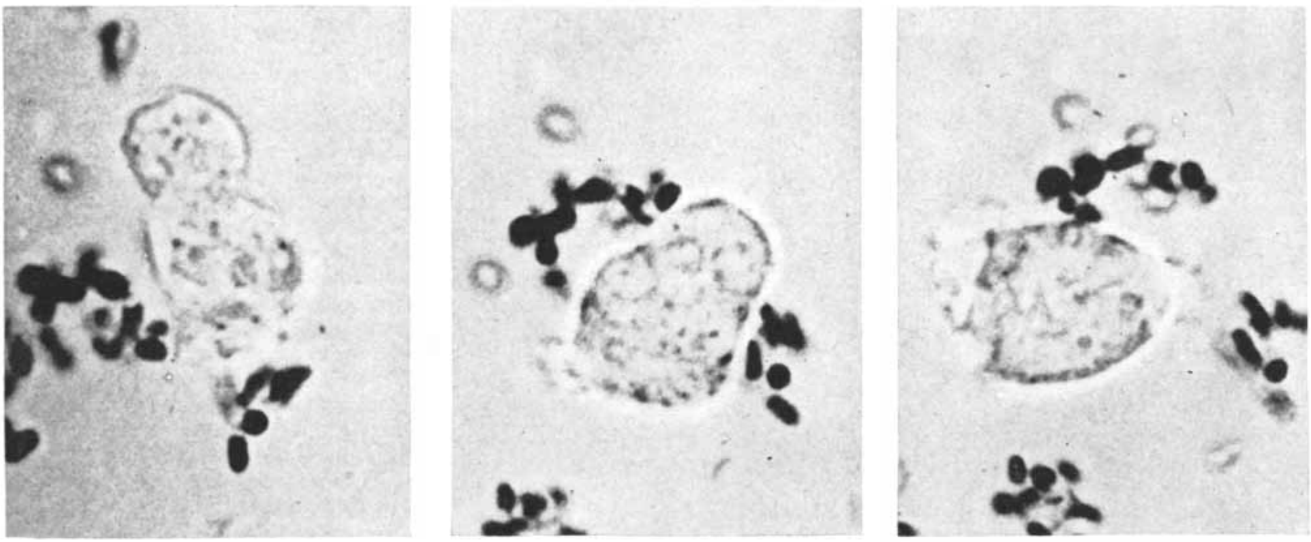
Today, however, Metchnikoff's views can be strongly defended. It has recently been demonstrated that phagocytes play a far more important role in the cure of acute bacterial infections than had been conceded by immunologists.

Here we must note an important distinction between acute and chronic infections. Most bacteria that cause acute infections in man do damage to the body only when they are outside of cells. Once ingested by phagocytes, they are promptly destroyed by ferments in the phagocytic cells. Their virulence is due in large measure to outer capsules that protect them from the phagocytes. Most of the bacteria that cause chronic infections, on the other hand, are essentially intracellular parasites. Though readily swallowed by cells, they can survive and even multiply within the cells.

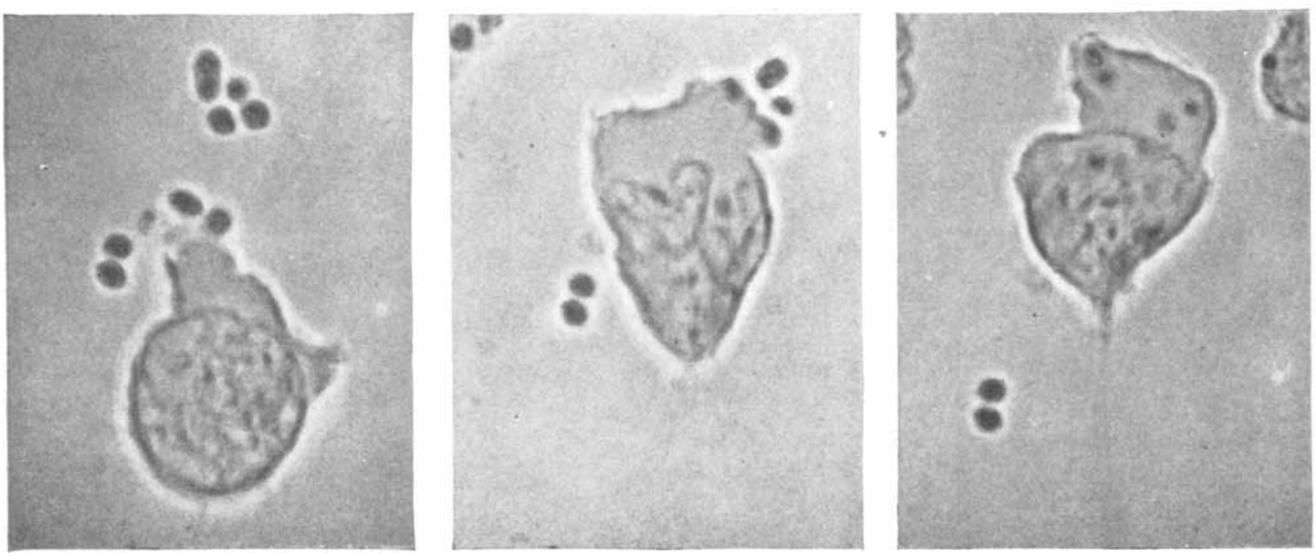
Thus in acute infections the critical phase of the struggle between the host and the bacteria is waged in an extracellular environment; in chronic infections it is waged inside the cells. It follows that phagocytosis as a defense mechanism is far more important in acute infections than in chronic ones. Had Metchnikoff and his contemporaries been able to draw this distinction between acute and chronic infections, many of their disagreements concerning immunity would have been resolved.

The most conclusive evidence supporting Metchnikoff's phagocytic theory has come from studies done with pneumococci and Friedlander's bacilli, two species of microbes causing acute pneumonia in man. These two species possess capsules that render them relatively resistant to phagocytosis. In their virulent forms they are surrounded by a capsular gel which serves as an armor against phagocytes. If the capsule is removed, the microbe becomes susceptible to phagocytosis. The capsular gel is composed of a polysaccharide, so-called because it is a combination of a number of carbohydrate molecules. The polysaccharide is chemically different in each type of pneumococcus (there are now more than 75 known types). It is the polysaccharide in the microbe's capsule that acts as the antigen calling forth the production of antibodies. When an animal is infected or immunized with a given type of pneumococcus, the antibodies formed are highly specific and react only with that particular type. They have a specific molecular structure which allows them to "fit" the antigen with which they react. The reaction changes the physical properties of the material in the capsule and thereby renders the pneumococcus susceptible to phagocytosis. A microbe thus coated with type-specific antibody is said to be opsonized.

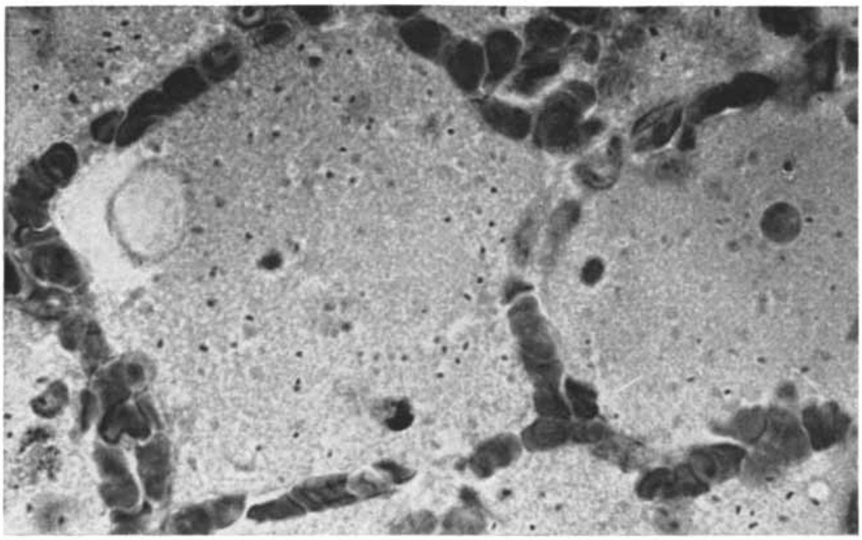
When suspended in fluid, phagocytes



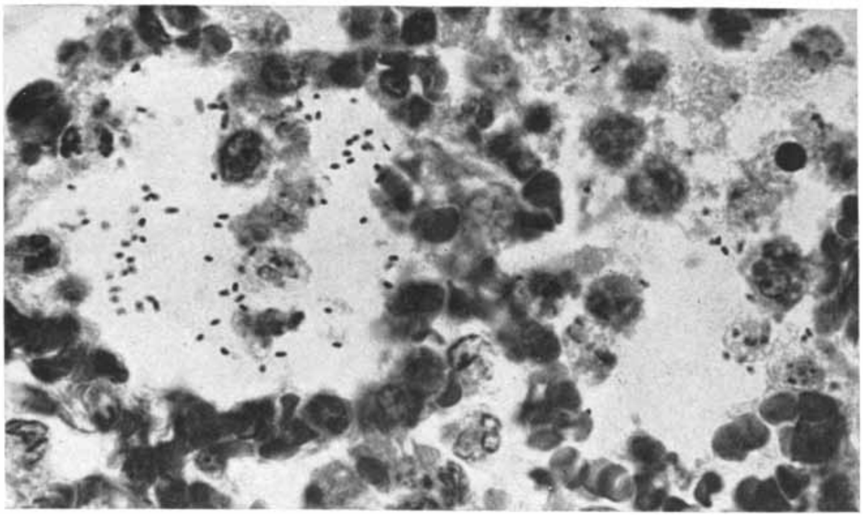
PHAGOCYTE FAILS TO INGEST Friedlander's bacilli that are floating freely in a fluid medium, even when its advancing projections come in contact with them. Photomicrographs were made at intervals of 30 seconds.



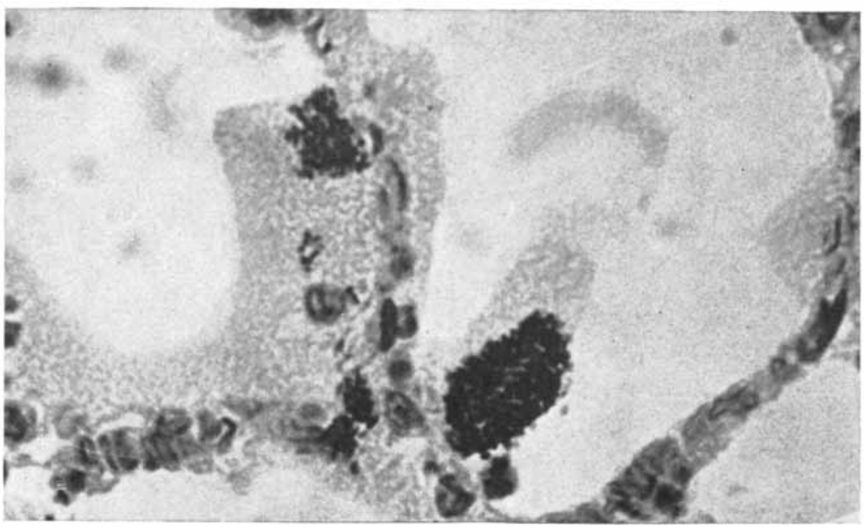
PHAGOCYTE READILY INGESTS pneumococci that have been exposed to antibody. The pneumococci appear to adhere to the phagocyte before they are drawn into it. Photomicrographs were made at intervals of two minutes.



AIR SACS of an experimental animal with pneumococcal pneumonia are filled with a fluid containing pneumococci (*small dark spots*) and red blood cells.



PHAGOCYTES enter the air sacs. Normally the air sacs are free of fluid, but they are flooded when their capillaries are damaged by pneumococci.



ANTIBODIES cause the pneumococci to clump and stick to the walls of the air sacs. This keeps the pneumococci from spreading to other air sacs.

are unable to engulf fully encapsulated pneumococci or Friedlander's bacilli. Under the microscope it can be seen that the phagocytes' pseudopods push aside the bacteria without ingesting any of them. But when type-specific antibody is added to the preparation, the opsonized bacteria stick to the surfaces of the phagocytes and are quickly engulfed. This striking effect of antibody upon the microbes' resistance accounts in part for the therapeutic effectiveness of the antipneumococcal serums which were so widely used in the 1930s. Specific antibody also causes the pneumococci to stick to one another and to surrounding tissues. The multiplying microbes are thus immobilized and fall easy prey to the phagocytic cells.

IT IS clear, therefore, that antibody does indeed play an important part in the development of an acquired immunity to pneumococcal pneumonia. But what happens before the antibodies are formed? The accumulation of antibodies in an infected host is a relatively slow process; in human patients with pneumonia, for example, antibody can rarely be detected in the blood until the fifth or sixth day of the disease. Yet man possesses a natural immunity that often enables him to gain the upper hand over the pneumococcus many hours before antibodies appear in his blood. Moreover, the antibody theory cannot account for the prompt recovery of patients who are treated with modern drugs.

The "sulfa" drugs are effective in the treatment of bacterial infections by virtue of the fact that they slow the multiplication of the bacteria. Penicillin and other antibiotics not only slow the growth of susceptible bacteria but also kill some of them outright. It has been assumed that the curative effect of these drugs depends in part on the patient's ability to manufacture sufficient antibody to opsonize the slowed bacteria. It is well known, however, that patients treated with such drugs often recover several days before antibody can be detected in the blood. Similar observations made on experimental animals indicate that phagocytosis takes place in the lungs long before antibody can be demonstrated either in the blood or in the tissues. Thus it appears that during chemotherapy phagocytosis of pneumococci occurs in the lungs *in the absence of antibodies.* The following experiment offers strong evidence in support of this conclusion.

The lungs of normal rats were removed and fixed in Formalin. The fixed lungs were washed for 24 hours, and a mixture of washed phagocytes and pneumococci suspended in salt solution was then injected into them. The injected lungs were incubated for 30 minutes, at the end of which time they were sliced for microscopic examination. All sections showed phagocytosis, in spite of the fact that there was no possible outside source of antibody in the chemically fixed tissue.

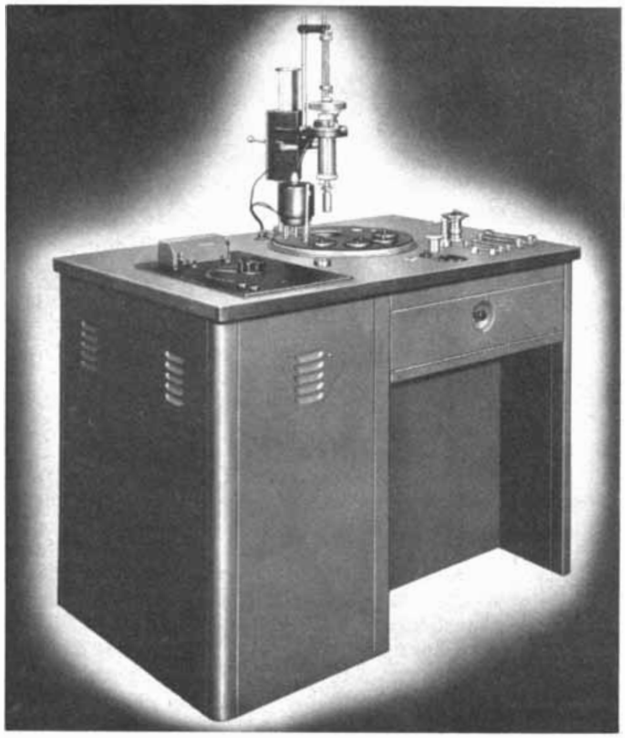
Further study has revealed that the ability of the phagocytes to destroy bacteria without the aid of antibody depends upon the presence of a suitable surface upon which the phagocytes may operate. They need a relatively rough or "sticky" surface. When the mixture of phagocytes and pneumococci is placed on rough material such as moist filter paper or cloth, the phagocytes engulf the microbes just as effectively as they do on body tissue. In contrast, the phagocytes are unable to attack fully encapsulated organisms on a smooth surface such as that of glass or cellophane. The failure of earlier investigators to observe phagocytosis of pneumococci in the absence of antibody appears to be due to the fact that phagocytic tests in the laboratory are routinely performed either in glass test tubes or on the smooth surfaces of glass slides or cover slips. The Danish bacteriologist J. Oerskov did observe spontaneous phagocytosis of pneumococci without antibody on the relatively rough surface of solid agar more than 10 years ago, but he attributed no biological significance to the observation.

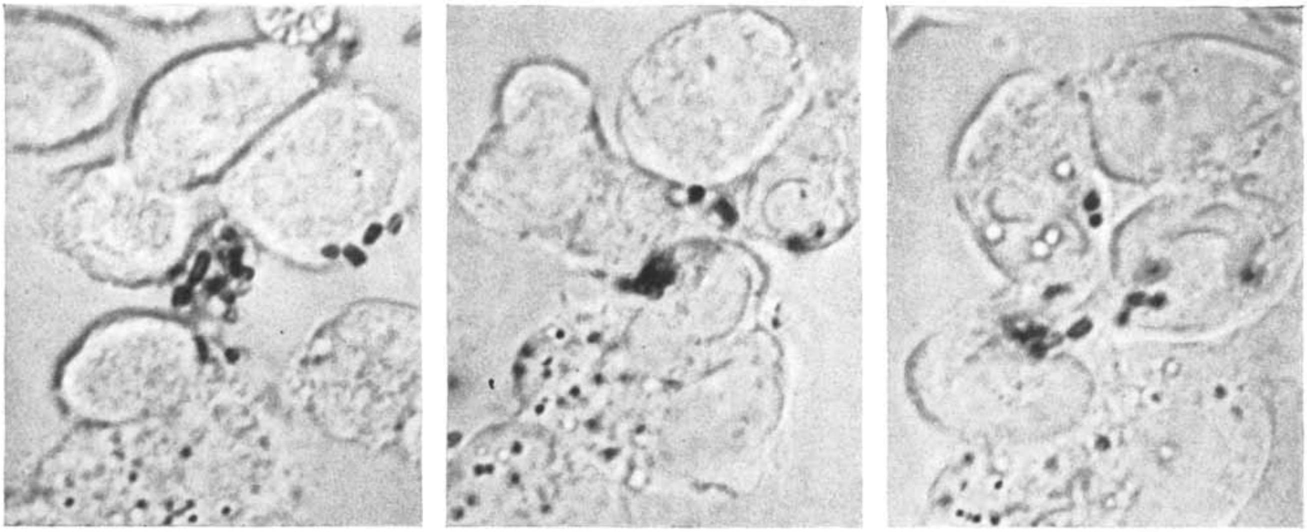
Under the microscope one can see the phagocytes trap the encapsulated bacteria against the tissue surfaces and then swallow them. In the case of lung tissue, for example, the phagocytic white blood cells pin the bacteria against the walls of the alveoli (air sacs). The forward part of the white cell engulfs the bacteria. Once inside the cell's cytoplasm, the bacteria are usually moved to the rear of the cell and promptly killed, within a matter of less than 30 minutes.

Occasionally, when many phagocytes are present, they team up and trap the bacteria between their own surfaces. The efficiency of this cooperative procedure can be demonstrated by crowding leucocytes and bacteria into a more concentrated mixture by means of centrifugation. When the white blood cells are brought sufficiently close together by this method, they are able to phagocyte microbes in the absence of antibody.

The strands of fibrin that are formed in clotting blood plasma serve the same purpose. Fibrin formation is a common feature of the inflammatory reaction that occurs in acute bacterial infections of the lung and other tissues of the body. Investigation shows that white blood cells use the surfaces of the fibrin strands to trap encapsulated bacteria and thus phagocyte them in the absence of antibody. The fibrinous property of acute bacterial exudates appears to contribute to the body's anti-bacterial defense by promoting such phagocytosis.

THE general process here described has been named "surface phagocytosis," because of the critical role played





SEVERAL PHAGOCYTES hem in encapsulated bacteria. These photomicrographs cover a span of 30 minutes. When a phagocyte can trap bacteria against a rough surface, it can devour them in the absence of antibody.

by the surface against which the bacteria must be pinned. There is evidence that surface phagocytosis is an important factor in the body's defenses against infection in many tissues besides the lung: for example, in subcutaneous tissue, in lymph nodes, in the liver and in the spleen. Recent experiments indicate that surface phagocytosis operates in the blood itself. White blood cells sticking to the walls of small capillaries throughout the body may phagocyte blood-borne bacteria by trapping them against the sides of the vessels, particularly where blood flow is sluggish or has temporarily ceased altogether. This appears to account, at least in part, for the remarkable ability of the bloodstream to clear itself of invading bacteria.

On the other hand, surface phagocytosis is relatively inefficient in the potential "open" cavities of the body, such as the peritoneal cavity in the abdomen, the pleural and pericardial cavities in the chest and the meningeal cavity about the brain. In these relatively large spaces the proportion of fluid to phagocytic cells during infection is far greater than in the "solid" tissues of the body. As we have seen, phagocytes diluted in fluid are unable to engulf fully encapsulated bacteria. The reason for this is now clear: white blood cells separated by appreciable amounts of fluid are deprived of sufficient contacts with one another and with tissue surfaces to carry out efficiently their function of destroying bacteria.

As might be expected, natural resistance to acute bacterial infection is significantly lower and response to chemotherapy is less satisfactory in body cavities than in tissues possessing a tightly knit structure which provides only small interstitial spaces for the accumulation of fluid. Phagocytosis is also relatively ineffective in the cavities of abscesses, where the normal architecture of the tissue has been destroyed. Not only are the phagocytes diluted by fluid, with relatively few tissue surfaces against which to pin the microbes, but many of those located within the mass of pus are killed by want of oxygen. The ineffectiveness of phagocytosis in such areas accounts for the fact that even the most vigorous therapy with potent anti-microbial agents, such as penicillin, will rarely cure an established abscess unless some form of drainage is instituted to remove the accumulated pus.

AMONG the common microbes that cause acute infections in man, only one, the pneumococcus known as type III, has been found to be resistant to surface phagocytosis. This organism possesses a unique capsule. On its outer surface is a layer of loosely packed polysaccharide, sometimes called the "slime layer." The slime-covered pneumococci are able to resist ingestion by phagocytes even after being trapped against tissue surfaces, apparently because of the protective effect of the slime layer. Fortunately for the microbe's victims, the type III pneumococci possess the slime layer only during the very earliest stages of infection, when they are multiplying at a maximum rate. As the lesion matures and the bacteria's multiplication slows, the slime layer disappears from the surface of the capsule, and the organism then becomes susceptible to surface phagocytosis. The fact that virulent strains of type III are the most highly pathogenic pneumococci encountered in nature appears to be due to their ability to produce the slime layer.

It is clear, then, that phagocytosis plays an important role in the mechanism of recovery in acute bacterial disease. It operates effectively not only in the late stages of infection, when antibodies have had time to accumulate, but also in the early stages, when no immune bodies are demonstrable either at the site of infection or in the serum. Were it not for surface phagocytosis, a person infected with such well-armored microorganisms as pneumococci or Friedlander's bacilli would be overwhelmed long before antibodies had reached effective concentrations within the body. The patient's constantly ready supply of phagocytes, combined with the antimicrobial action of modern chemotherapeutic drugs, has far more effect in determining the outcome of acute bacterial infection than do the relatively slow mechanisms that involve the manufacture of antibodies.

Today, nearly 70 years after Metchnikoff's ingenious experiment with the starfish larva, the importance of phagocytosis in infectious disease can be clearly defined. In acute bacterial infections caused by extracellular parasites, phagocytosis occurs in the absence of antibodies and promptly destroys the invading microbes. Here phagocytosis *per se*, as first postulated by Metchnikoff, frequently determines the outcome of the disease. In essentially intracellular infections, caused by viruses, some bacteria and certain protozoa, phagocytosis is considerably less crucial, because of the ability of the infecting parasites to survive and even multiply in an intracellular environment. The destruction of intracellular parasites depends upon defense mechanisms operating within the cytoplasm of host cells. The nature of these intracellular processes is at present unknown. Their elucidation may well constitute the next important advance in the science of immunology.

W. Barry Wood, Jr., who was an All-American quarterback as an undergraduate at Harvard University in 1932, is professor of medicine at Washington University School of Medicine in St. Louis.

THE PERKIN-ELMER

INSTRUMENT DIGEST

A condensation of some of the articles appearing in past issues of THE PERKIN-ELMER *INSTRUMENT NEWS*, a quarterly publication of The Perkin-Elmer Corporation, manufacturers of scientific instruments—Infrared Spectrometers, Tiselius Electrophoresis Apparatus, Universal Monochromator, Flame Photometers, Continuous Infrared Analyzer, Low-Level Amplifiers—as well as Astronomical Equipment, Replica Gratings, Thermocouples, Photographic Lenses, Crystal Optics, and Special Instruments for the Government. **For further information, write The Perkin-Elmer Corp., Norwalk, Conn.**

Norwalk, Conn. | January, 1951 | Vol. 2, No. 4

PIN-TYPE THERMOCOUPLE HAS SPEED, SENSITIVITY

Treatments of the design and performance of existing thermocouples fail to include the advantages and distinctive features of pin-type construction.

The Perkin-Elmer Thermocouple, combining as it does both speed and sensitivity, has many applications other than that for which it was originally designed. The construction and size of the thermocouple may be varied to suit particular applications.

Sensitivity and time constant may be expressed by the following equations:

$$(1)\ E_0 = \alpha \frac{Q}{L} \qquad (2)\ T = \frac{C}{L}$$

where E_0=thermoelectric voltage or sensitivity, α = thermoelectric coefficient of the materials used, Q = the radiant energy per second falling on the receiver, T = time constant, C = heat capacity, and L = energy loss per second per degree C.

It will be seen that a high E_0 depends upon a low L and short T depends upon a large L. The Perkin-Elmer Thermocouple is a compromise in that L is purposely made large due to the pin-type construction, and by selecting materials with a large α (making C as small as possible), the desired characteristics of speed and sensitivity are obtained.

You can receive the complete publication from which these articles were digested.

Write The Perkin-Elmer Corporation, Dept. SA, Main Avenue (Route 7), Norwalk, Conn., and you will receive regularly THE PERKIN-ELMER INSTRUMENT NEWS, an 8-page quarterly devoted to news of the latest advances in electro-optical instrumentation. Here are some of the features of the current issue:

ELECTROPHORESIS AIDS CANCER RESEARCH
Report on European Developments

ADH SCHMIDT CAMERA IN SOUTH AFRICA
First Photographs Reach U. S.

PIN-TYPE THERMOCOUPLES
Theory, Design and Performance

OSCILLOGRAPHIC INFRARED
Report by Shirleigh Silverman

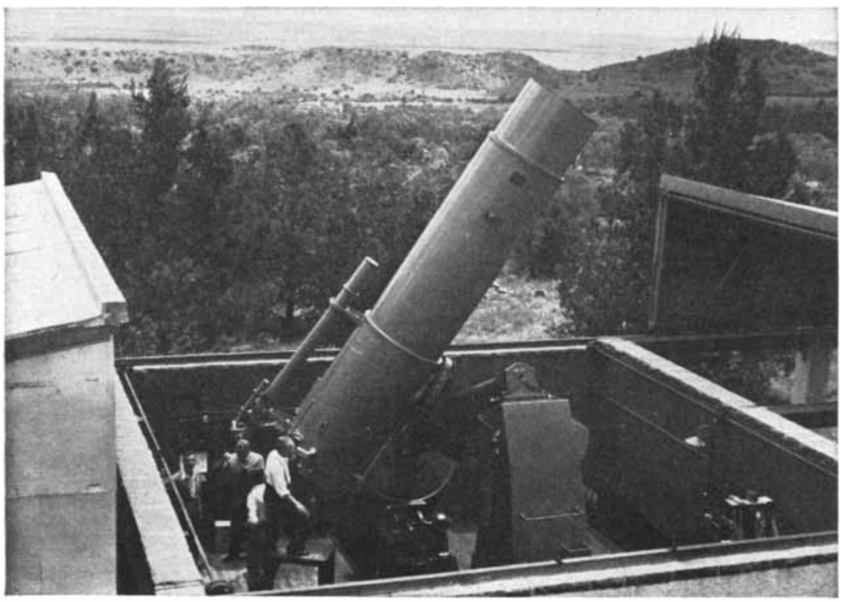
NORWALK PLANT OPENED

Perkin-Elmer has completed moving its plant and office facilities to its new 54,000 square-foot building at Norwalk, Conn. Old friends and new are cordially invited to visit the new plant.

SAFETY SWITCH AVAILABLE

A simple safety switch, designed to prevent damage to the source housing on Model 12 spectrometers, is now available from Perkin-Elmer.

These switches are constructed of a bimetallic strip and microswitch, as reported in INSTRUMENT NEWS, 1, *4, 5.* They are adjusted to open at approximately 100° C.



© The Friend, Bloemfontein, South Africa

First picture of 32" Baker-Schmidt ADH telescope, made by Perkin-Elmer, used for photographing the Milky Way at Harvard Observatory's Boyden Station, Bloemfontein, S. A.

BOILERWATER CHECKED WITH FLAME PHOTOMETER

Three new 1250 psi Cyclone steam generators at the Dow Chemical Company's Midland, Michigan, power plant have an intake of approximately 4000 gallons of water per minute. Since the water must be silica-free, Dow demineralizes it in a series of ion exchange units.

Frequent sodium determinations with a Perkin-Elmer Flame Photometer on incoming feedwater makeup enable Dow engineers to maintain a tight control over water quality and ion exchange resin capacities. The instrument also serves to locate leakage from mechanical trouble in valves, etc.

A Perkin-Elmer Flame Photometer in use at the Dow Chemical Company.

ELECTROPHORESIS AIDS IN CANCER RESEARCH

Swiss investigators at the University of Zurich have found marked changes in the electrophoretic serum patterns of rats with chemically induced sarcomas. Total serum proteins were reduced to less than 4 gms per cent, with a marked decrease in albumin; α-globulin was increased to the point where it was sometimes greater than the albumin. English scientists report similar patterns from human patients with various types of cancer.

In Scotland, studies are being carried out on proteins extracted from normal and cancerous tissue. Preliminary results show that virus-induced and chemically-induced fowl sarcomas differ both from each other and from the normal.

A digest of the second of a series of articles on Electrophoresis Developments in Europe by Dr. Dan H. Moore, head of the Electrophoresis Laboratory at Columbia University's College of Physicians and Surgeons.

(Advertisement)

STEEL SAWDUST is from a circular friction saw beginning to cut through a piece of steel. Such a saw is rotated at high speed and cuts even when it has no teeth. This photograph magnifies the dust 10 diameters.

MELTED GLOBULES of steel appear in the dust after the saw has been running a short time; the saw apparently advances through the metal by melting a thin layer of it. This photograph magnifies the dust 25 diameters.

FRICTION

One of the most familiar phenomena is one of the most difficult to explain. What is responsible for it: surface roughness, molecular cohesion or electrical attraction?

by Frederic Palmer

STANDING on the platform of a railway station, we see a train approach and come to a stop with the wheels spitting sparks. The events we have observed have taken place because of friction, one of the most familiar phenomena of nature. Friction produced by the pressure of the air-brake shoes on the steel wheels halts their turning, and the sparks are bits of steel dust scraped from the wheels which burn in the air because friction has raised their temperature very high. As the train starts once more, frictional force comes into play again. The driving wheels, turned by the engine, grip the track because of frictional resistance, and since they push back on the track, the track *pushes forward* on them so that the engine moves ahead, pulling the train behind it. On the other hand, to make the train easier to pull frictional resistance at the axles of the wheels must be reduced. Hence their metal bearings are kept lubricated by oil-soaked waste in a "stuffing box."

All this is familiar enough, but how does friction occur? What causes it, and what are the laws that govern the action of frictional forces? The surprising fact is that, basic as they are, these are still moot questions. The action of friction, simple as it may seem, is much harder to understand than one might expect. This article will deal chiefly with some of the fundamental work on the problem, as illustrated by the simple case of the dry sliding friction between two nearly parallel surfaces.

The earliest experiments on friction were carried out by the versatile genius Leonardo da Vinci about 450 years ago. He recorded in his *Codice Atlantico* drawings of a rectangular block sliding over a plane surface in different ways. From his experiments he deduced the laws governing the motion of the block. Da Vinci's drawings illustrate experiments which high-school physics students still perform with similar equipment today, but his work had no influence on the history of the investigation of friction, because his notebooks were not reproduced and published until after other investigators had carried out and reported such experiments independently.

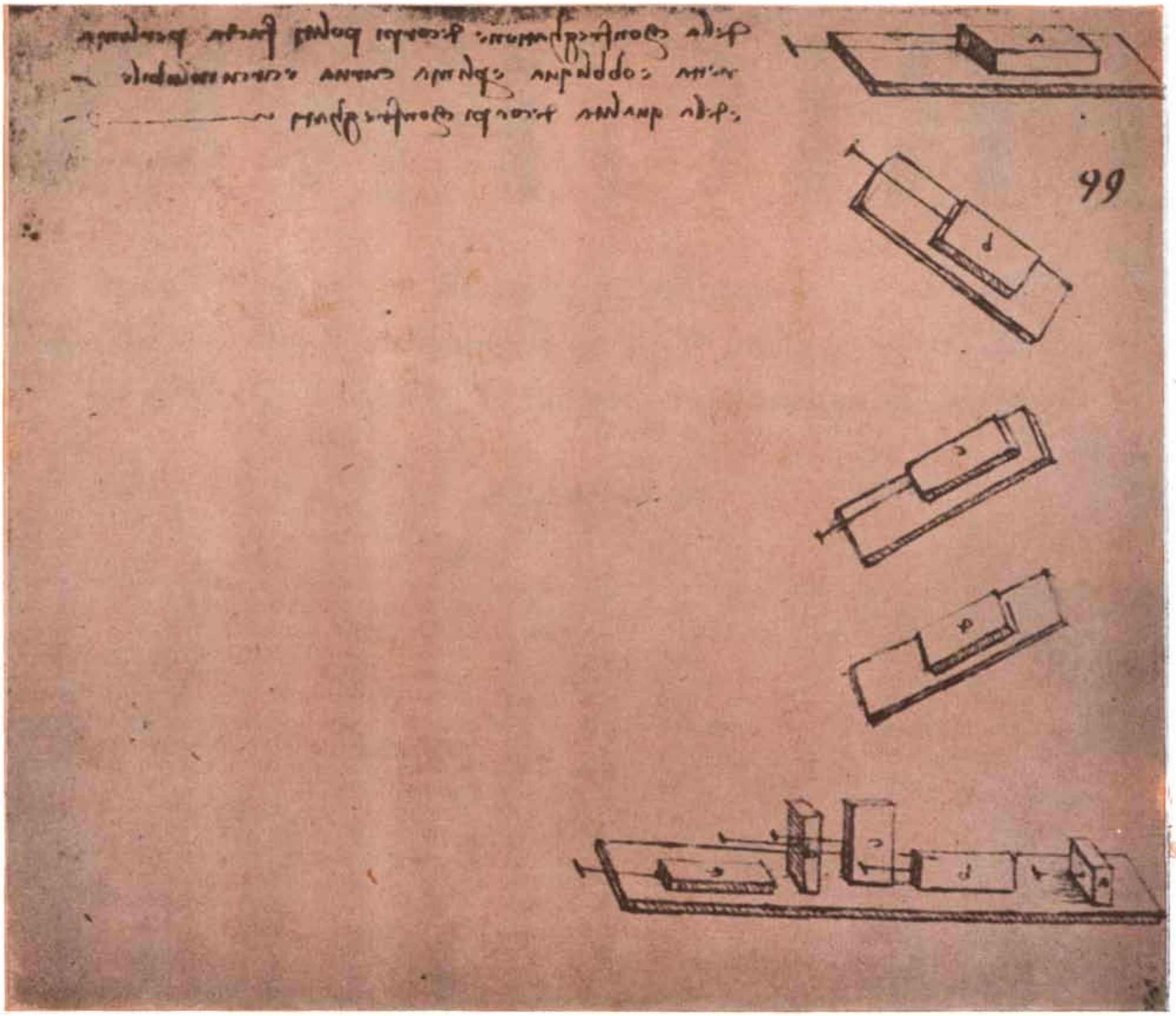
IT WAS three French physicists of the 17th, 18th and 19th centuries—Guillaume Amontons, Charles A. Coulomb and A. Morin—whose work established what are known as the classical laws of friction. Everyday experience teaches us that whenever one surface is made to slide over another a frictional force that opposes the motion springs into action. This force is always measured parallel to the two touching surfaces. If the surfaces lie in a horizontal plane and the upper one slides over the lower, as a puck on ice, they are pushed together by a vertical force equal to the weight of the slider. The classical laws established by the three Frenchmen may be summed up in four brief statements: 1) the frictional force, F, is directly proportional to the load, W; 2) the frictional force depends on the nature of the sliding surfaces; 3) it is independent of the area of contact between the surfaces; 4) it is also independent of the sliding velocity.

Morin devised clever means for measuring and automatically recording both the frictional force and the load. Through many measurements with large and small loads he confirmed the conclusion of his predecessors that for most substances the frictional force is one third to one fourth of the load. This ratio, F/W, is called the coefficient of friction for a given pair of sliding surfaces, such as oak on oak, steel on steel, oak on steel and so on.

Amontons and Coulomb attributed frictional resistance to the intermeshing of surface roughnesses, much as two brushes rubbed across each other would engage their bristles. Morin objected that such a theory led to results which he could not verify, but he offered no other theory to replace it. From that time to this a large majority of physicists and engineers have clung to the theory of intermeshing roughnesses and have incorporated this belief in their textbooks.

According to this theory, the smoother the sliding surface, the less should be the frictional resistance. But in recent times many tests by automobile manufacturers and others have proved that bearings and cylinders show lower frictional resistance and less frictional wear when one of the sliding surfaces is *rougher* than the other! Moreover, steel journal bearings of varying degrees of polished smoothness exhibit no significant differences in frictional torque. Actually it is now known that there is a limit beyond which further polishing of a surface *increases* rather than decreases the frictional resistance.

THESE facts favor another theory of friction—one which Coulomb himself suggested, but discarded, as early as 1785. This is that friction is caused by cohesion of the surfaces through the attraction of molecules, the same attraction that prevents any solid from falling to pieces. Under what conditions do surfaces cohere? The answer is that they do so when the molecules of one surface come so close to the molecules of the other that the two groups attract each other. Now all polished surfaces are found under high magnification to be dotted with hills and valleys. Two such surfaces in contact touch each other only at the hilltops. But when pressure is applied, the hilltops are pressed down by plastic deformation into little plateaus. The greater the applied force, the greater is the total area of all the plateaus and



LEONARDO DA VINCI illustrated his friction experiments in *Codice Atlantico.* The inscription is in mirror writing, the means by which da Vinci concealed his thoughts from those who might consider them heretical.

the greater the area of *actual contact* between the two surfaces. This area of actual contact must be clearly distinguished from the area of coverage of one surface by the other. The point is well illustrated by a golfer's spiked shoes. On a pavement the shoes slip easily, because the area of contact is only that of the ends of the spikes. But on sod the spikes sink in and the whole area of the shoe sole comes in contact with the ground. Of course, a further obstacle to slipping is provided by the fact that the spikes dent the sod and intermesh with it. Correspondingly, surface roughness plays a part in the friction between any two surfaces, since the humps on one surface slightly dent the other, sometimes enough to wear observable grooves. Such roughness cannot, however, be the principal cause of friction, in view of the facts cited above.

If molecular cohesion is the primary cause of friction, the frictional resistance should be proportional to the area of actual contact instead of to the load. But since the area of actual contact depends directly upon the load, how can we tell which of the two is the primary factor on which frictional resistance depends?

The Australian physicist F. P. Bowden (now at Cambridge University, England) and his co-workers found the answer to this question. They measured the force required to move sliders of various shapes over a steel surface plated with the soft metal indium. The slider sank into the soft metal and its load was supported mainly by the underlying steel. However, the area of contact between the slider and the indium could be varied without changing the load by varying the thickness of the indium coating. The results proved that frictional force is independent of the load, W, but directly proportional to the area of actual contact, A. If this seems to contradict our everyday experience and common sense, we need not be disturbed, for in all ordinary circumstances the load is proportional to the area of actual contact, so we can still write F/W instead of F/A for the coefficient of friction and be happy. The distinction between W and A emerges only in this special case by which Bowden ingeniously separated their effects.

FURTHER evidence that friction is caused largely by cohesion rather than by intermeshing humps is provided by an examination of the surfaces after sliding has taken place. Particles of material from one surface are always found clinging to the other. This holds true for both surfaces even when one material is harder than the other or when the surfaces are lubricated. It holds true when the load is very small and when the slider merely rests upon its base and is removed without sliding. We are indebted largely to the radioactive tracer technique for the demonstration of this fact. There is a great need for much more research by this highly sensitive method, which can measure the transfer of material in amounts so tiny that they are otherwise undetectable. Tests should be made with materials of different kinds, different hardnesses and different melting points in order to clarify results which are still obscure.

It is more difficult to duplicate experimental conditions in the field of friction than in many others, because the sliding surfaces may acquire unrecognized properties during their mechanical or heat treatment or may be affected by the atmosphere surrounding them.

At all events, radioactivity experiments by a number of investigators, of whom one of the first was the physicist J. T. Burwell, Jr., have proved the basic fact that molecules are transferred from one surface to the other. The finding that they are transferred even when one surface merely rests on the other gives strong support to the cohesion theory.

There is, however, another force that may also play a part in frictional resistance: namely, electrical attraction. When two surfaces rub together, one surface may gain electrons and become negatively charged, while the other loses electrons and becomes positively charged. The two surfaces of opposite charge attract each other and therefore retard sliding. The size of the electric charge depends upon the nature of the sliding surfaces and upon the nature, pressure and humidity of the surrounding gas; for example, in an atmosphere of oxygen the charge is much smaller than in an atmosphere of hydrogen or nitrogen. It is hard to see how to avoid attributing at least a part of the force of frictional resistance to such a separation of electric charges during contact, at least for nonmetallic materials. So little work has been done in this field, however, that the results are difficult to interpret; hence the supporters of the electrical theory are as yet few in number.

Now let us consider another of the classical "laws" of friction: that frictional force is independent of the velocity of sliding. Although Coulomb himself expressed some doubt about the validity of this statement when he made it in 1785, to this day a large majority of writers accept it unqualifiedly, untrue as it is easily shown to be. Every driver knows that he must ease up on his brake in order to stop his car without an unpleasant jerk. This implies that when the pressure is kept constant, the frictional force increases as the car slows down. Conversely, it decreases as the car speeds up—though drivers do not usually attempt to test this.

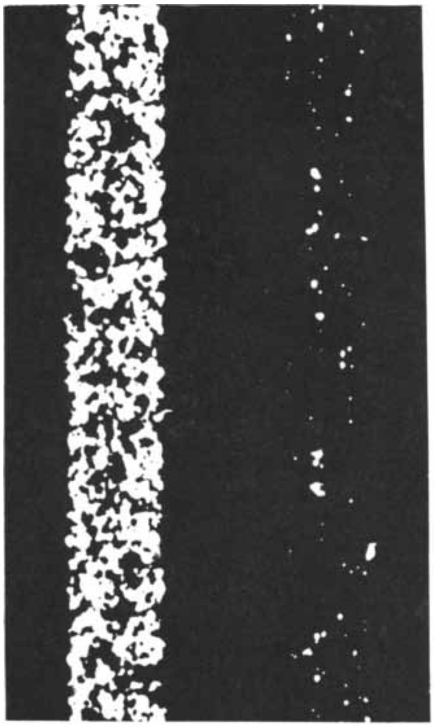
In the range of medium speeds, the range most convenient to use in the laboratory, it is true that the frictional force is nearly independent of sliding speed. At bulletlike velocities, however, it decreases with speed, and at tortoiselike velocities it increases with speed. Experimental work in the speed ranges at both extremes is beset with special difficulties, but the problem is a most important one for the designer of any vehicle that is to be stopped by the application of a brake, for the user of a friction saw cutting metal and for the expert in interior ballistics—the science dealing with whatever takes place as a bullet travels through a gun barrel.

THE German engineers G. Grötsch and E. Plake determined, by experiments of great ingenuity, that as the speed of a bullet increases, the frictional resistance of steel on steel at first drops rapidly, then declines at a slower rate until the bullet reaches a velocity of about 300 feet per second and above that speed virtually levels off. Such behavior is consistent with the cohesion theory of friction. The heat generated by friction must raise the temperature of the points of contact between the bullet and the gun barrel. The high temperature then facilitates plastic deformation of the surfaces and reduces frictional resistance. Assuming that when the bullet's speed reaches about 300 feet per second the heat generated is sufficient to melt the metal at the points of actual contact, the bullet thereafter would travel on a thin layer of liquid metal. The viscosity, or resistance, of the liquid changes little with increasing speed, which explains why the frictional resistance at higher speeds remains nearly constant.

If it is true that a high-speed bullet travels along the gun barrel on a thin layer of melted metal, we should expect to find traces of that metal frozen to the rifling after the gun has been fired. Projectiles often are fitted with a band of copper, like a cuff, of slightly larger diameter than the projectile itself. As motion along the barrel begins, grooves are cut in the copper band by the steel rifling. The spin requisite for accurate flight is thereby imparted to the tightly fitted projectile by the time it reaches the muzzle. Now since copper melts more easily than steel, we might guess that if we should saw the barrel in two lengthwise after the gun has been fired many times, enough copper should have been melted and fused to the steel to be visible. Such a "coppering" of the barrel is exactly what often occurs. This condition may become a serious defect, and if allowed to go too far may even obstruct the passage of the projectile.

The friction saw consists of a disk of thin steel rotated at high speed. At a circumferential speed of 250 to 300 feet per second this disk, even without teeth, cuts steel and other metals as a knife cuts a piece of cheese. It is thought that the saw works by generating so much heat through friction that it melts the metal on which it is working in a thin layer and advances through this momentarily liquefied metal. If that metal happens to be copper, the disk becomes "coppered" in the same manner as a gun barrel. The function of teeth in a friction saw for cutting steel seems to be to carry enough oxygen from the air into the cut to maintain a flame essential to the proper functioning of the saw. With such a saw it is possible to cut hot steel rails and bars, armor plate, aluminum, glass, plastics and many other materials, but not rubber.

TWO thousand years ago every charioteer knew that the wheels of his vehicle would turn more easily if he rubbed animal fat or tallow on the axles. From that time to the present much has been learned and written about lubrication; yet its basic mechanism is still uncertain. Those who hold, with Coulomb, that friction is due to the meshing of surface roughnesses believe that the function of the lubricant is to fill up the hollows so that sliding can take place more easily. Those who accept Bowden's cohesion theory believe that the lubricant forms a film which separates the deformed hilltops, thus reducing their molecular attraction. Those who hold to the electrical theory maintain that the film, by increasing the distance, reduces the electrical attraction between oppositely charged points on the sliding surfaces. All schools of thought agree that as lubricant is added its effect soon reaches a limit. This condition, called full lubrication, occurs when the film becomes so thick that the solid surfaces no longer are in contact with each other, even at the high spots. Sliding takes place entirely within the film of lubricant and hence is conditioned only by the internal friction (viscosity) of that film.



LUBRICATION EFFECT is illustrated by contrast in two tracks left by copper on steel. The track at the left was produced by copper rubbed over steel without lubrication. At the right, where surfaces were lubricated, comparatively few copper particles stuck to the steel.

Some metals, such as iron and copper, acquire a layer of oxide because of the chemical union between their molecules and those of atmospheric oxygen. Since heat accelerates this reaction, friction may promote the formation of an oxide layer. Such a layer in turn behaves like a thin film of lubricant; it hinders the direct action of one surface upon the other and hence makes sliding easier. The oxide layer sometimes flakes off, as in the case of hard steel bearings, leaving patches of steel exposed to further attack by oxygen and forming debris. Continued sliding of hard steel is thus accompanied by excessive wear.

Even when there is no chemical formation of oxide, the surface of every body exposed to the air becomes coated with a layer of adsorbed gas, mostly oxygen and water vapor. Since nearly all measurements of frictional forces have been conducted in air at atmospheric pressure without consideration of the possible lubricating effect of such gas layers, it is not surprising that the results obtained by different observers are sometimes inconsistent. Attempts have been made to measure pure frictional forces by heating metallic surfaces in a vacuum to remove the gas layer. In these experiments the frictional forces are found to be surprisingly large: F is several times greater than W. The frictional forces are unaffected when the surfaces are exposed to either hydrogen or nitrogen, but fall immediately in the presence of even a trace of oxygen or mercury vapor. They increase when the surfaces are exposed to cigarette smoke or that of burning insulation.

IN spite of 250 years of study and the excellent work now being done in France, Germany, England, Australia and the U. S., our knowledge of frictional phenomena is pitifully meager, and agreement is still lacking as to the fundamental cause of friction. Sometimes the things we can do most easily are the hardest to explain.

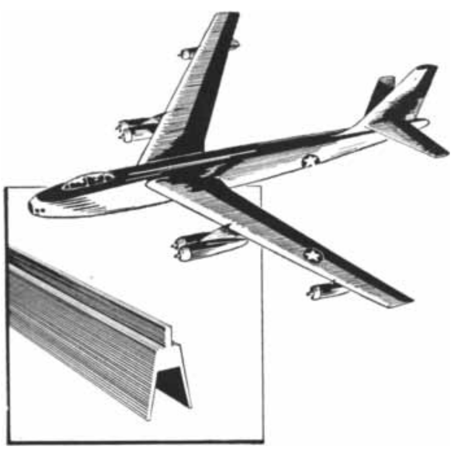
Frederic Palmer is emeritus professor of physics at Haverford College and editor for the research staff of the Franklin Institute.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

For many years Revere has been saying that the important figure for industrial buyers to watch is not the price per pound of a given material, but the cost of the finished part made from it. On that basis, it sometimes turns out that an "expensive" metal actually is cheaper than a "cheaper" one. We have seen many illustrations of this during our 150 years of experience.

One of the most recent of these cases involved an airplane part. Large planes, such as bombers, use counter-weights on elevators and rudder, to eliminate flutter and obtain smooth control in flight. For a long time it has been customary to use steel for these counter-weights. Since steel is magnetic, it was necessary to shift the fluxgate compass from its most advantageous location to an inferior one, to avoid the influence of the magnetic metal. Bronze was suggested as a substitute, but of course everybody knows it is more expensive than steel, and hence it was at first considered technically ideal but economically impractical. Then the manufacturer gave consideration to the fact that while steel was being bought in rectangular bars and then machined, bronze could be obtained in extruded shapes, conforming almost exactly to finish requirements.



At this point Revere was called in. In close collaboration with the designers on such matters as weight, design, tolerances, balance, and similar details, it was found likely that Revere Architectural Bronze No. 283, a readily extrudable alloy, would meet the requirements. Dies were made and in experimental runs the final design questions were solved. This alloy is now being supplied as extruded shapes in the required forms, dimensions and tolerances. As a result, the compass can be located where it should be, control is as smooth as it was before, money is saved and everybody is happy, particularly navigators and pilots.

Note the statement that "money is saved." True, the bronze costs much more per pound than the steel. But there is a great saving because the bronze is delivered in such forms that very little machining is needed. Finished parts are made more quickly, and machine tools and the skilled men to operate them are released for other essential work. Thus our country's resources are made to go further.

Let us give you some figures on the mere weight of materials, disregarding the expensive matter of man-hours and machine-hours. In order to obtain 242 pounds of finished counter-weights in bronze, only 287 pounds of Revere extruded shapes are required, and the scrap is of course salable. But to produce the same part in steel, 1048 pounds of rectangular steel bar have to be purchased and machined.

Such an example of the "more expensive" material proving to be not only much more satisfactory but definitely more economical is by no means unusual in Revere's experience. Probably every supplier to industry has similar instances in his files, though perhaps not so startling. Here is the key to this case history: the plane manufacturer asked Revere to collaborate, and explained the problem in detail. No matter what you make, nor from whom you buy, you will find your suppliers eager to give you the benefit of their knowledge and experience, and it will pay you very well indeed to call on them for it.

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WINDOWS

Because glass is transparent to some kinds of radiation but opaque to others, it can be used to trap solar energy. This will be a major method of heating in houses of the future

by Eugene Ayres

TWO hundred years ago Dr. Samuel Johnson, then living in Stourbridge amidst the glowing fires of Britain's infant glass industry, marveled at this window material that "could admit the light of the sun and exclude the violence of the wind." We have almost lost the salutary capacity to wonder. Actually we still have no more idea than had Dr. Johnson why glass can be made transparent to light, why it is a solid instead of a liquid or why it is in general opaque to thermal radiation. What we do now realize, however, is that these qualities, which make glass a superb means of trapping the heat of sunlight, have not been sufficiently exploited.

Glass will be increasingly important in the space-heating of the future. We seem destined to become more and more dependent upon the sun for all energy. It happens that sunlight is somewhat more easily adaptable to space-heating than to the development of power. These two circumstances taken together are full of fortunate significance, for we actually require more energy for heating our homes and our places of work than for transportation in our motorcars or for industrial power. Even in the highly industrialized U. S. nearly a third of the total energy consumed is for the heating of homes and offices; in the poorly industrialized communities containing the great majority of the population of the earth space-heating is the dominant energy demand, every other energy use being relatively minor.

Solar heating of houses is not new. It has been going on ever since houses were first built. Before fuel was available widely enough for general use, man had to depend mainly on the sun. But the ways of taking heat from the sun were primitive and ineffective. As our mineral fuels dwindle and we gradually become more dependent upon solar heating, we shall have to find more effective methods of using sunlight. Already there are blueprints which suggest that solar energy could be harnessed to provide a most convenient, flexible, clean system of heating.

Only a few centuries ago, before window glass could be made abundantly and cheaply, windows were either mere openings for ventilation or sheets of mica, alabaster, shells, thin slices of horn or varnished parchment. Later small bits of glass without parallel plane surfaces were pieced together in the same form. The materials were translucent or irregularly refractive or even opaque. They "excluded the violence of the wind" and sometimes admitted a little light, but they did not possess the optical properties necessary for the entrapment of solar energy. Many homes had little or no fuel to burn, and habitability was dependent upon the warmth stored up by the roof and walls during capricious periods of sunshine.

GLASS was first made many thousands of years ago, but well into the present millennium it was a costly material used mainly for the same purposes as semiprecious stones and precious metals. By the fourth century colored pieces of glass were appearing in church windows, and the 12th century found the stained-glass technique (with its "dim religious light") at its height. In the 14th century the wealthy merchants of the Netherlands had at least a few uncolored glass windows. These were made up of a honeycomb of circular pieces of thick glass. Such leaded windows appear in a number of the paintings of Jan Van Eyck (1382-1440), notably the celebrated works titled *Virgin and Donor* and *Jan Arnolfini and his Wife*. King Richard II of England had a few such windows in his castle at Stamford. The 15th-century painter Pieter Breughel pictured in his *Flemish Proverbs* what may have been a typical inn of his period, with glassless windows throughout except for a leaded-glass transom over the entrance door. By the 17th century glass windows had become something less of a rarity. Jan Vermeer has a number of fine paintings of the windows of his period. Examples are *Woman at the Casement, The Milkmaid* and *The Letter*. The last named is of particular interest because it shows a honeycomb section crowning a casement of sheet-glass panes. This is one of the earliest portrayals of sheet glass. However, it is evident that glass was then still a luxury material which could not be commonly afforded even by kings. In 1661 King Charles II of England had glass only in the upper parts of the windows of a few of his principal chambers.

Isaac Newton was then making fundamental discoveries about the nature of sunlight. René Descartes was making experiments on the reflection and refraction of sunlight. It is not certain that either of these great men ever lived in a house with glass windows. They were far from wealthy. It is possible that Shakespeare carried on his prodigious literary labors without ever looking through a transparent pane of glass, for he died in the first part of the century. We know that he was familiar with mirrors, and he *may* have seen sheet or plate glass installed in a royal coach or in a ship of the Royal Navy or in the palaces where his company occasionally performed.

WINDOW glass is made from sand, lime and soda ash. In those early days there was plenty of sand and lime but not much soda ash. In the Middle Ages the soda ash was obtained in France from the burning of ferns; in Spain from the dregs of wine. Later ashes of wood and of seaweed were used. Wood, of course, was the fuel used to supply the heat for the process of manufacture.

The year of the fall of the Bastille was also the year of the invention by the French chemist Nicolas Leblanc of a process for the making of soda ash from common salt. The French Revolution forced the project to remain idle for a number of years, and Leblanc finally committed suicide. The process is now obsolete, but it was used during the industrially sluggish 19th century to obtain soda ash to take care of the growing demand for glass. The use of wood ashes for glassmaking did not completely disappear, nor was wood completely displaced as a fuel, until after the middle of the 19th century.

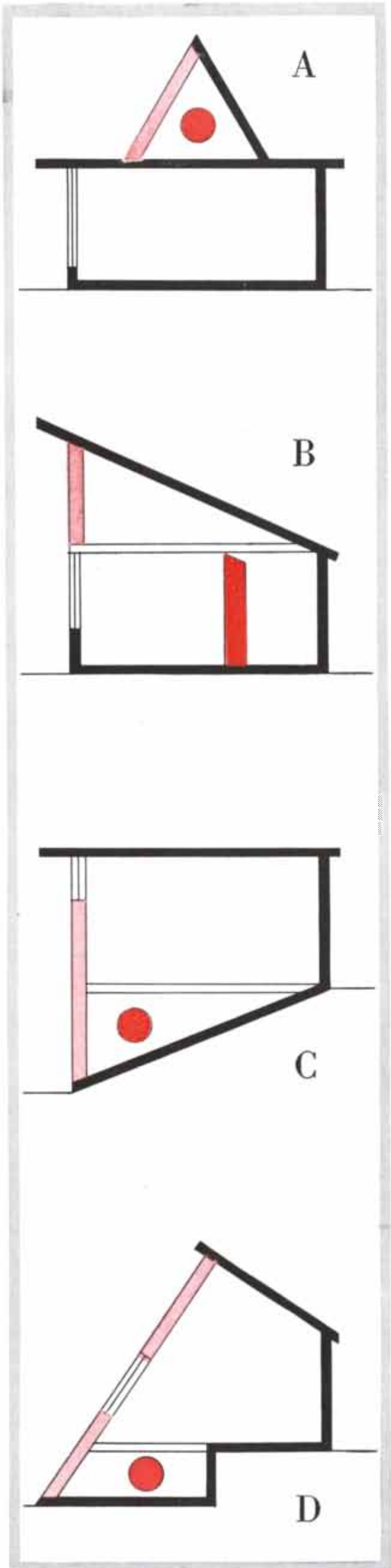
From the beginning the making of glass has been surrounded with an atmosphere of mystery so profound that the industry has never quite shaken it off. Even today information regarding the British glass industry is largely unavailable. Glass was one of the first things manufactured in the American colonies, but the glass industry has been one of the last to mature in the U. S. The history of glassmaking is a chronicle of a multitude of business failures. There are many reasons for this. An important factor was fuel. Before 1860 glassworks were built near forests, which were soon laid waste. Then, until the transportation of coal was developed, glassworks had to be located near coal mines. Later natural gas was used, and a glassworks was built near almost every producing gas well.

Up to the start of the 20th century the making of glass belonged to the highly skilled and muscular artisan. It was therefore so expensive that the possession of windows was a mark of affluence, and windows were heavily taxed. Even today one may see old buildings in England with windows that were permanently blocked up centuries ago to avoid the luxury tax. It was only 46 years ago, in 1905, that window glass was first manufactured by machine. From then until 1930 the production of window glass in the U. S. remained at a practically stationary rate of three square feet per capita per annum. This was enough to take care of the prevailing style of building houses with small windows. During the past two decades there has been a virtual revolution in window-glass manufacture, primarily because of a change in attitude toward windows. Between 1930 and 1940 window-glass production per capita doubled. By 1950 about 10 square feet of window glass was being produced per capita. Windows are no longer luxuries. Now, for the first time in history, window glass is cheap enough to be available to everyone.

ORDINARY window glass is transparent to nearly all solar radiation. A little is reflected and a little is absorbed, but about 90 per cent of both the light and the heat of the sun pass through. On the other hand, window glass is almost opaque to the long-wave infrared reradiated by interior objects that are heated by the sunshine. Thus the solar energy can come in but cannot

DOVER HOUSE in Cambridge, Mass., is heated by solar energy. What appear to be large windows in the second story are glass heat-collectors.

M.I.T. HOUSE in Cambridge has heat collectors on the roof. The heat of this house is stored in water; of the Dover house, in Glauber's salt.



CROSS SECTIONS of real and potential solar houses show collector (*light red*) and storage (*dark red*) areas. A is M.I.T. house; B, Dover house; C and D, houses not yet built.

be radiated out. This is why cars parked in the sun become so incredibly hot, and why greenhouses are made of glass.

Some heat does escape from a glass-enclosed space by convection, because the glass is cooled by the outside air and the cool glass absorbs heat from the warm interior air in contact with it. When this phenomenon became understood, the plan was adopted of using storm windows. The function of the storm window is not to seal the window more effectively but to provide insulation, while still permitting the sunshine to deliver its warmth. The quiet air space between two sheets of glass serves as insulation because air conducts heat poorly. Hence though the outer glass may be cool, the inner glass remains warm. Instead of storm windows it is now possible to use double panes of glass manufactured as a unit, with dry air space sealed between. The insulation with double glass is not perfect, of course. It is about equivalent to an ordinary wall eight inches thick.

Many houses are now designed with south walls almost completely of glass. In some houses 75 per cent of the total wall area is glass. This has been made possible by several things. Large sheets of glass are relatively less expensive to manufacture. Since 1930 the price of glass has risen only 31 per cent, while the average price of all building material has gone up 114 per cent. Window glass now costs less per square foot than lumber, tile or brick.

In summer large glass windows can be objectionable unless they are shaded. Selective shading is sometimes accomplished by an overhang over the windows wide enough to keep out the rays of the high sun in summer but narrow enough to let in the low rays in winter. The width of the overhang of course varies with the latitude. Nature herself has a better solution, however, in deciduous trees, which put up a screen of leaves in the season when shade is desirable and drop the leaves when the house needs the sun. Properly placed trees or vines provide an automatic seasonal control of solar radiation: if the summer is late, foliage will also be late, and an early fall will see the premature dropping of the leaves no longer needed for shade.

Already it has been thoroughly demonstrated that properly designed glass houses in favorable locations can get along on less than normal amounts of fuel. In Philadelphia and Chicago, for example, it is not uncommon to find the fuel bills reduced by about a third by double-paned glass south walls, even with a conventional convection heating system. When solar heat is supplemented by a radiant heating system, radiating low-temperature heat from floors, ceilings or walls, the fuel bills can sometimes be cut in half.

Such houses possess a certain charm—a feeling of living outdoors and an awareness of the perpetual drama of nature. Indeed, these homes are usually built to take advantage of the psychological and physiological attractiveness of sunshine rather than for heating economy. The charm is dependent, of course, upon the attractiveness of the landscape and is unfortunately completely absent for many urban (or even suburban) locations. Architects are studying ways of placing houses on small lots with appropriate planting and arrangement of fences.

THE floors of houses designed for fuel economy are usually of heavy concrete with imbedded heating elements, thermostatically controlled to maintain a moderate temperature. The heating elements may be electrical or hot-water tubes. When the sun shines in upon the floor, the solar energy is absorbed by the concrete, which is capable of storing up a certain amount of heat. Hours after the sun sets or is obscured by clouds, the concrete continues to radiate heat to the room. Eventually it cools down to the point where the heating elements must begin to function to prevent the temperature of the room from falling below a desired minimum. It is a disadvantage that during periods of bright sunlight there is usually no control of the maximum temperature (except to open windows or doors), but an absolutely uniform temperature is not always desirable.

There is a further modification of windows which makes them serve only the function of heating. These "flat-plate heat collectors" perhaps should not be called windows at all, for they can be used neither for ventilation nor for light. They are essentially multipaned windows (usually two or three sheets of glass) permanently curtained with a black sheet of copper. In this system the solar heat is absorbed by the copper backing on the windows instead of by floors or furniture inside the house. The heat absorbed by the copper can be carried into more effective storage than is provided by the concrete floor. It is then withdrawn from storage as required. The collectors serve one purpose only—the relatively efficient accumulation of solar energy.

A large amount of work has been done, particularly by the Massachusetts Institute of Technology, to determine the functional properties of heat collectors with glass of various quality and thicknesses, with different numbers of glass plates variously spaced, and with various structural arrangements.

The amount of solar energy reaching the earth is dependent upon the variable nature of the atmosphere. The transmission of solar heat through the atmosphere at a particular time and under particular conditions is expressed as a percentage. A transmissivity of 100 per cent would mean no atmospheric interference at all—which is, of course, impossible. In practice the transmissivity even on the brightest day is well below 100 per cent and on the darkest day well above zero. It has been decided that in a climate where the mean atmospheric transmissivity during the winter season is above 55 per cent, there should be no difficulty in solar house-heating without fuel. This is based on house walls of good insulating properties and the use of solar collectors with an area of one fifth of the total house envelope. In Boston, where the M.I.T. experiments have been conducted, the mean atmospheric transmissivity is definitely lower than 55 per cent in winter. Therefore it is not yet certain that a solar-heated house could be operated in New England without some auxiliary heat. It would be necessary at least to use a larger ratio of heat collectors to total house envelope, and the walls would need exceptionally good insulation.

Paul A. Siple, Military Geographer of the Office of the Chief of Staff, U. S. Army, has prepared a map dividing the U. S. into three areas: 1) a Southern region where properly designed houses could be warmed comfortably by solar energy alone; 2) an intermediate region, including Boston, where houses could receive at least the major part of their heating from the sun; 3) a section in the Middle West where only a minor part of space-heating could be obtained from the sun. The latter region of "minimum feasibility" includes Ohio, West Virginia, most of Pennsylvania and of course the Northern plains. This interesting map is based upon the present state of technology.

Hoyt C. Hottel of M.I.T. concludes that in Boston a householder would not now be justified on economic grounds in arranging for solar heat-collection, for construction costs have not yet been brought low enough. But he points out that in certain areas of zone 2 the yield of heat from collectors would be twice as high as the yield in the Boston area, because they get more sunlight in winter. In these more favorable areas, the economic value of the collectors would therefore be twice as great.

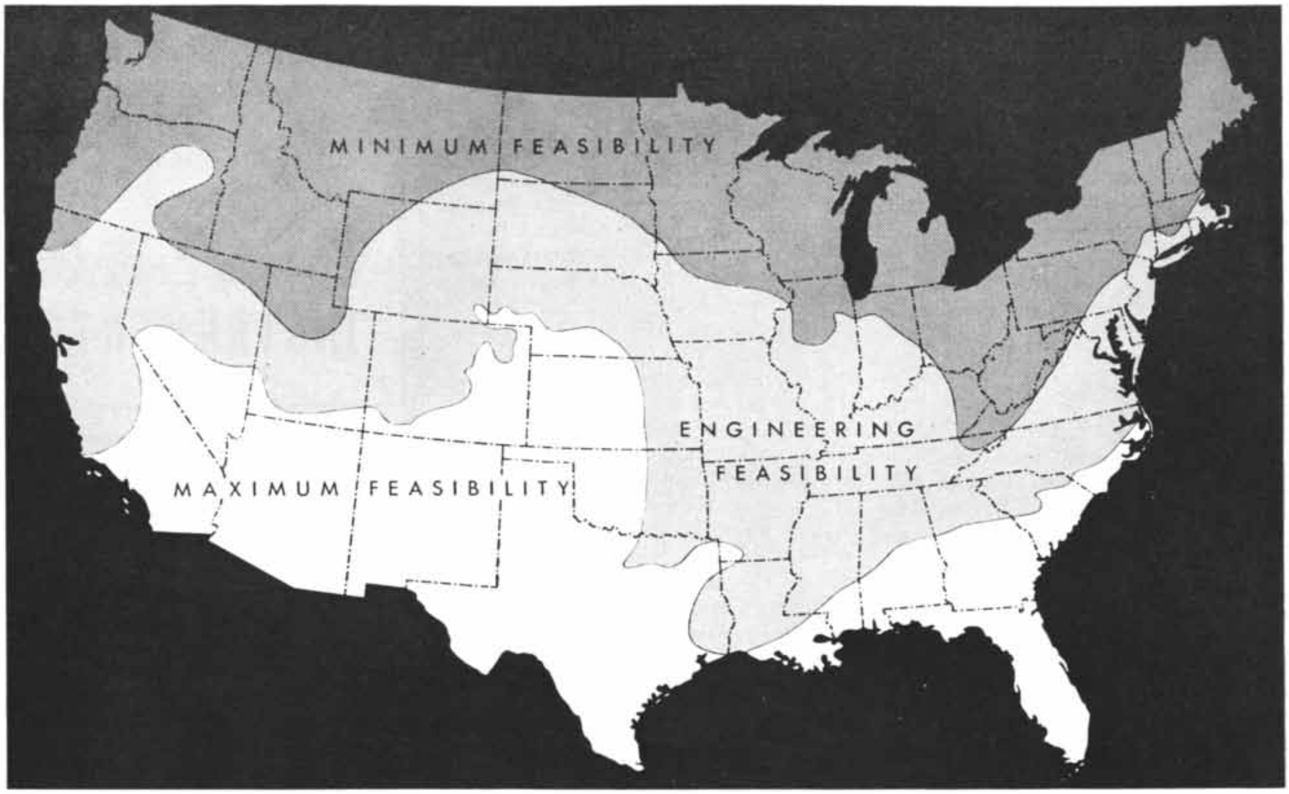
To the economic and technical problems of solar house-heating we must add the problem of architectural esthetics. The idea of a house with many windows through which we cannot see is not appealing. We want to look out, and in the temperate zone we want the advantages of personal contact with all the sunshine we can get in the winter months. Proposals have been made to combine the felicity of maximum sunshine in the living areas of the house with effective collection and storage of solar heat. Some of the many ways of doing this have been described by Lawrence B. Anderson, head of the Department of Architecture at M.I.T. All of the combinations will doubtless be tried. Two such houses will be briefly discussed here.

One of these houses uses an insulated tankful of water to store the heat. Solar heat is absorbed by flat-plate collectors forming the south slope of a tilted roof. It is then transmitted to a water tank with a capacity of 25 pounds of water per square foot of collector area. This has been found sufficient to take care of the house-heating load for two average sunless days. A larger storage system would, of course, carry over for a longer period. The house is also provided with large south windows that admit sunshine directly to the house. During two winter seasons solar energy contributed 91.3 per cent and 81.3 per cent, respectively, of the total heating load of this house. The deficit was made up by supplemental heating. It is of particular interest that about one third of all the heat used by the house was contributed by the south windows and about one half by the roof collector.

The other experiment is the famous Dover house engineered by Maria Telkes, research associate in the Department of Metallurgy at M.I.T. In this case the flat-plate collectors were placed on the vertical south wall of the house above a tier of large south windows. The fundamental difference between this house and the first one described is that a chemical salt instead of water is used for the storage of heat. This represents such a long forward step that it merits some explanation.

We are all familiar with the idea that certain solids (*e.g.*, ice) require considerable heat for melting. We are not so familiar with the idea that the same amount of heat must be given up when the liquid solidifies. Perhaps the reason for this intellectual blind spot is that we intuitively associate heat with relatively high temperatures. It takes some effort to understand that when water at the freezing point congeals to ice, it yields a tremendous amount of heat—the same amount, in fact, that is required to raise the temperature of the water from the freezing point to about 176 degrees F. But this is "cold heat" which can be used only to raise temperatures from subfreezing up to freezing.

The heat absorbed or evolved in changing from solid to liquid or *vice versa* is called the "heat of fusion." Many substances possess this property to a marked degree; others, such as ordinary glass, do not. Water has a higher latent heat of fusion than almost any other common material, hence ice would be a highly effective agent for storing heat—provided we were content to limit the temperature of our homes to, say, 25 degrees F. Since we do not regard such a low temperature with favor, we must hunt for materials that have not only a high heat of fusion but also a higher melting point than ice. Dozens of salts have melting points between "comfort



SOLAR MAP was plotted by Paul A. Siple for the *House Beautiful* Climate Control Studies. It shows the regions where houses might be entirely heated by solar energy (*white*), partly heated (*light gray*) or little heated.

temperatures" and the temperatures conveniently obtained from sunlight, and some of these salts are cheap and abundantly available. Dr. Telkes conceived the idea of using such chemical substances.

The scheme works this way: Trapped air or water is heated by the sun to a temperature above the melting point of the salt. The sun-warmed air or water is circulated through an insulated tank filled with small cans of the salt. The salt melts. So long as much of it remains liquid, air or water flowing from the tank to the places where it heats the house is at the relatively warm temperature near the melting point of the salt. Thus if the total mass of salt is sufficiently large, heat can be delivered to the house for days after heat has been received from the sun. Actually some solar energy is collected even on a cloudy day. It is not uncommon for the stored solar energy to tide this house over two weeks of cold, sunless weather.

The supply of salt does not need to be kept in a tank. It may be located in the concrete floor of the house, in the walls or in the ceiling. This has the advantage of simplifying the problem of insulation, because heat leaking from storage to the living areas of the house is not lost. When such storage of heat is coordinated with electrical heating elements, the "power factor" of the system is raised. A higher power factor means lower cost of power, because the demand for electric power is at a more nearly constant rate. With or without the utilization of solar energy, effective heat storage is likely to become an essential part of space-heating designs in the future.

THE two experimental houses just described have their solar heat-collectors in fixed position. The maximum rate of absorption of solar energy is at the time when the rays of the sun fall perpendicularly upon the glass covers. It would be a great advantage, of course, if the collectors moved to remain perpendicular to the sun, in the same fashion as a telescope is made to follow the course of a star. This problem, however, is somewhat complicated by the fact that the apparent motion of the sun across the sky is different every day of the year. And the precise or even approximate oscillation of large collector areas presents engineering difficulties. Nevertheless some houses are being constructed in this way. It is too early to decide whether the higher efficiency will compensate for the extra construction cost.

Some study is being given to the testing of substances that might perhaps be more effective than glass in trapping sunlight. Although glass so far seems to have the best combination of economic and technical qualities, plastics are not being neglected. Some have the necessary properties for the entrapment of solar energy and have the advantage of low weight. Also they may be cast more easily in certain shapes. For example, plastic plates are now being made with ridges on the underside to focus sunlight along a line. The pipe of circulating fluid to be heated is located on this line. In this way useful temperatures for space-heating can be obtained when the sun is so obscured by clouds that ordinary flat-plate collectors would fail to operate.

In Boston, Philadelphia or San Francisco it should be possible by means of radiant heating and south windows to cut down the consumption of fuel by at least one-third. With solar heat-collectors and heat storage the fuel-saving can be increased by at least another one-half. This leaves about one sixth of the normal requirement of heat still to be met by conventional fuel. But fuel consumption can be reduced still further by the device called the heat pump, which, operating on the same principle as the household refrigerator, takes heat from the ground, from a deep well or from any body of water. Under favorable circumstances the heat pump can cut the space-heating energy requirement in half. Thus it is technically possible today to design a home in a favorable solar climate to keep comfortably warm in winter with only one twelfth of the customary consumption of fuel—and without chimneys, odors or the soot of combustion. Furthermore, by the turn of a valve the system can be reversed and the house can be cooled in the summer.

About one third of the fuel for space-heating in the U. S. is consumed in the

Northern belt, where the solar climate is relatively unfavorable for solar heating. About a tenth is consumed in the Southern region, in which complete solar heating could be managed without difficulty. Nearly half of our population, consuming nearly 60 per cent of all the fuel used for space-heating, is in the intermediate zone, where solar heating aided by the heat pump could theoretically reduce the consumption of fuel to one twelfth of what it is now.

THE use of solar energy for space-heating has definite practical limits. The population of the earth is not nicely arranged for the purpose. We cannot all live in separate houses with correct exposures and with suitable plantings of vegetation. We cannot all live near bodies of water, or where deep wells can be drilled, or surrounded by adequate land. On the contrary, many of us must spend our time in city houses, apartments, hotels, tenements, office buildings and factories. Such congested living presents many problems. If some of these problems can be solved so that we can bring the utilization of solar energy up to half of the total space-heating demand, the world consumption of fuels for all purposes will be cut by almost a quarter. The chances are that we shall eventually do much better than this, for the simple reason that we must. The rate of progress is likely to rise in geometric proportion to the rising cost of fuels. All of the ingredients of the formula for successful development are here. The glass industry has come to a belated maturity. The plastics industry has made a promising beginning. Effective insulation of buildings has become commonplace. The technology of heat storage has leaped suddenly ahead. The heat pump is no longer a device of purely academic interest. Space-heating engineers and architects have thrown off the shackles of precedent.

No house has yet been built to employ all the known devices for optimum fuel economy. In fact, there is no economic reason for building such a house, for the annual interest on the additional investment would now be somewhat higher than the annual fuel-saving. But the separate strands of endeavor gradually are being woven together. The eventual depletion of fossil fuel will not be disastrous. On the contrary, for our children's children the dream of our architects and engineers will come true—communities of people who live in comfort without combustion, free from atmospheric pollution, with no dark corners, with windows everywhere.

Eugene Ayres, director of the chemistry division of the Gulf Research and Development Company, was the author of Power from the Sun, *which appeared in the August, 1950, issue of this magazine.*

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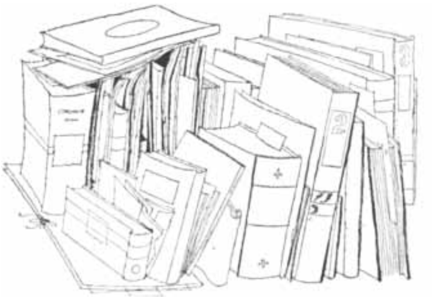


BOOKS

On the first volume of Henry E. Sigerist's imposing history of medicine and society

by I. Bernard Cohen

A History of Medicine. Vol. i: Primitive and Archaic Medicine, by Henry E. Sigerist. Oxford University Press ($8.50).

IN a period of world turmoil, when arresting events focus our minds upon immediate problems, and when few of us would dare to plan a lifetime of study or to contemplate projects requiring decades of preparation, it is heartening to know that two great scholars in similar fields are beginning to write surveys that promise to require eight volumes each. The scholars are George Sarton and Henry E. Sigerist; the former is writing a general history of science and civilization, while the latter is preparing a similar work about medicine and society. The lives of Sarton and Sigerist are in many ways parallel: both were trained in Europe; both have done their major work in America; each has become the leader in his subject and the editor of the foremost journal devoted to it; each has now retired from teaching to set down his acquired knowledge and wisdom.

Sigerist has brought out his initial volume first, and it merits the closest attention. Sigerist has always conceived of medical history as illuminating not only medicine but also history itself, as providing a major tool for the understanding of man, society and culture. We must therefore examine the volume in the terms that the author intended: not as a pedantic compilation for the use of scholars and antiquaries, but rather as a book for all who would understand man and his works.

Sigerist has devoted a lifetime to preparing his history. In the introduction to its first volume he explains how it was necessary, among other things, for him to learn 14 languages. He mentions that "one cannot master all tongues equally well at the same time, and for every volume I have to engage in preparatory language studies. This explains why my progress was not as rapid as I had hoped." Sigerist began his career as a student of oriental languages in Zurich and London; then he decided to study medicine. It occurred to him that he "might be able to combine [his] various interests in the study of medical history or the history of science."

In 1937 Sigerist came to the U. S. as Director of the Institute of the History of Medicine at the Johns Hopkins University. Up to that time U. S. medical history had been pursued chiefly by gifted amateurs, and there was no headquarters for the professional study of the subject. Under Sigerist's leadership the Institute not only became the center of such studies in our country, but was responsible for stimulating the amateur medical historians to produce more professional works, and for integrating medical history with medical teaching.

Sigerist's first volume is devoted to primitive and archaic medicine, notably that of ancient Egypt and Mesopotamia. Though this might seem a subject of greater interest to the specialist than to the general reader, Sigerist's account is exciting to read. He discusses "health and disease through the ages, the conditions for health and disease, and the history of all human activities that tended to promote health, to prevent illness, and to restore the sick." His approach to medical history is to "find out what health conditions were in a given society at a given time. Was there much illness or little? What diseases prevailed? Did people die young or did many of them live to a ripe old age?"

Sigerist thus begins his account with palaeopathology, the study of disease from human and animal remains of prehistoric and early historic times. The evidence of diseases in such early peoples and animals is meager, yet some of it is of great importance. For example, there is evidence for hydrocephalus, congenital clubfoot, Paget's disease, tuberculosis, arthritis and so on. One disease that was conspicuously absent from the Near East and pre-Columbian America is rickets; not a single mummy appears to have been found in Egypt that "could have been diagnosed with any certainty as having been affected by rickets, although the number of children's bodies preserved is large." This disease is due to a deficiency of vitamin D and develops when children are not sufficiently exposed to the ultraviolet rays of the sun; in Egypt and in tropical America young children were nude a good deal of the time. Rickets, notes Sigerist, "is primarily a disease of the city slums and of the North." Traces of it have been found in Neolithic bones unearthed in Scandinavia.

Palaeopathology teaches us that disease is "as old as life itself"; in fact disease "is life, a manifestation of life, the reaction of a living organism to abnormal stimuli." While many pathologists have taught that the human organism developed and perfected its defense reactions in the course of time, "palaeopathology teaches us that these mechanisms are not the prerogative of man perfected through long generations, but that animals millions of years ago possessed them as well and perhaps in much greater perfection." Indeed, declares Sigerist, "we find that the lower an organism is in the evolutionary scale, the greater its defense and repair mechanisms are." His conclusion is that man's ability "to survive and to attain the position he holds in nature is due to the fact that he was endowed with a larger brain and greater intelligence, which enabled him through long generations to perfect not his natural but artificial defense mechanisms, to direct and increase the natural healing power of the body with artificial means, learning to use physical, chemical and biological forces to that end."

The next section, on primitive medicine, has a current importance, since this rudimentary form of the healing art is still practiced by backward people over a large portion of the globe. Sigerist compares the primitive attribution of disease to some malevolent force with the psychology of the patient in our own society who asks: "Why am I stricken? What have I done to be cursed with such a disease?" Yet here one feels that Sigerist is not at his best. An examination of his sources reveals a distinct bias; for example, nowhere does he cite the work of the late Bronislaw Malinowski, nor does he address himself anywhere to the problem of science, magic and religion as contrasted to that of medicine, magic and religion. Although, following W. H. R. Rivers, he points out that medicine, magic and religion constitute "in the mind of primitive man" an "inseparable whole," he ignores the writings of those anthropologists who have pointed out that for primitive man, science, magic and religion are three associated but in many ways distinguishable planes of experience and not at all so inseparably linked as at first appears. Indeed, many of the simple therapeutic practices described by Sigerist indicate that at least a part of primitive medicine is based on experience and a rational interpretation of it.

Sigerist's section on ancient Egypt will enlighten many readers as to the general history of that region. The problem of evaluating ancient accounts is illuminated by Sigerist's discussion of Herodotus, who described the Egyptians as "the healthiest of men." In 1938 Egypt had a death rate of 26.4 per thousand, one of the highest ever recorded. The average Egyptian male had a life expectancy at birth of only 36 years; the average female, 31 years. "How can we reconcile these terrifying figures with the optimistic report of Herodotus?" asks Sigerist. "Must we assume that health conditions deteriorated in the course of 2,500 years, or was Herodotus wrong, or were standards so very different?" He points out that Herodotus formed his judgment on the basis of a general impression, such as any traveler might have, and not on comparative statistics. Travelers' impressions are often wrong. A visitor to South Africa might admire the splendid physique of the Bantu and conclude that they were the healthiest people on earth. If he knew that "a woman needs twelve pregnancies on an average in order to have two surviving children," that "eight pregnancies end in miscarriage," while out of every four children who are born "two die during the first years of life," he would have an altogether different opinion.

Yet there is reason to believe that general health conditions were better in ancient than in modern Egypt. The population was probably only half of what it is today; "the same area, in other words, cultivated as primitively as it was in antiquity," now has to feed twice as many people, and much of the area is given not to food but to export crops such as cotton. Sigerist also notes that Herodotus was probably impressed by the rarity of intermittent fevers in comparison with his malaria-infested native land; perhaps this was "an important factor in his favorable judgment about health conditions."

One of the most interesting chapters in the section on Egypt is that devoted to "empirico-rational medicine," in contradistinction to its predecessor on "magico-religious medicine." Before 1922 this distinction could not have been made in any real sense; until then an "empirico-rational medicine" in Egypt had been suspected by many scholars but could be documented only in the most fragmentary way. In that year James H. Breasted published his preliminary account of the famous Edwin Smith Papyrus, and in 1930 he brought out his magnificent text, translation, facsimile and commentary. This ancient surgical document was, as Sigerist describes it, "almost entirely rational [*i.e.*, almost devoid of magic], revealed a keen observation of nature, and reflected a great amount of sound empirical knowledge and practices." The Smith Papyrus provides the earliest documentary evidence of the separation of medicine from magic and religion. While it shows us that the ancient Egyptians had names for many internal organs, we must note that Egyptian anatomy was based on speculation, with information derived from the kitchen and the ritual of sacrifice rather than autopsy and dissection. While physiology was likewise speculative, there was nonetheless an Egyptian anatomy and an Egyptian physiology!

Sigerist finds in ancient Mesopotamia one factor that clearly differentiates it from ancient Egypt: the beginnings of science "in our sense of the word." In the fertile crescent, as opposed to the region of the Nile, there developed an astronomy that is one of the glories of man's past. Sigerist devotes several pages to Mesopotamian astronomy, a passage all the more conspicuous because in the rest of the book there is little mention of any other human activity that might be called science or science-in-the-making.

Mesopotamian law tended to be divorced from religion and magic; even before the time of Hammurabi, Sigerist points out, "a distinction was made between priestly and civil jurisdiction and gradually the administration of the law was taken away from the priests entirely and placed in the hands of civil judges and secular courts." But "such a divorce from religion never took place in medicine and the various categories of healers were always made up of members of the clergy." This helps to explain why the Mesopotamians placed so much emphasis on omens, on health prognoses based on the examination of the liver of a sacrificed animal, on dreams in the diagnosis of disease. The conclusion to which we are led is that the rational content of Egyptian medicine was on a vastly superior plane to that of the Mesopotamians, whereas the astronomy and mathematics of the Mesopotamians was on an incredibly superior plane to that of the Egyptians.

These few facts indicate the rich treasure of information in Sigerist's first volume. No one who is interested in human culture can fail to find the book continually fascinating. It is possible, however, that the general reader will be disconcerted by Sigerist's abrupt termination. This will doubtless be rectified by the seven other volumes to come, but this reviewer felt a distinct need for a provisional summing up.

Sigerist's introduction stresses his belief that "general health conditions are determined primarily by two factors, geography and economics," and in many places he adopts an oversimplified economic determinism that is not completely justified by the facts. In describing the social and economic conditions in ancient Egypt he writes: "The church took a great deal from the people because it was they who created the wealth that went to the temples. It gave them in exchange holidays, emotions, the illusion that they had a part in the wealth and pomp of the church, and the hope that life would not end with death, although the hereafter did not promise to be any better than the life on earth." Surely such a statement grossly underrates the nonmaterial values of human existence. Sigerist's intense concentration on economic factors occasionally blinds him. Even if we agree to the general proposition that health accompanies wealth, we must keep in mind that the psychological aspect of security is also important to the health of the individual. Sigerist declares that "in our Western capitalistic societies an individual's security is determined by his bank account, by his savings at large"; but his security must also be determined by his familial relationships, his acceptance of his life problems and responsibilities, and his personality adjustments. The insecurity of person and mind which Sigerist deplored in Nazi Germany and Fascist Italy, and which still exists in large portions of the world under totalitarian domination, is certainly of profound importance to mental and physical health, and must be reckoned along with the security of the bank account.

Sigerist emphatically states that "medicine is not a natural science, either pure or applied." But he does not place medicine in the traditional category of an "art." Instead, he holds that although "methods of science are used all the time in combating disease, . . . medicine itself belongs much more in the realm of the social sciences because the goal is social." Medicine, for him, "is but one link in a chain of social-welfare institutions." These are of course very personal opinions; Sigerist wisely points out in his introduction that the writing of history is a personal testament. But even if the reader disagrees with some of Sigerist's views, especially in relation to modern society, he can profit enormously from the reading of this magnificent work.

I. Bernard Cohen is assistant professor of general education and of the history of science at Harvard University.

PSYCHOANALYSIS: EVOLUTION AND DEVELOPMENT, by Clara Thompson, M.D., with the collaboration of Patrick Mullahy. Hermitage House ($3.00). Dr. Thompson, a member of the Washington School of Psychiatry, subscribes to the point of view of Erich Fromm and Harry Stack Sullivan, namely that the causes for personality difficulties lie more in the cultural framework of society and the intricate web of relationships between men than in their biologically determined impulses. Nonetheless she is objective in her description of the contributions as well as the weaknesses of all the major creative psychoanalytic theorists from Freud to Karen Horney. A cool-headed appraisal in a field that is usually enveloped in heat and ambiguity, this book is of interest to the general reader as well as to the specialist.

N[illegible] INTO WORD, by Eric Partridge. The Macmillan Company ($4.50). A "discursive dictionary" tracing the absorption into the English language of proper names. Some examples are: boycott (Captain Boycott), braggadocio (Braggadocio in Spenser's *Faerie Queene*), macadamize (John Loudon McAdam), guillotine (Joseph Guillotin), silhouette (Etienne de Silhouette), marijuana (Mexican-Spanish Maria Juana, or Mary Jane), ohm (Georg Simon Ohm), loganberry (James Harvey Logan), tuxedo (Tuxedo, N. Y.), ottoman (Sultan Uthman), maudlin (Mary Magdalen), mausoleum (Mausolus, King of Caria), magnolia (Pierre Magnol) and so on. A learned and a fascinating book, ideal for browsing.

DICTIONARY OF THE UNDERWORLD, BRITISH AND AMERICAN, by Eric Partridge. The Macmillan Company ($9.00). From "academy buzz-napper" (an apprentice pickpocket) through "zib" (a sucker) this is another of the indefatigable Mr. Partridge's absorbing compilations, this time of the lingo of convicts, racketeers, crooks, beggars, tramps, white-slave and drug-traffic operators, spies and other unpleasant or unfortunate inhabitants of Australia, New Zealand, Canada, South Africa, Britain and the U. S.

ADVANCED ATLAS OF MODERN GEOGRAPHY, by John Bartholomew. McGraw-Hill Book Company ($8.50). This is a complete revision of a handsome and justly popular work, including maps showing not only the latest political boundaries but giving the salient points on rainfall and oceanography, agriculture, ethnology, vegetation, population, climate, religion, language, economic areas, commerce routes. Ideal for the house library.

ALL ABOUT SHIPS AND SHIPPING, edited by Edwin P. Harnack. Faber and Faber, Ltd., London ($4.50). This, the eighth edition of a snug and agreeable little compendium, contains as much popular nautical information as the average reader is ever likely to need or crave. Diagrams, plans, ship silhouettes and colored plates in abundance.

ILLUSTRATED ENGLISH SOCIAL HISTORY, VOL. I, by George M. Trevelyan. Longmans, Green and Company ($3.75). This is the first volume of an attractively illustrated edition of a noted work describing through six centuries (Chaucer to Queen Victoria) the "variegated and wonderful" life of England, including the character of family and household life, the conditions of labor and of leisure, the attitude of man to nature, the culture of each age and its forms in religion, literature and music, architecture, learning and thought. A superb survey.

ISAAC NEWTON, by E. N. da C. Andrade. Chanticleer Press, Inc. ($1.75). "What I have tried to do in this little book," writes Professor Andrade, "is to set down what I should myself have liked to know of Newton when I was young. I have endeavored to bring back the past time, to show the problems which Newton solved against the background of contemporary thought." An informal, graceful and sensitive portrait by a leading British physicist, known also for his popular writings and historical memoirs on 17th- and 18th-century science.

THE BURDEN OF DISEASES IN THE UNITED STATES, by Alfred E. Cohn and Claire Lingg. Oxford University Press ($10.00). On the basis of raw data supplied mostly by the Bureau of the Census the authors have compiled a useful 50-year record of both morbidity and mortality, presenting their material in graphic form with an accompanying critical account and comparisons with other countries. Despite the lavish format of this work, the colored charts unfortunately are jumbled and poorly designed, confusing the reader instead of facilitating his comprehension.

ELECTROMAGNETIC THEORY, by Oliver Heaviside. Dover Publications, Inc. ($7.50). An excellent reprint on the 100th anniversary of his birth of the papers of one of the great modern scientists, noted as much for his misanthropic traits of character, colorful and polemical style of writing, as for his profound and extensive contributions to physical and mathematical theory.

TREASURY OF EARLY AMERICAN AUTOMOBILES, by Floyd Clymer. McGraw-Hill Book Company ($5.00). Between 1877 and 1925 there were manufactured in the U. S. some 2,200 separate makes of automobile (of which no more than a dozen names survive) ranging from the ABC through the Zip, from runabouts costing less than $300 through "Berlines," limousines, landaulets and cabriolets costing 20 times that much. The noted automotive antiquary Floyd Clymer has gathered hundreds of photographs and thousands of facts about these vehicles, their accessories, their feats and failures, the advertisements, songs, cartoons, slogans, wisecracks and folklore pertaining to them. Included in this highly diverting and nostalgic collection are such cars as the Apollo, Apple, Blood, Climber, Everybodys, Izzer, Klink, Pungs-Finch, Puritan Steamer, Mondex-Magic, Pneumobile, Serpentina, Seven Little Buffaloes, Hupp-

Yeats Electric, Grabowsky, Jem, Coyote, Buggycar, German-American, Gadabout, La Petite, Kissel Kar, Peter Pan, Quick, Red Bug, Brazier, Barbarino, Fwick, K.R.I.T., Leuding Haus, O-We-Go, Kerosene Motor-Surrey, Piscorski, Robe, Twombly, Twincity, Vixen, Wasp. There are also such forgotten items as the Boyce Moto-Meter, Woodworth Tread "chrome leather steel riveted puncture proof tires," Brown "dust gards," Clark's "maroon velvet plush auto heaters," Prest-O-Starters, the "Auto-Inspector and Tail-Lamp" ("Just One Match"), The Gas-Au-Lec auto "without starting crank, gears, clutch, cams, or tappets" ("The Simple Car"), Henry Ford's Coupelet (the first convertible), the Aermore Exhaust Horn ("Warn the Pedestrian but Don't Terrify Him"), the Octoauto ("The only car in the world built on the principles of a Pullman Palace Car"), the Duck (with driver and steering wheel in the rear), the Hancock Oiler (force feed).

ROBERT BOYLE'S EXPERIMENTS IN PNEUMATICS, edited by James Bryant Conant; THE EARLY DEVELOPMENT OF THE CONCEPTS OF TEMPERATURE AND HEAT, prepared by Duane Roller; THE OVERTHROW OF THE PHLOGISTON THEORY, edited by James Bryant Conant; THE ATOMIC-MOLECULAR THEORY, by Leonard K. Nash. Harvard University Press (various prices). The aim of each of these volumes in the series of Harvard Case Histories of Experimental Science is to give the scientist, student or "inquiring citizen," a detailed account of one of the epoch-making advances in science and thereby a better understanding of modern science and technology and their role in the modern world. Each study, carefully documented and clearly written, will prove useful to the student who can turn to his instructor for further guidance; the "inquiring citizen," with no such resource available, is not likely to find these brief monographs unusually helpful.

SOURCEBOOK ON ATOMIC ENERGY, by Samuel Glasstone. D. Van Nostrand Company, Inc. ($2.90). The Atomic Energy Commission authorized Dr. Glasstone to prepare this handbook of technical information on all aspects of atomic theory. He writes unpretentiously and he has done his job conscientiously and well, but the product is somewhat difficult to describe. It is not intended for the expert; nor is it for the average reader, most of its sections being both too difficult and too detailed. As an authoritative compendium of facts known to scientists everywhere, which the AEC therefore is prepared to risk imparting to our own citizens, this is undoubtedly a useful volume for students, textbook authors, editors, and perhaps the more persistent and serious of inquiring laymen.

CHANCE AND CHOICE BY CARDPACK AND CHESSBOARD, by Lancelot Hogben. Chanticleer Press ($12.50). From its title and its author's reputation as a popularizer of science, one might suppose this volume to be a layman's guide to the theory of probability. It is in fact a presentation for the fairly advanced student of the mathematical basis of statistical procedures, illustrated with many color charts and other graphic devices favored by Hogben in his broad program to renovate the teaching of science and other subjects by the use of fresh visual methods. Unusual and interesting but not for the innocent amateur.

Also Noteworthy

MOLECULES IN MOTION, by Thomas G. Cowling. Hutchinson's University Library, London ($1.60). An introduction to the theory of gases, with some stress on mathematical methods and a survey of the historical background.

ART OF THE NORTHWEST COAST INDIANS, by Robert Bruce Inverarity. University of California Press ($10.00). Dr. Inverarity's authoritative text and a superb group of illustrations make this a distinguished as well as fascinating contribution to art and anthropology.

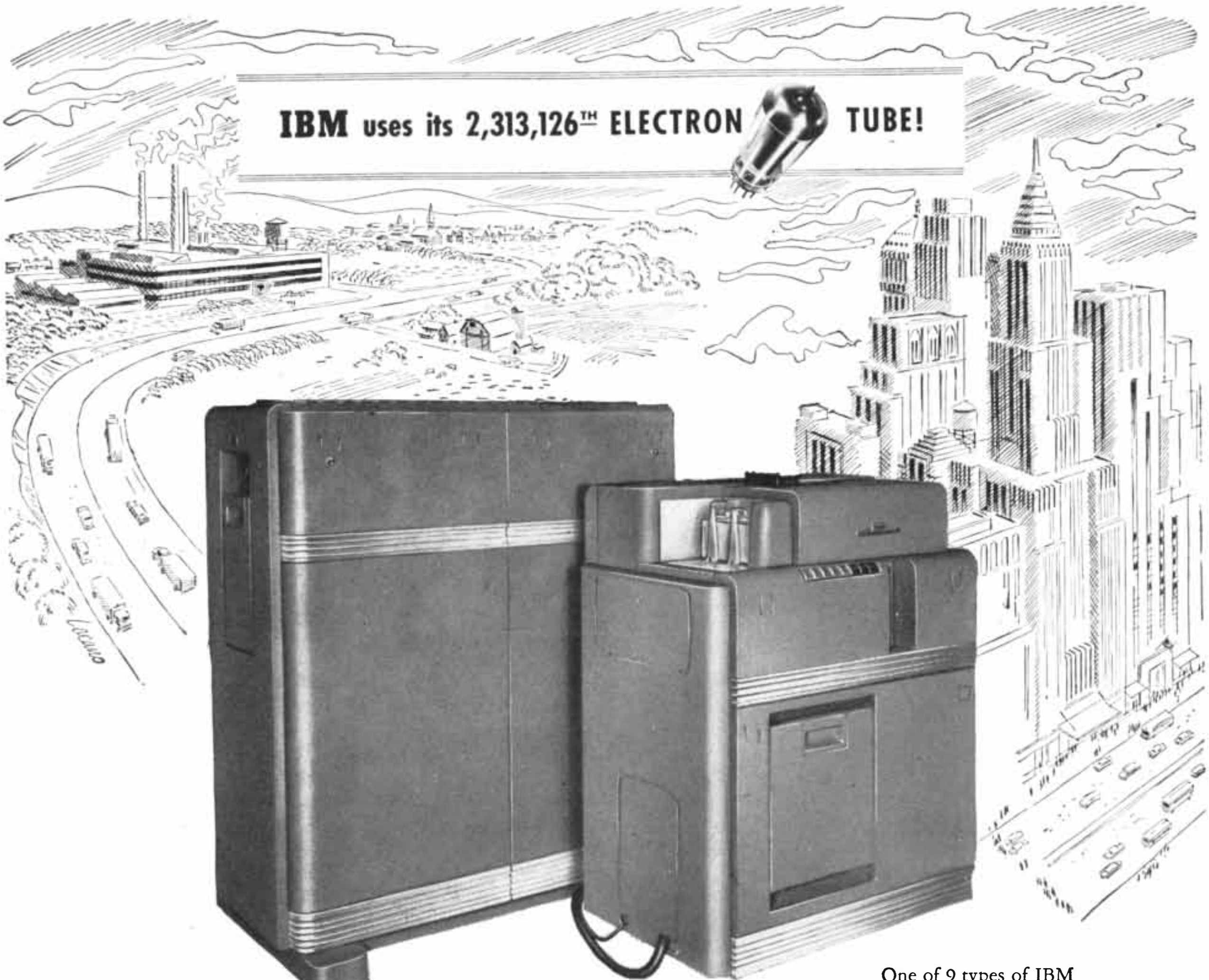
HEREDITARY GENIUS, by Sir Francis Galton. Watts and Company, Ltd., London ($1.20). A reprint of the second edition (1892) of this classical work attempting to demonstrate that "a man's natural abilities are derived by inheritance, under exactly the same limitations as are the form and physical features of the whole organic world."

PRINCIPLES OF MATHEMATICAL LOGIC, by David Hilbert and Wilhelm Ackermann. Chelsea Publishing Co. ($3.50). The translation of a noted text in this field.

THE CHEMICAL ELEMENTS AND THEIR COMPOUNDS, by N. V. Sidgwick. Oxford University Press ($14.00). A well-organized, exceptionally valuable handbook presenting a detailed discussion of the properties of the elements and their compounds "in the light of modern ideas of atomic and molecular structure."

THE FIRST TRANSCONTINENTAL RAILROAD, by John Debo Galloway. Simmons-Boardman Publishing Corp. ($5.00). A historical account of the political, financial and engineering aspects of the building of the Central Pacific and Union Pacific divisions of the famous Overland Route from Chicago to San Francisco.

MARINE GEOLOGY, by Ph. H. Kuenen. John Wiley & Sons, Inc. ($7.50). An introductory text summarizing the present state of knowledge of this comparatively new branch of an old science.



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THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

IN his chapter on the warmed observing room in *Amateur Telescope Making*, Russell Porter discussed a collection of ingenious arrangements by which an amateur astronomer may sit cozily indoors and direct his telescope outdoors through a partition. Porter built several of these indoor telescopes, and all his life sought to originate new arrangements of the same sort for others. Probably no one else in the long history of telescope making so searchingly explored the possibilities of new types of mountings. To this favorite activity he applied all his versatility and inventiveness, remaining uninfluenced by the cramping conventionalities which, as he often remarked, cause many astronomers to look with suspicion on novel mountings. Porter also noted with the keenest interest the combinations that were submitted to this department by other amateurs. (He always considered himself an amateur.) He never ridiculed an idea because he had failed to think of it first, though he did turn thumbs down on some that seemed impractical. When one of these was sent to him by the editor of this department, Porter would usually return the proponent's letter with the simple notation: "Nothing to it—P." His trademark was a circle drawn around the P. Unhappily most of the proposals proved to be original with the inventor but old in the lore of telescopes. Sometimes, however, Porter would remark cautiously and hopefully: "I almost believe this is a really new one." He was pleased that so many minds were exploring where once he had worked almost alone.

Frank McCown, Box 176, Holtville, Calif., has submitted the proposal for a telescope in a warmed observing room that is shown at the upper left in the illustration on the opposite page. On preliminary analysis this arrangement appears to contain elements of the Porter turret telescope at Stellafane, shown in *Amateur Telescope Making* at VI in Figure 42 on page 51. Yet McCown's telescope includes other details.

The polar axis is expanded into a cone with end-thrust bearing at the south. This cone, and the telescope mounted at one point on its periphery and counterweighted at the opposite point, are out of doors. The eyepiece and observer are inside the warmed enclosure. Of course this warmth will radiate outside, to the detriment of the image, unless the enclosure is well insulated and not too thoroughly heated. Even then the image will be somewhat affected; all telescopes involve many compromises, as every telescope maker knows.

The design is not well suited for either too large or too small a telescope. Its proportions are virtually dictated by the physical proportions of the observer, unless he aspires to become a contortionist. The illustration shows a V-shaped pier that provides leg room in rather the same manner as a kneehole desk.

McCown's design for an eyepiece mounted eccentrically in a sleeve which can be rotated to bring the finder focus into view is shown at the upper right of the illustration. An erecting eyepiece stretches out the cone of rays from the primary mirror to the eye, obviating the need for an unduly large diagonal mirror. As an alternative a Barlow lens has been suggested by Henry Paul. The smaller central inset drawing indicates the analogous eyepiece scheme for a refractor. The design is offered for others to mull over, modify, improve and perhaps construct according to their lights.

The two drawings in the middle of the illustration show two versions of a method that permits a double-yoke-mounted telescope to reach the celestial pole. It was devised by Alan McConnell of Millstone, N. J., who suspects, however, that it is not new. His own telescope follows the first version, but he proposes the second.

A. WALLACE EVEREST of 85 Ridge Avenue, Pittsfield, Mass., writes as follows: "To remove zones on a mirror there is one procedure I forgot to mention in *Amateur Telescope Making—Advanced*. Zones are usually related to channel spacing in the lap. For a central bump use strokes such that the center of the mirror travels over the centers of the facets in the two rows nearest the center of the lap. [*This is shown at the lower left of the illustration; the center is marked* X.] Occasionally change the direction of your strokes 90 degrees to prevent 'lemon peel.' For a hole in the middle use similar strokes, with the center of the mirror traveling along the two channels nearest the center of the lap.

"Don't overdo these strokes, as they work fast. Any slight hangover from this treatment will disappear with the zigzag stroke which should be used during the rest of the figuring. The width of the zigzag patterns (path of center of mirror) should be equal to the channel spacing. That is, work out to an overhang of one half the channel spacing on one side, then back to the same overhang on the other, and so on, back and forth."

THE drawing at the bottom center in the illustration reveals the principle of an automatic tracelet or toolhead as used by professional instrument makers in England for graduating circles on surveying instruments. A brief description of this was recently discovered in *The American Machinist*, Volume 41, 1914, page 813. By varying the heights of the bumps on the drive wheel desired sequences of long and short lines can be cut again and again without error. This supplies a more elegant alternative to the method depicted in *Amateur Telescope Making—Advanced*, page 290, Figure 3, and renders superfluous the anvil shown there. In an alternative design found elsewhere the graver is lifted by an eccentric mounted on the same shaft that carries the bumps. Possibly the user can further simplify this mechanism. In numerous instances those who have graduated their circles by the ordinary, or memory, method reported the fallibility of the human equation, in the form of single slips in line length that threw the system of the entire circle out of correctness.

IN THE lap-channeling dingbat sweepstakes J. William Wright of Baltimore, Md., has entered the wooden ring with cross-wires shown in the drawing at the lower right of the illustration. First the lap is poured in the usual manner. When the lap has lost most of its fluidity, its surface is dipped briefly into cold water to form a skin over its fluid interior. Only the surface can be dipped because otherwise the hot glass tool would be broken. Then the channeling tool, which has previously been soaped, is pressed clear through to the glass and left several hours to cool before removal. The secret of success is in correctly judging when to press in the channels. The substitution of flat strips of sheet metal (resistance wire from an old toaster) in place of thick round wires enabled Wright to make laps having the desirable thickness (twice the wire diameter plus your favorite lap thickness). Two courses of heavy round wires resulted in laps that were too thick.

IN AUGUST of last year this department published a series of focograms by Dr. C. P. Custer that revealed the successive stages in the figuring of a typical maiden mirror by a typical amateur telescope maker. As a result the following instructions have been inserted in a new stock printing (not a new edition) of *Amateur Telescope Making.* The instructions have been inserted on page 388 of that book in space gained by deleting and condensing other matter on the page.

Making Focograms: Dr. C. P. Custer, 155 East Sonoma St., Stockton, Calif., has made many of these. For a camera he uses a cigar box with film taped inside one end and a ½-inch hole, placed about where the eye was, in the other end. There is no lens. The source of illumination for the pinhole lamp is a 7½-watt, circular, frosted refrigerator bulb 1½ inches in diameter, which can be screwed into a standard-sized socket.

First Custer adjusts the knife-edge. Then he places the camera on its narrower edge on top of another cigar box. This has three nails along the sides and front of the camera for stops, so that the hole is in proper position.

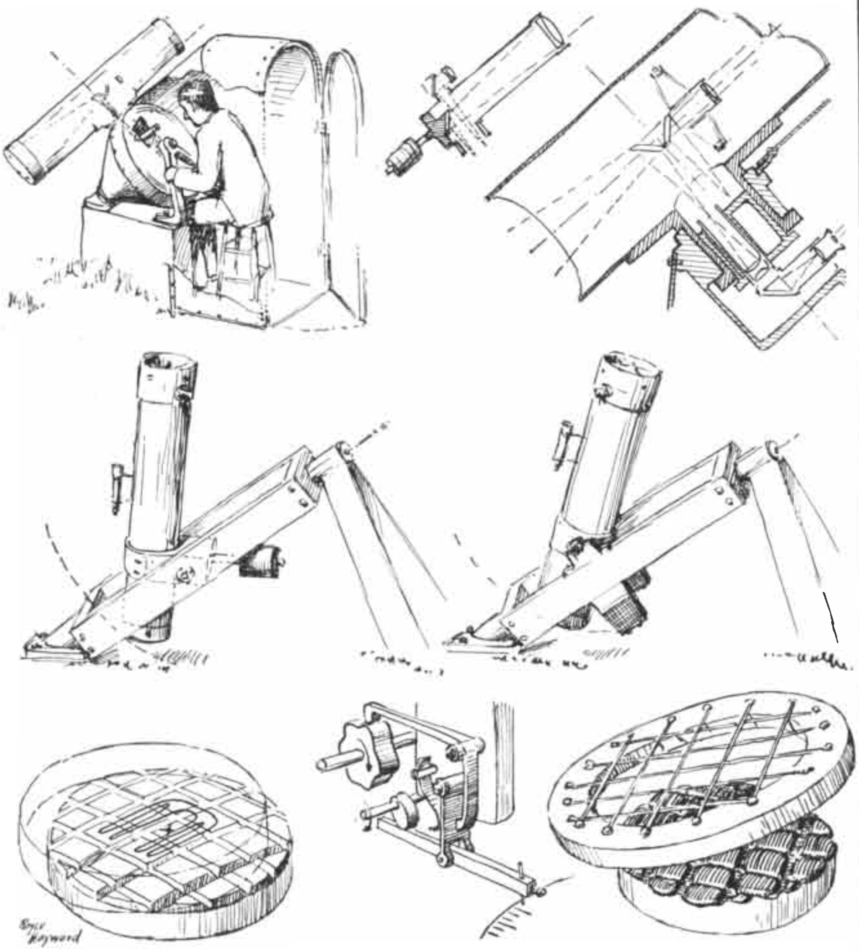
Now the room light is turned off and the camera is loaded by taping inside its end a 2¼ by 3¼ Eastman Super Press Type B film, with the concave emulsion side facing the hole. A 10-minute exposure is tried using a 1.25 millimeter (1/20-inch) pinhole. With the smallest pinhole, about an hour's exposure is needed; for paraboloids, about two hours. A very sharply turned down edge may require a narrow mask on the mirror, probably because of light reflected from its back surface.

The films are developed by using the 10-cent packages of Eastman developer and fixer according to directions. The image is ½-inch wide and enlarges well.

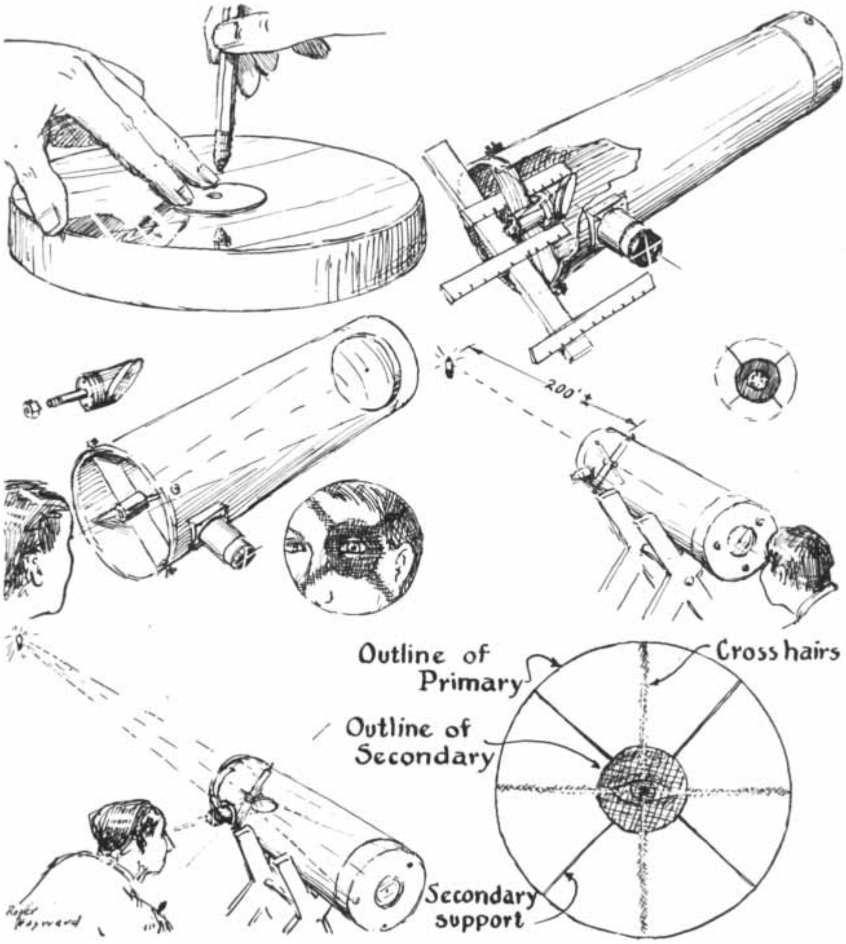
Time can be saved if the camera is carefully removed after the exposure is finished, and the image examined by leaning over from the side. If it has turned black or brilliant white, a movement has occurred and development of the film is useless. Correct the knife-edge and re-expose. Vibration caused by people walking about the house will ruin the exposure.

ALIKA K. HERRING of 2228 Winton St., Middletown, Ohio, whose 12½-inch *f*/6 telescope was described in this department in the December issue of last year, describes his method of making focograms as follows:

"My camera is a home-made box with a 2-inch lens and a plateholder for 4-by-5 film, which I originally made for a camera to photograph star fields. To make focograms the lens is removed and the box is placed some distance behind the pinhole. Thus during exposure there



Proposed telescope mountings and mirror-making techniques



A method for aligning an optical system

is room to place the eye behind the knife-edge occasionally to check the setting—a necessary precaution when the local steel mill causes the earth to vibrate.

"The extended path to the film makes a large image at the expense of longer exposure. About one hour is right for my 10-inch mirror, varying from 20 minutes to three hours according to the figure and the focal ratio. The nearer the mirror is to spherical, the longer the exposure required to produce an image of sufficient density.

"With a 1/25-inch diameter pinhole I use a 25-watt oven lamp, but this is too weak. On long-focus mirrors it is difficult to see the cone of rays to set the knife-edge."

Theoretically the time of exposure should be increased in proportion to the square of the focal ratio. Thus a mirror of *f*/8 should require increased exposure over an *f*/4 as (8 × 8) / (4 × 4), or 4.

INSTRUCTIONS for the adjustment, alignment and collimation of telescopes do not make lively reading, but are most welcome when they are needed, which is every time a new telescope is assembled. One telescope maker recently wrote that this task, for which he had scarcely made allowance in advance, proved to be a major one; another worker said that it would be impossible to publish too wide a variety of instructions for the job. Walter R. Redmond of Greenwood, N. Y., a teacher of science and mathematics, contributes a rigorous new method of aligning reflecting telescopes:

"Many an amateur has been ready to throw out his mirrors lock, stock and barrel because of poor results, when in reality lack of proper mirror alignment has been the chief reason for his distress.

"It is hoped that the method to be described will prove helpful for those who have some difficulty in making a quick alignment of the optical system of their Newtonian reflector.

"Preparation for making the first alignment by this method will require some time, but for all realignments thereafter the optical and geometric alignment of the telescope should take a matter of minutes. It will be assumed that the primary mirror can be centered with respect to the telescope tube, that there are adjusting screws for tilting the primary in relation to the body of the tube, that the adapter tube is perpendicular to the telescope tube, and that the secondary mirror has provisions for both rotational and tilt adjustment.

"The first step is to make a circular hole in the primary mirror coating, about ⅛-inch in diameter and in the exact center of the primary. This hole will of course lie within the silhouette of the secondary mirror and therefore can in no way affect the light-gathering power of the primary. To locate this hole precisely the mirror must be carefully measured at its diameter. With a compass the radius can then be found, and a pin-point mark made on the primary coating at the center of the mirror.

"Next a circular piece of cardboard is cut out with a diameter of about 1½ inch and a 3/16-inch circular hole in the center. This cardboard is placed over the primary so that the pin point in the coating is in the center of the 3/16-inch hole in the cardboard.

"Then with the tip of a pencil eraser which has been somewhat pointed with a knife an opening is made in the primary coating by rotating the eraser in the hole in the cardboard [*drawing at the upper left-hand corner of the illustration at the left*].

"The next step is to remove the eyepiece from the adapter tube and fix cross-hairs over its end, using white thread attached to friction tape wrapped near the end of the tube. As shown in the upper right-hand drawing, one cross-hair should be placed longitudinally with the telescope tube, the other perpendicular to it. Some may desire to make a permanent piece of equipment for this part of the test. In my case a 6-inch extension of lightweight tubing was obtained which fitted snugly in the adapter tube, having the same outside diameter as the eyepiece. At one end of this tube cross-hairs were arranged as described but wrapped more securely by friction tape. With this prepared tube, the eyepiece can be removed, the prepared tube inserted, and the telescope alignment checked in a matter of seconds by the method to be described.

"This will be a convenient time to check the position of the secondary mirror, to make sure that its effective reflecting plane is centered with respect to the center of the adapter tube, which will now be marked by the intersection of the cross-hairs. This can be done, by measuring from the open end of the tube to the top and bottom of the secondary, taking an average of these two readings, and then measuring down the inside of the tube to a point in line with the intersection of the cross-hairs [*drawing at upper right*]. If this last measurement agrees with the average of the other two, the center of the secondary will be opposite the adapter-tube opening. If it does not agree, longitudinal movement of the spider assembly will be necessary until it does.

"The secondary mirror should now be removed from its support and the primary mirror and cell placed at its proper location. The worker should then step to the open end of the telescope [*draw-*

ing at left center] and sight back to the primary mirror through the small central opening in the spider assembly left by the removal of the secondary mirror. If the opening in the spider assembly is not circular it may be made so by pasting over it a small piece of paper with a hole of about ⅛-inch diameter. This opening must be accurately centered with respect to the diameter of the telescope tube. Then when the primary mirror is properly oriented with respect to the tube, the opening in the spider assembly will be reflected directly back to the pupil of the eye, and will appear coincident with the opening in the coating on the primary. In fact, when the primary has been properly aligned by adjusting the screws on its cell, the reflection of the pupil of the eye will appear to be exactly cut out by the opening in the coating of the primary.

"This alignment of the primary is basic and must be carefully done. When the described conditions are met, the optical axis of the primary and the geometric axis of the telescope will be coincident.

"Next it will be necessary to sight from the back of the mirror [*drawing at right center*] through the opening in its coating and through the central opening in the spider assembly toward some small shiny object from 150 to 200 feet away. When the sun shines this object may also serve as an artificial star for testing. I use the silvery portion of a discarded radio tube with good results. When this object is sighted in, the telescope is left without further movement until the alignment is complete.

"Now the secondary mirror is placed in its assembly [*drawing at bottom left*] and, while the worker looks through the center of the adapter-tube opening, it is rotated slowly until the reflection of the pupil of the eye and the opening in the coating of the primary mirror fall upon the cross-hair which is in longitudinal alignment with the axis of the telescope tube [*drawing at bottom right*]. Then the spider is adjusted until the reflected image of the pupil of the eye and the same opening meet at the intersection of the cross-hairs. At this point the following conditions may be noted: the intersection of the cross-hairs and of their reflection, the pupil of the eye and the opening in the primary are all coincident. If the extension to the adapter tube was prepared as described above, the foregoing conditions may be quickly checked at any time in case bumps, jars or temperature changes alter the optical alignment.

"If the cross-hairs are now carefully removed from the adapter tube and an eyepiece placed in it without moving the telescope, the artificial star will appear in the center of the field. When this occurs the worker will have the satisfaction of knowing that both the optical system and the body of the tube are on the target."

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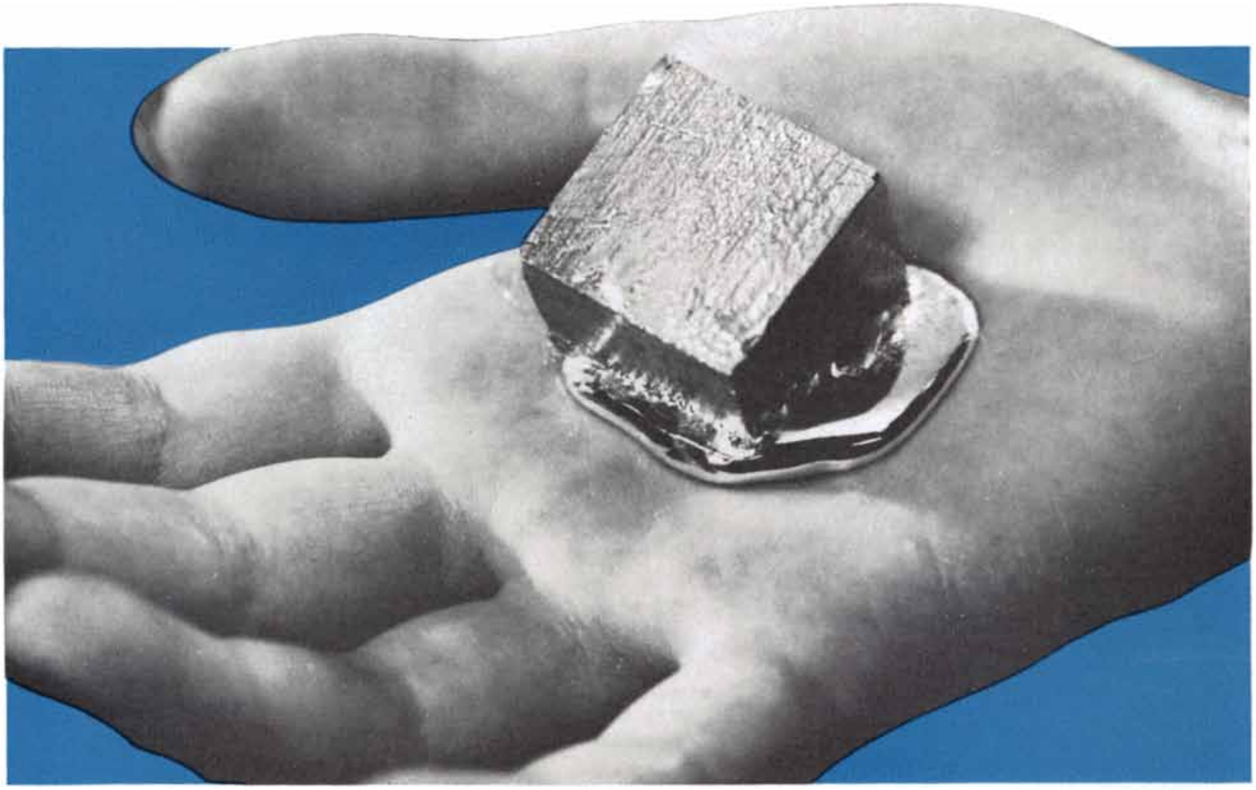

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