SCIENTIFIC AMERICAN

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FIFTY CENTS

October 1950

Photo by Ylla

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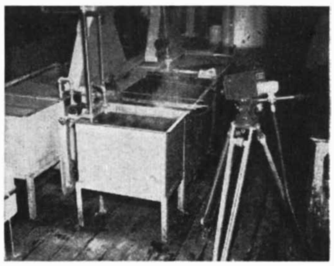

Here's RCA's Vidicon system at work beside a steaming vat. Note how the television camera is getting a safe "close-up" of the action.

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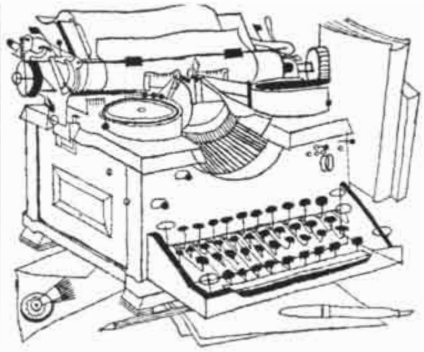

LETTERS

Sirs:

In the interesting article by Donald R. Griffin in the August issue of *Scientific American*, the author suggests that the *tensor tympani* muscle suppresses the sensitivity of the receiving device while the original signal is being emitted, presumably to prevent the loud signal from masking the faint echo. As is well known from studies of animal ear mechanisms, the effect of masking is to raise the threshold for weak sounds, so the *tensor tympani* is then working in the wrong direction if it merely lowers the sensitivity. Earlier he stated that the ear must hear properly the echo when the reflecting object is close enough to cause the echo to interfere with the transmitted pulse; a somewhat contradictory supposition.

I suggest that the explanation of the function of the variation in frequency of emitted pulse is that by the same process as used in the absolute radio altimeter: the beat between the frequency-modulated pulse and its echo is used to obtain range information in those cases where the reflecting objects are located such that the maximum pulse repetition rate need not be exceeded. Objects further away than this would then be located by echo timing alone, or perhaps not sensed at all. Here, then, is the reason for the increased pulse rate of the bat when flying near confusing objects; all such systems are characterized by an increased sensitivity with increased repetition rate. Also, the function of the *tensor tympani* would be to make the ear response nonlinear, which property it must have in order to detect the beat note.

Some simple experiments could be devised to test these hypotheses using generators working in the frequency range of beat frequencies expected to make the bat turn, and triggered by the bat's emitted pulses.

HOWARD J. CARTER

University of Chicago
Chicago, Ill.

Sirs:

Concerning "The Navigation of Bats" by Donald R. Griffin, I have a suggestion as to the use of frequency modulation by these interesting creatures. It was assumed in the article that the time-lag between the beginning of the emission of the signal and the beginning of the echo might be the indication of range and that frequency modulation might be used to enable the bat to hear a returning echo from a target so close that the emission is still occurring when the echo returns. The echo would then be different in pitch from the emission due to the fact that the frequency of emission had been continuously decreasing. Perhaps in the case of these close targets the bat hears the echo as a beat note between the emission and the echo. The beat frequency would be a function of the distance, as it would depend upon the decrease in emission frequency from the beginning of emission to the moment of the return of these first vibrations in echo. The animal could thus sense small distances as a pitch rather than as a time-lag.

The well-known Doppler effect may enter into this. Whenever the bat rapidly approaches another object which is very close to him, the beat frequency will be decreased by the Doppler effect in the echo and the object will seem closer than it actually is at the instant of reflection of sound. Perhaps this error in actual range indication is a service to the bat, giving him a sort of "predicted range."

F. B. KORSMEYER

Wyckoff, N. J.

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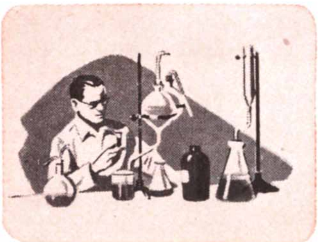

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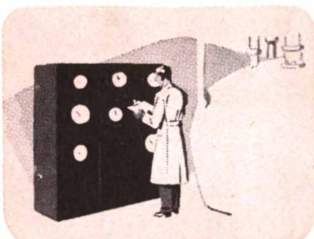

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OCTOBER 1900. "M. Demarçay has made another observation of the spectrum of radium, by which he finds that the chloride of radium has been prepared in an almost pure state; the sample was furnished by Madame Curie. It is remarkable to observe that the spectrum of radium gives it as strong an analogy to the metals of the alkaline earths as is shown by the chemical reactions. The experiments were made entirely by the photographic method, as the quantity of material was too small to permit observation by the eye."

"Prof. A. A. Michelson, of the University of Chicago, has been awarded a Grand Prix at the Paris Exposition for his echelon spectroscope."

"The formal rules and regulations relating to the awarding of prizes under the Nobel bequest have now been formulated and published. The three corporations awarding the Nobel prizes are the Royal Academy of Science at Stockholm, the Swedish Academy at Stockholm, and the Carolin Institute of Medicine and Surgery at Stockholm. The first award will take place December 10, 1901."

"The second trial of Count Zeppelin's colossal airship is described in press reports from Friedrichshafen as being a notable success. After rising to a height of about 2,000 feet, the vessel remained poised at that level for three-quarters of an hour. It then made a series of tacks, and went through certain turning maneuvers. The stability and steering powers of the airship are described as being excellent."

"The whole system of modern chemistry is based upon the axiom of the indestructibility of matter, and that indestructibility is proved by the permanence of the weight of a given substance through all the physical or chemical changes it is made to undergo. Any experiments, therefore, which shake our belief in that primary property of matter must have a far-reaching effect. Landolt's classical researches in 1893 embodied the first work done with all the modern instruments of precision. Certain minute changes of weight were then placed in evidence, and these have since been confirmed. A. Heydweiller has endeavored to trace some connection between the change of weight and the changes in other physical properties, such as magnetic permeability, electrolytic dissociation, and material or optical density. He has failed to trace any such connection, though he has distinctly established a diminution of weight of about one part in 50 million in a number of reactions, such as the mixture of copper sulphate with water, where a loss of weight of one milligramme was observed."

"An important development of the electron theory has been carried out by Robert Lang in his article on atomic magnetism in the *Annalen der Physik* (No. 7). It may now be said that the phenomena of magnetism have at last been successfully reduced to those of electricity. We know from the work of Thomson and of Drude that an electric current in a wire consists of a stream of very small particles called electrons. These electrons are formed by the splitting up of the metallic atoms into a larger positive and a smaller negative portion. Now, according to Lang, the negative electrons revolve around the heavier positive electrons in a magnetized metal, like a planet around the sun, and the electric convection-currents thus produced are nothing more nor less than Ampère's 'elementary molecular currents.' Lang calculates the speed of the electrons and the diameter of their orbits. The speed is that of light, and the figures obtained lead to conclusions in close agreement with known facts."

OCTOBER 1850. "On Saturday afternoon before last, Joshua Pusey ascended with a balloon from Reading, Pennsylvania. When at an altitude of two miles, he was overtaken in a snow storm, and, what was strange to him, and will be so to everybody, was the fact that the snow flakes ascended."

"By a law of the solar system just discovered, we can determine the original magnitude of the broken planet long after it has been shivered into fragments; and we might have determined it even after a single fragment had proved its existence. This law we owe to Mr. Daniel Kirkwood, of Pottsville, an humble American, who, like the illustrious Kepler, struggled to find something new among the arithmetical relations of the planetary elements. Between every two adjacent planets there is a point where their attractions are equal. If we call the distance of this point from the sun the radius of a planet's sphere of attraction, then Mr. Kirkwood's law is that in every planet the square of the length of its year, reckoned in days, varies as the cube of the radius of its sphere of attraction. This law has been verified by more than one American astronomer, and there can be no doubt, as one of them expresses it, that it is at least a physical fact in the mechanism of our system. This law requires the existence of a planet between Mars and Jupiter, and it follows from the law that the broken planet must have been a little larger than Mars, or about 5,000 miles in diameter, and that the length of its day must have been about 57½ hours."

"A singular discovery has been made in Madagascar. Fossil eggs of an enormous size have been found in the bed of a torrent. The shells are an eighth of an inch thick, and the circumference of the egg itself is 2 feet 8 inches lengthwise, and 2 feet 2 inches around the middle."

"Conspicuous among agricultural implements stands the Grain Reaper of C. H. McCormick, formerly of Virginia, but now of Chicago, Illinois. The employment of these machines has become very common, especially among our Western farmers; no less than 1,800 machines have been sold this year. They are manufactured by Mr. McCormick, at Chicago, Ill."

"Since the successful attempt to connect England and France by means of a submarine telegraph, the great question of uniting England, or rather Ireland, and America has been the theme of conversation in various circles. The distance between Cape Clear near Galway, in Ireland, and Newfoundland is about 1,600 miles; and a line of this length consisting of four separate wires perfectly insulated, in a cord of the size proposed, would last for hundreds of years, as its lateral strength would be almost equal to iron. Such a line would weigh about 8,000 tons, and would require 600 anchors. The cost of everything, when in complete working order, would be less than 3,000,000 of dollars.

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Arrow points to tube containing a wire specimen under test for surface conductivity. The tube and wire are excited to resonance by microwaves from generator at extreme left. Conductivity is calculated from frequency values indicated by barrel-shaped wavemeter (top center) and resonance curves traced on an oscilloscope screen (not shown).

In the waveguides which conduct microwaves to and from the antennas of radio relay systems, current is concentrated in a surface layer less than 1/10,000 inch thick, on the inner surface of the waveguide. When these surfaces conduct poorly, energy is lost.

To investigate, Bell radio scientists devised exact methods to explore this skin effect at microwave frequencies.

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THE COVER

The painting on the cover shows part of a micromanipulator, a device for moving tiny needles and tubes of glass within a single cell (*see page 48*). At the upper left is the barrel of a microscope. Beneath its objective is a "moist chamber," where the cells under study are kept from drying out. Entering the moist chamber from the right are two glass tubes, the ends of which taper down to dimensions smaller than those of the cell. By means of these tubes droplets of oil may be injected into the cell to provide information about its microscopic structure. The tubes may be moved up and down by turning the two knobs at the lower right. They are moved forward and back and from side to side by the knobs in the center of the painting. This apparatus is a modification of the Chambers micromanipulator, designed by Robert Chambers of New York University. The modification was conceived by M. J. Kopac of N.Y.U. and was built by the Gamma Scientific Company.

THE ILLUSTRATIONS

Cover by Walter Murch

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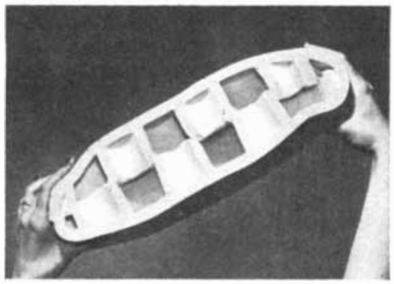

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SCIENTIFIC AMERICAN

OCTOBER 1950 VOL. 183, NO. 4

PREJUDICE

An account of a significant statistical study of racial discrimination from the standpoint that hostility is the consequence of insecurity

by Bruno Bettelheim and Morris Janowitz

ONE of the central difficulties facing present-day society is the problem of how to deal with the dissatisfactions and aggressions which seem to be generated by man's close proximity to his fellow men. Since hostility is the force most disruptive to social living, the scientific analysis of group hostility should be one of the chief concerns of social scientists.

This article will report on a recent attempt to study the problem. Of the many tension areas within our society the particular one selected for our investigation was ethnic hostility—a polite term for racial prejudice. To learn whether hostility is actually the result of frustration, we needed a group of subjects with some common life experiences, and this we found in a sample group of Army veterans who had returned to civilian life. Since all had experienced comparable wartime deprivations, they offered an excellent opportunity to examine the hypothesis that the individual who suffers frustrations tries to restore his emotional balance by some form of hostile behavior. Our sample consisted in 150 former G.I.'s who were residents of Chicago and represented all economic classes.

Through intensive interviews in which free association was always encouraged these men were sounded out on their attitudes toward Negroes, Jews and other ethnic minorities. The interviewers were psychiatrically trained social workers experienced in public-opinion surveying. The wide range of personal data sought required long interviews which took from four to seven hours and in several cases were carried on in two sessions. The veterans themselves were offered ample opportunity to express personal views on many issues and to recount their wartime experiences before the matter of ethnic minorities was first mentioned. The extensive contents of these case histories were then subjected to statistical and content analysis, which allowed us to make quantitative statements about the degree and type of ethnic hostility, as well as about feelings of deprivation, anxiety and a range of other psychological and sociological characteristics.

In general the analysis did not bear out the hypothesis that frustration necessarily generates dissatisfaction or hostility. Army experiences which seemed to involve objective hardship (*e.g.*, combat, wounds, long service) did not in themselves appear to heighten dissatisfaction. For example, a 25-year-old infantry private first-class who had fought in North Africa, Italy and Germany, and who claimed, with some justification, that Army life had ruined his health, described his war experience as follows: "I was a teletype operator in Africa for three or four months, and wasn't in combat then, but all the rest of the time I was laying wire in combat areas. We lost 80 per cent of our company. I never thought I had a chance to come out of it alive. I came out lucky. I came out swell on money and passes. I didn't get any breaks, but to come back and be alive today is really swell." Another typical response was that of a 30-year-old staff sergeant who had once been demoted: "In my Army career I got a good break. I was made staff sergeant in 1942, only I was busted. But I made it back in another outfit. And I got to be mess sergeant, and mess sergeants eat good."

On the other hand, a number of veterans whose experiences, objectively speaking, had been relatively free of hardship, felt that they had had bad breaks. A typical response in this group was the following: "I wanted to get somewhere. But somebody else always got it. I deserved a rating and never got it. When they wanted somebody to repair something on a gun, I was always called because the other guy didn't know. That's why I never had no use for the Army. They never gave a rating to a person who should get one."

Thus a man's evaluation of his Army career in retrospect was largely independent of the actual deprivations experienced and depended mainly on his emotional attitude toward this experience in particular, and, one may add, to life experiences in general.

Our main purpose was to find out how all this affected ethnic intolerance. On the basis of an exploratory study we found it possible to classify the veterans in four types according to the degree of intolerance or tolerance toward a specific ethnic group. With respect to their attitude toward Jews, for example, the four types were: 1) the intensely anti-Semitic, who spontaneously expressed a desire for restrictive action against the Jews even before the question was raised; 2) the outspokenly anti-Semitic, whose hostility toward the Jews emerged only on direct question; 3) the stereotyped anti-Semitic, who merely expressed various stereotyped notions about the Jews, some of which were not necessarily unfavorable from the interviewee's point of view; 4) the tolerant, who revealed no elaborately stereotyped beliefs about the Jews.

THE ATTITUDES of the 150 veterans toward Jews and Negroes, graded according to this scale, are summarized in the charts on the opposite page. There was a considerable difference in tolerance toward Jews and Negroes, and the results showed that true ethnic tolerance, *i.e.*, a tolerance which also included Negroes, was a rarity among these veterans.

Further analysis revealed that the men's actual Army experiences bore little relation to their attitude toward ethnic groups, nor was there any significant correlation between intolerance and age, education, religion, political affiliation, income, social status or even the subjects' preferences in newspapers, magazines or radio programs.

There was a close relation, however, between ethnic attitude and social mobility, *i.e.*, a move up or down on the socio-economic scale, as compared with previous civilian employment, after the veteran was discharged from the Army. Ethnic hostility proved to be most highly concentrated in the downwardly mobile group, while the pattern was significantly reversed for those who had risen in social position. Those who had experienced no change were "middle-of-the-roaders." Over 70 per cent of the stereotyped anti-Semites were found in this middle category; on the other hand, most of the same group were in the outspokenly anti-Negro category—a reflection of the fact that in this Northern urban industrial community it was "normal" to have stereotyped opinions about the Jews and to be outspoken in hostility toward the Negro.

It turned out that while the men's actual Army experiences showed no relation to intolerance, their subjective evaluations of those experiences definitely did. Those who felt they had had bad breaks in the Army were the most inclined to be hostile toward Jews and Negroes. A further study was made of the relation between intolerance and a readiness to submit in general to controls by society. If, by and large, an individual accepted social institutions, it seemed reasonable to assume that his acceptance implied a willingness to control his aggressive tendencies for the sake of society. Or, to put it another way, one might say that those men who felt that society was fulfilling its task in protecting them from unavoidable frustrations were also the ones who were willing in return to come to terms with society by controlling their aggressions.

Control, as a psychologist defines it, is the ability to store tension internally or to discharge it in socially constructive action rather than in unwarranted hostile action. There are three sources from which such control may come: 1) external or social pressure, 2) the superego, or the unconscious "conscience," and 3) the ego, or rational self-control.

In actuality the three types of control are nearly always coexistent, and in any individual control will depend in varying degrees on all three. In the men studied, wherever control was present it was overwhelmingly the result of a combination of external and superego control, with the first dominant. Few men were also motivated significantly by rational self-control, and in even fewer was this dominant over superego or external control. Hence a study of external (*i.e.*, societal) control was the only one that promised to allow insight into the correlation between a man's attitudes toward social control and the extent of his ethnic intolerance.

The analysis indicated that veterans who had stable religious convictions, regardless of the church they belonged to, tended to be the more tolerant. When the political party system was viewed as another norm-setting institution, a similar relationship of at least partial acceptance was found to be associated with tolerance. Whether the veteran was Democratic or Republican was in no way indicative of his attitude toward minorities. But the veteran who rejected or condemned both parties ("they're both crooks") tended to be the most hostile toward minorities.

TO EXPLORE more fully this relationship between tolerance and control, the responses to other symbols of societal authority which signify external control of the individual also were investigated. The four institutions singled out as being most relevant were: the Veterans Administration, the political party system, the Federal government and the economic system, as defined by the subjects themselves. The analysis showed that only an insignificant percentage of the tolerant men rejected these institutions, while nearly half of the outspoken and intense anti-Semites did so. (This is in marked contrast to studies of certain types of college students, in whom radical rejection of authority is combined with liberalism toward minority groups.) In the case of the attitude toward the Negro, societal controls merely exercise a restraining influence; they do not suppress hostility but only make it less violent. The men who were strongly influenced by external controls were, in the majority, stereotyped and outspoken but not intense in their intolerance toward Negroes.

Thus it appears that in our society intolerance is related first to a lowering of social status, to feelings of frustration and insecurity. Next, the degree to which it finds open expression depends on the degree to which society approves or disapproves its expression. But the question remains: Why is ethnic hostility a favorite channel for discharging aggressive feelings?

Some of the reasons emerged, albeit indirectly, in an analysis of the stereotypes used by the veterans in describing minorities. With respect to the Jews, the composite pattern of stereotypes did not stress personally "obnoxious" characteristics; the members of this sample of veterans, predominantly of the lower class and lower-middle class, did not often characterize Jews as pushy, overbearing or loud. In the main the Jews were represented as a powerful, well-organized group which by inference threatened the subject. The most frequent assertion was that Jews were clannish, and that they helped one another. In the context in which this statement was made it almost invariably indicated that the veteran was decrying what he considered to be the unfair advantage in business and politics which accrued to the Jew who enjoyed greater social solidarity than himself.

On the other hand, the stereotypes used about the Negro stressed personally "offensive" characteristics—his alleged dirtiness and immorality. The intolerant white described the Negro as a threat to the white man's economic and social status, maintaining that the Negro was "forcing out the whites."

This situation differs from that in Germany under the National Socialists. In Germany the National Socialists applied the whole list of stereotypes to the Jews; their anti-Semitic propaganda greatly emphasized the Jews' alleged dirtiness and lack of morality. In the U. S., where more ethnic minorities are available as possible targets, a tendency has emerged to separate the stereotypes into two sets and to assign them to separate minority groups. One set of stereotypes indicates feelings of anxiety over the Jews' supposed power. The other set indicates anxieties aroused by the Negroes' (and the Mexicans') assumed ability to permit themselves the enjoyment of primitive, socially frowned upon forms of indulgence or gratification. The selection and use of stereotypes seems to depend on the needs of the person applying them. It also appears that the minority that shows the greater difference from the majority in physical characteristics, such as skin color, is used for projecting anxieties associated with dirt and sex desires, while the minority that is more like the majority in appearance becomes a symbol for anxieties concerning overpowering control.

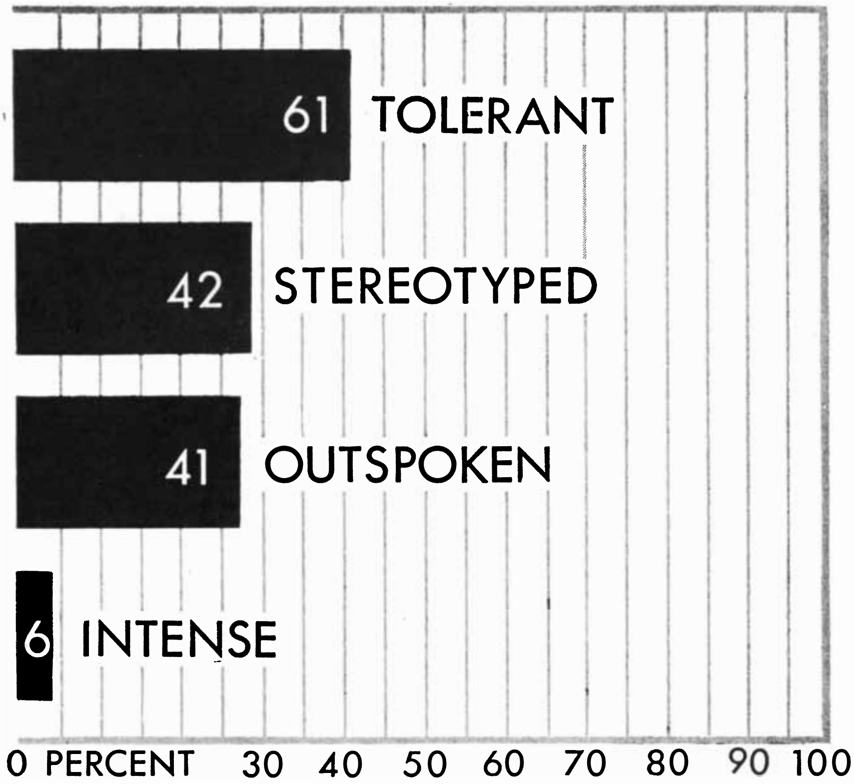
HAD the veterans' contacts with Jews and Negroes in the Army affected their attitudes? Detailed analysis showed little apparent effect; their stereotypes of Jews they had met in the Army were largely just an extension of civilian concepts. A typical comment: "There were only a few Jews in our outfit. One of them was a master sergeant. They did get up faster in rank and promotion, but we couldn't do anything about that. They would do favors for the officers and get promoted."

Even when the veteran felt a personal attachment and respect for an individual Jew in his outfit, the stereotype remained: "Oh, there was one Jew, Lieutenant Blank . . . almost forgot about him. He took pictures of me and a buddy of mine the day before he was killed. He was really white. At first I didn't like him and he knew it and picked on me at first, too. But then I changed my mind. He took care of his platoon all right. He saw to it that they had things they needed. They had cigarettes all the time when there weren't many around. That's the Jew in him—he was good at getting things like that. He'd do anything for his men and they'd do anything for him."

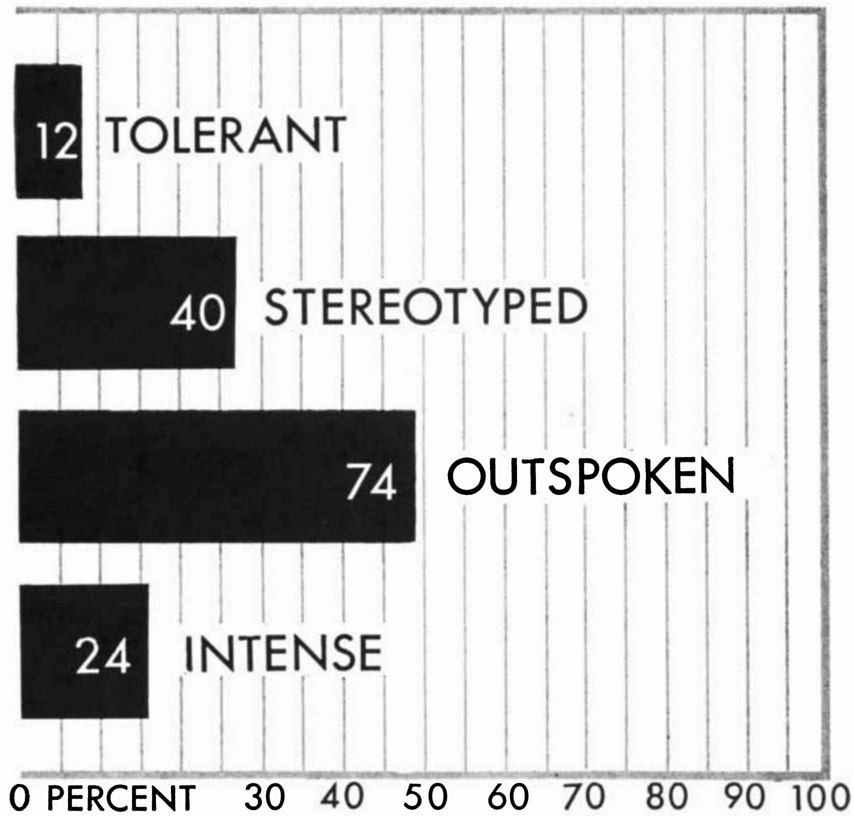
These and many similar statements support the hypothesis that the individual's stereotypes are not only vitally needed defense mechanisms but are persistent, even under the impact of such immediate and realistic experiences as service with Jews and Negroes under conditions of war. Once a stereotype is formed, it is not easily changed by experience.

It seems reasonable to assume that as long as anxiety and insecurity persist as a root of intolerance, the effort to dispel stereotyped thinking or feelings of ethnic hostility by rational propaganda is at best a half-measure. On an individual level only greater personal integration combined with social and economic security seem to offer hope for better interethnic relations. On the social level a change of climate is necessary. The veterans who accepted social controls and were more tolerant of other minorities were also less tolerant of the Negro, because discrimination against Negroes is more commonly condoned, both publicly and privately. This should lead, among other things, to additional efforts to change social practice in ways that will tangibly demonstrate that ethnic discrimination is contrary to the mores of society—a conviction which was very weak even among the more tolerant veterans.

Bruno Bettelheim is associate professor of educational psychology and principal of the Orthogenic School at the University of Chicago. Morris Janowitz is assistant professor of social science at the same university. They are co-authors of the recently published book Dynamics of Prejudice.



ATTITUDES TOWARD JEWS of the group studied were classified in four categories. The horizontal bars indicate the percentage of the group in each category. Numbers on the bars indicate the number of men in each category.



ATTITUDES TOWARD NEGROES were similarly classified. There were about the same number of stereotyped anti-Negro as stereotyped anti-Semitic expressions. There was larger number of outspoken anti-Negro expressions.

The Abundance of the Elements

Physicists and astronomers have been engaged in a cosmic inventory of the various kinds of atoms as a clue to their primordial creation

by Armin J. Deutsch

HOW WAS the universe created, and under what conditions? Until man began to explore the nucleus of the atom there was little evidence as to what the beginning was like or how the varieties of matter that make up the stars and planets came to be formed. Nuclear physics has now given some scientific point to this ancient philosophical speculation.

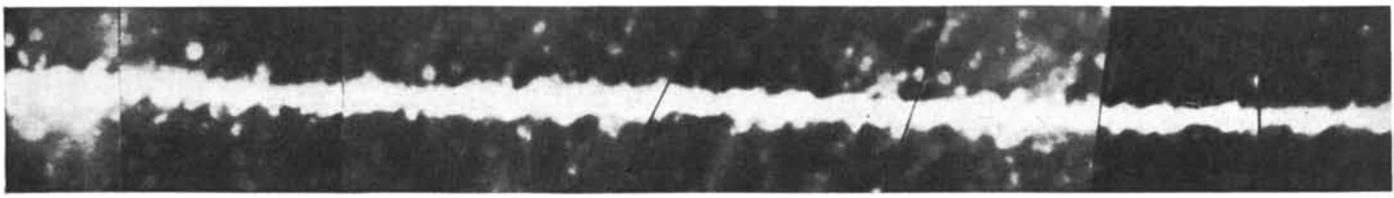
The nuclei of atoms in general are well-preserved relics of the very remote past. If the nuclei of iron atoms, for example, were ever created from something else, that event must have taken place in a primitive state of the universe probably dating back at least three billion years—before stars or planets were formed. Iron nuclei are too stable for radioactive decay to occur and they repel other nuclei too strongly to be transmuted by collisions, even at the center of the hottest star. Hence the abundance of iron in the known universe has not changed appreciably since the universe has existed in anything like its present state. This is true of most of the elements. It follows that the relative abundances of the elements in today's universe were largely determined by the conditions that prevailed in the primordial universe. If we can discover the relative abundances, we can hope to deduce the circumstances of creation.

With this remarkable prospect in view, physicists and astronomers have recently turned more and more to the task of taking a cosmic inventory of atomic species. The easiest place to begin, of course, is the crust of the earth, which includes the atmosphere and the oceans as well as the granitic continents and the underlying basalt that constitutes the bulk of the earth's shell. Of the 90 elements occurring naturally in the crust, oxygen accounts for nearly half of the crust's mass, silicon for another quarter, and aluminum, iron, calcium, sodium, potassium and magnesium—in that order—for nearly all the rest; the remaining 82 elements all together contribute less than one per cent of the crustal mass.

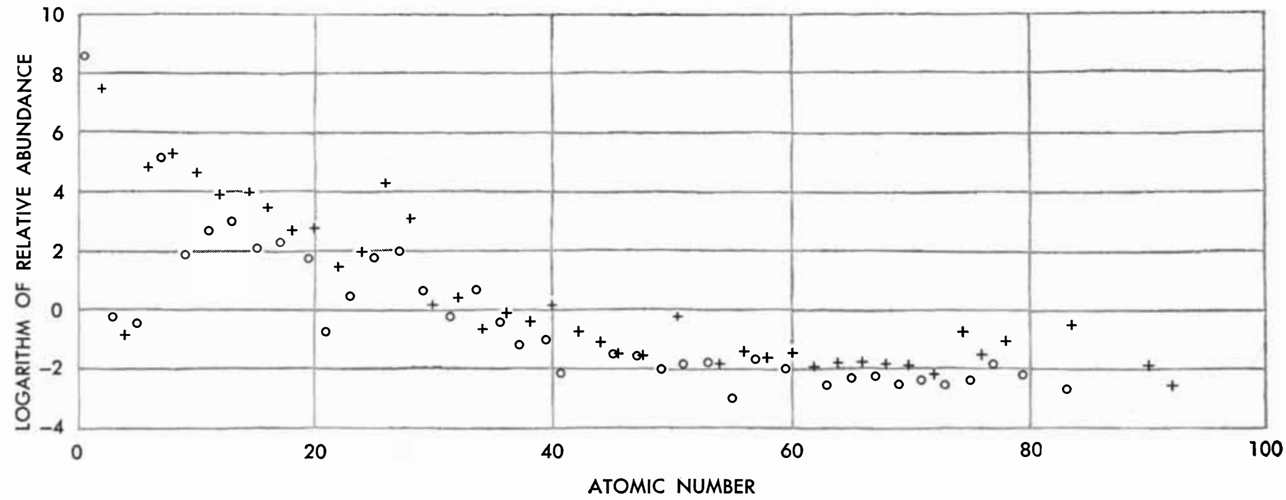
But what of the interior of the earth, where practically all the mass resides? Inaccessible for direct chemical sampling, these parts of the earth must be analyzed by indirect methods: the propagation of seismic disturbances, the mean density, the thermal conductivity, and so forth. Based on these criteria, the consensus is that the interior consists of a nickel-iron core extending halfway from center to crust, and surrounded by a silicate mantle of approximately equal mass. Although the detailed composition of the interior is not known, we can at least be sure that the crust is not a fair sample of the whole earth. The radioactive elements, for example, cannot be as abundant throughout the earth as they are in the crust; if they were, they should have liberated enough energy during geological history to raise the temperature of the interior far beyond any reasonable value.

THE CRUST of the earth being so atypical a sample of bulk matter, chemists have given considerable attention to the meteorites. These bodies, which are believed to be fragments of a shattered planet, generally belong to one of two types: the "stones" and the "irons." In the stones the atomic abundances are probably about the same as in the mantle of the earth; oxygen, silicon, magnesium and iron predominate. In the irons, iron atoms contribute 90 per cent of the mass, and nickel another eight per cent. The irons look suspiciously like fragments of the hypothetical nickel-iron core of a planet, and the stones like fragments of the mantle.

If meteorites are actually fragments of a disintegrated planet, average abundances of elements in them are probably more truly representative than those in the crust of the earth. But the difficulty is that we do not know what proportion of the planet was made up of stones and what of irons. Harrison Brown of the University of Chicago, who has made a careful analysis of meteorites, has concluded that the ratio of stones to irons is two to one. On this basis the average relative abundances of elements in meteorites, and therefore presumably in the whole planet from which they came,



PRIMARY COSMIC RAY is a sample of matter from extraterrestrial space. The track extending across these two pages was made in a stack of special photographic plates by a nucleus with an atomic weight of about 15,



RELATIVE ABUNDANCE of the elements decreases in a general way from hydrogen (1) to uranium (92). Those elements with an odd atomic number are indicated by circles; those with an even atomic number, by crosses. The abundances are distorted by the logarithmic scale; there is more hydrogen than all other elements.

prove to be very different from the abundances in the earth's crust. Iron, for example, is 10 times as abundant in the average meteorite as in the earth's crust, while oxygen is only half as abundant and potassium only one twentieth as abundant!

But even granting that the average meteorite has abundances typical of whole planets like the earth, can we expect that these abundances will be typical of the entire known universe? The first indication that we cannot appears when we consider the giant planets. Jupiter, for example, is about 1,300 times as big as the earth in volume but only 317 times as massive, which means that its average density is one quarter that of the earth. In Jupiter and the other giant planets light elements must be far more abundant than in the earth. The spectrum of Jupiter's deep and cloudy atmosphere shows that the Jovian atmosphere is exceedingly rich in hydrogen. In fact, the very low mean density of Jupiter suggests that the planet has a high abundance of hydrogen through a large part of its bulk. Rupert Wildt of Yale University in 1938 worked out a model of Jupiter that would account for its known physical features. In his model the planet has a dense rock-and-metal core extending about halfway to the surface, overlying this is a vast mantle of ice, and topping the ice is an 8,000-mile-thick shell of hydrogen—frozen solid! Wildt derived similar "stone-in-a-snowball" models for the other giant planets. Recent spectrographic observations by Gerard Kuiper of the University of Chicago lend strong support to Wildt's models, for Kuiper has found evidence of frost or ice on the rings of Saturn.

The evidence is strong, then, that the giant planets are rich in hydrogen, and there are good reasons to believe that the earth and other small planets originally also had a great deal of hydrogen but have lost most of it because, being less massive, they are less able to hold light elements.

But the planets themselves are not a representative sample of the universe's matter. To find out about the abundance of light elements we must turn to a more massive body such as the sun.

THE SUN is more than a million times as large as the earth and more than 300,000 times as massive. It is gaseous throughout, but highly opaque, so we can look down only a hundred miles or so into its incandescent atmosphere. Almost everything we know about the composition of the sun has come from spectroscopic studies of this atmosphere. The atmospheric gases absorb some of the light streaming out from the sun's interior. Since each species of atom absorbs light at certain characteristic wavelengths, an examination of the dark absorption lines in the spectrum of the sun tells us what elements are present in the solar atmosphere; we can even tell how much of the element is present from the strength of the absorption lines. There are complications, to be sure—the efficiency of absorption and the strength of the lines are influenced by temperature, electron pressure and a saturation effect—but by allowing for these factors we can make a rough quantitative analysis of the composition of the sun's atmosphere.

This analysis shows that hydrogen is by far the most abundant element in the sun's atmosphere—several thousand times as abundant as iron and several hundred times as abundant as oxygen, which dominates the crust of the earth. The second most common element in the solar atmosphere, about one seventh as plentiful as hydrogen, is helium, which is a rarity on earth. Then comes oxygen, and close behind it nitrogen and carbon, which on the earth are far down on the list in abundance.

But what about the sun as a whole? Have we any more reason for thinking that the sun's atmosphere is typical of its interior than that the crust of the earth is representative of the whole earth? Here again, as in the case of the earth's interior, we must rely on indirect physical evidence. We know the sun's mass, radius and luminosity. We know, further, that it is in a state of mechanical and thermal equilibrium, or at least very

that of the element phosphorus. The plates had been carried to a height of some 90,000 feet by a balloon in an experiment by Phyllis Freier, E. J. Lofgren, E. P. Ney and Frank Oppenheimer of the University of Minnesota.

nearly so. And we also know most of the details of the carbon cycle, which builds helium nuclei from protons in the deep interior, and liberates the energy that eventually flows from the surface. This knowledge is enough to let us discover the approximate abundances of a few of the commonest atoms in the interior. It leads to the conclusion that hydrogen probably predominates in the interior about as it does in the atmosphere, with helium atoms second in abundance. This apparent chemical inhomogeneity of the sun is not as surprising as it might seem. While we have every reason to expect a complex and chemically inhomogeneous structure within the solid earth, we have every reason to expect the opposite in the gaseous sun. We can think of many reasons why iron atoms should be concentrated toward the center of the earth; we can think of no reasons why they should be so concentrated in the sun, and a few good reasons why they should not be. Accordingly, we are inclined to accept the abundances in the solar atmosphere as fairly typical of the whole sun, except possibly in the cases of a few special elements.

The sun, then, is composed predominantly of atoms of low atomic weight—atoms which are relatively uncommon in the earth because they have largely escaped from that less massive body. The sun also appears to contain most of the elements that exist in the earth; 61 of the 90 found in the earth have been detected in the sun's atmosphere, and probably all the others are present but not detectable. Among the heavier elements, which probably could not escape the earth, the abundances in the sun are remarkably close to those in the planets. From iron to lead the metals exhibit practically the same abundances in the sun and in meteorites.

BUT THE sun is still only a very small sample of the matter in the known universe. It is one star, and the galaxy contains billions. To find out whether the abundances in the sun are a fair sample, we must examine the spectra of the stars. In our galaxy there are many stars like the sun, with the same size, mass, luminosity, spectra and atomic abundances. But the sunlike stars are outnumbered by other kinds. Sirius, for example, is 2.3 times as massive as the sun and radiates energy at 40 times the solar rate. The temperature of its atmosphere is nearly 11,000 degrees Kelvin, instead of 6,000 degrees as on the sun. And its spectrum is very different from the sun's; the hydrogen lines are many times stronger and the iron lines many times weaker. Yet an astrophysical analysis indicates that in spite of these differences Sirius has nearly the same chemical composition as the sun. Most of the differences between the spectra of Sirius and the sun can be accounted for by the difference in temperature alone: the hydrogen lines are stronger in the spectra of Sirius because hydrogen atoms absorb light at the observable wavelengths more efficiently at 11,000 degrees; on the other hand, iron atoms absorb more efficiently at 6,000 degrees. The abundance of hydrogen relative to iron is probably about the same in Sirius as in the sun, in spite of the wide dissimilarity of their spectra.

In our part of the galaxy, all the stars except a small fraction of one per cent show spectra that seem to differ from one another only because of differences in temperature. We are able to arrange the spectra of these stars in a simple temperature sequence; the group as a whole is known as the "main sequence." At one end of this sequence the stars have atmospheric temperatures of about 3,000 degrees, and the spectra are complex and crowded with absorption lines and molecular bands. At the other end the temperatures are of the order of 30,000 degrees, and the spectra are relatively simple and uncrowded. In all of the main-sequence stars investigated so far, the atomic abundances turn out to be about the same as in the sun, to the limit of present analytical techniques.

Are there any stars in which the abundances differ appreciably from those in the sun? Probably not along the main sequence. But the small percentage of stars lying outside the main sequence show differences in their spectra that cannot be explained as mere temperature effects. Some of these relatively rare stars are giants or supergiants, with atmospheres under much lower pressure than along the main sequence. In many cases the peculiarities of their spectra are explainable as pressure effects. A few outstanding anomalies remain, however. Among the hottest stars in the galaxy there is a group whose spectra indicate an abnormally large abundance of nitrogen, and another group that seem to be exceptionally abundant in carbon. And the coolest stars outside the main sequence also show an unexplained diversity of spectra. Carbon, zirconium and titanium appear to differ in abundance from one group of cool giant stars to another. Novae, too, exhibit puzzling anomalies. The spectrum of Nova Persei was dominated by emission lines of the terrestrially rare element neon soon after its cataclysmic outburst in 1901, and the nebula it ejected still shines most brightly in these wavelengths!

These relatively rare objects may really have chemical compositions different from that of the sun. But many astronomers are still unwilling to admit that this is the true explanation of their spectroscopic peculiarities. In all cases where we find apparent abundance anomalies, the spectra are influenced by physical processes still imperfectly understood. Horace Babcock of Mount Wilson and Palomar Observatories has found, for example, that some stars showing strong lines of the rare earths have strong magnetic fields, and he has described how these fields can act to intensify certain absorption lines more than others.

TENTATIVELY, then, we can conclude that the vast bulk of matter in our part of the galaxy has the same chemical composition. But before we can take the present abundances to be typical of those that existed at the beginning of the universe, a few questions remain to be answered.

Have the abundances changed since the stars were born? The answer is yes. Some atoms have been changed by radioactive decay: the abundance of uranium everywhere is probably one per cent less now than it was six million years ago. Others have been transformed by fusion into larger atoms: hydrogen is one per cent less abundant in the sun than it was 300 million years ago, for the carbon cycle consumes hydrogen at the rate of 560 million tons per second and transmutes it into helium. In all probability the carbon cycle burns hydrogen at a comparable rate in the interior of every main-sequence star. Yet these transmutations are no great problem, for we know the rates of change and can make the necessary corrections in present abundances to obtain those at any time in the past.

Did any matter escape into space as the stars were formed? Perhaps it did. If so, we should expect to find it somewhere in the galaxy. It turns out, as a matter of fact, that about half of the matter in the galaxy is thinly strewn in interstellar space. We do not know whether this interstellar matter was ever inside stars. The interstellar gas reveals itself by producing extra absorption lines in the spectra of remote stars. The spectroscopic results are sketchy so far, but they indicate that the elements are present in about the same proportions in interstellar space as in the stars. Another possible clue to the composition of the interstellar medium lies in the primary cosmic-ray particles, which are nuclei of atoms. Within the past two years physicists at the University of Minnesota and elsewhere have found and identified the tracks of many primary cosmic-ray particles in special photographic plates carried by balloons to heights of about 17 miles. Protons, the nuclei of hydrogen atoms, predominate among them; second in abundance are alpha-particles, the nuclei of helium atoms. About three particles out of every thousand are nuclei of heavier atoms; a few of these have masses as large as a hundred protons! The abundances given by counts of cosmic-ray primaries so far do not entirely agree with the astrophysical determinations, heavy nuclei being relatively more abundant among the cosmic rays. But these findings do not necessarily invalidate the spectroscopic results, since we do not yet know the origin of cosmic rays.

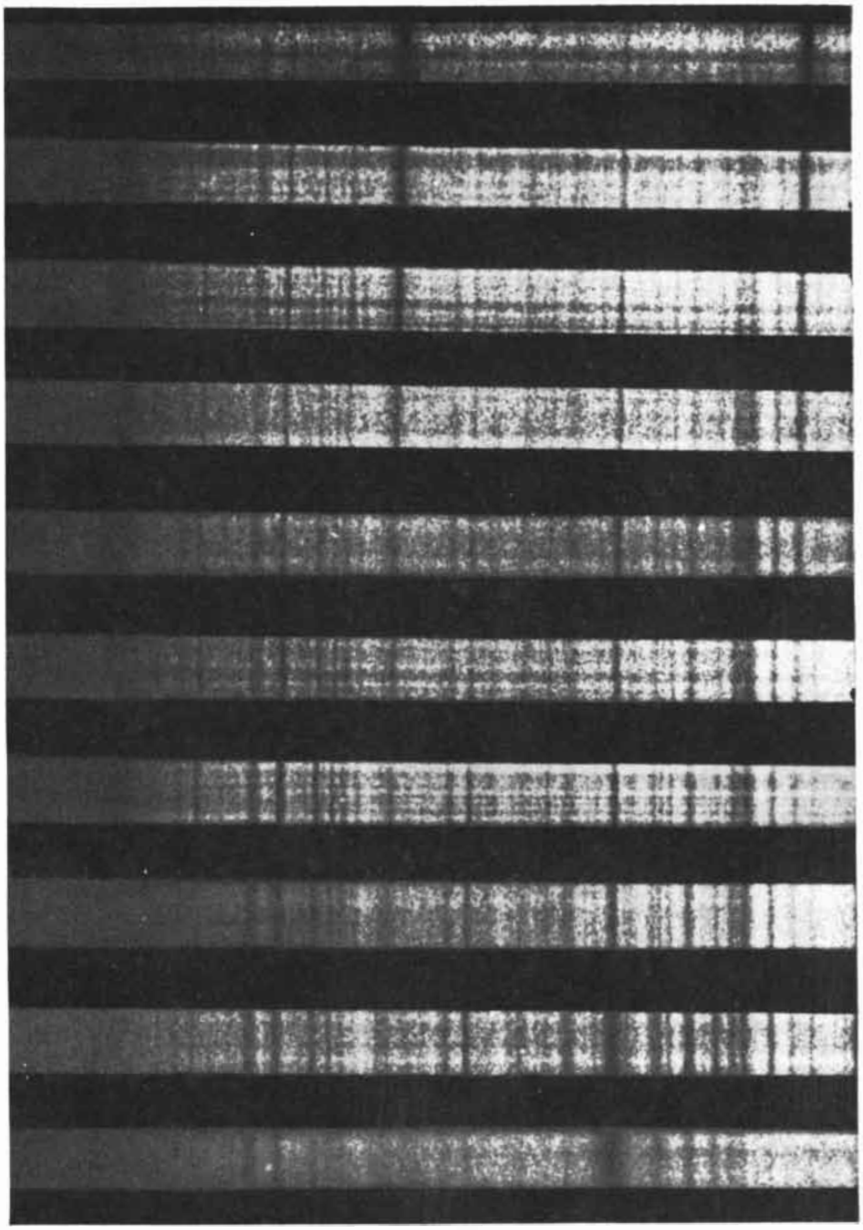
COMPILING all the results of chemical, geochemical and astrophysical analyses, we should now be in a position to give a reasonably accurate cosmic inventory of elements, and this inventory should represent very nearly the abundances in the primitive universe. Brown's compilation is the latest and the most complete. It shows that hydrogen atoms are more abundant than all other kinds together. As the atomic number increases from hydrogen (1) to selenium (34), the abundances drop precipitately. Helium (atomic number 2) is about one tenth as abundant as hydrogen, oxygen (8) less than one thousandth as abundant as hydrogen, and selenium a billion times rarer than hydrogen. The abundance curve does not drop smoothly, however. Atoms of even atomic number are usually more abundant than neighboring ones of odd atomic number; thus iron atoms (26) outnumber both manganese (25) and cobalt (27) about 200 times. Beyond selenium the abundance curve flattens out.

Even when we know the relative abundances of the elements, we need still another kind of information to complete our cosmic inventory. This information is a count of the relative abundance of isotopes found in nature for each element, and it is crucial for the construction of a theory as to how the various elements originated.

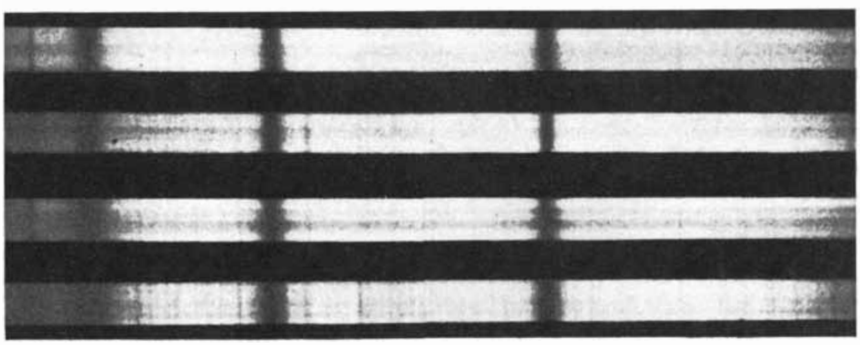
Physicists find that among the elements of small atomic number the lighter isotopes are more abundant; for example, 99.76 per cent of all oxygen found in nature consists in atoms of atomic weight 16 (eight protons and eight neutrons), while the heavier isotopes, oxygen 17 and 18 (with 9 and 10 neutrons, respectively) together account for only .24 of one per cent. Among the heavier elements, this rule is reversed, and the heavier isotopes are the more abundant; thus uranium 238 is 139 times as common as uranium 235.

These results strongly suggest that atoms lighter than, say, selenium, had a different origin from the heavier ones. Perhaps the nuclei of the lighter atoms were formed by a building-up of protons and neutrons in thermonuclear reactions of the general type that still convert hydrogen into helium within the stars. The heavier atoms may well represent the result of a breaking-down of primitive nuclei far more massive than any now known, in a chain-reaction of nuclear fissions on the scale of the universe itself.

Armin J. Deutsch, astronomer at Harvard University, was the author of the article The Sun *in the November, 1948, issue of this magazine.*



STARS OF MAIN SEQUENCE have similar spectra, indicating that they are composed of elements in substantially the same proportion. The differences from top to bottom in these 10 spectra are due to decreasing temperature. Notice that strong dark line of hydrogen at left center fades away.

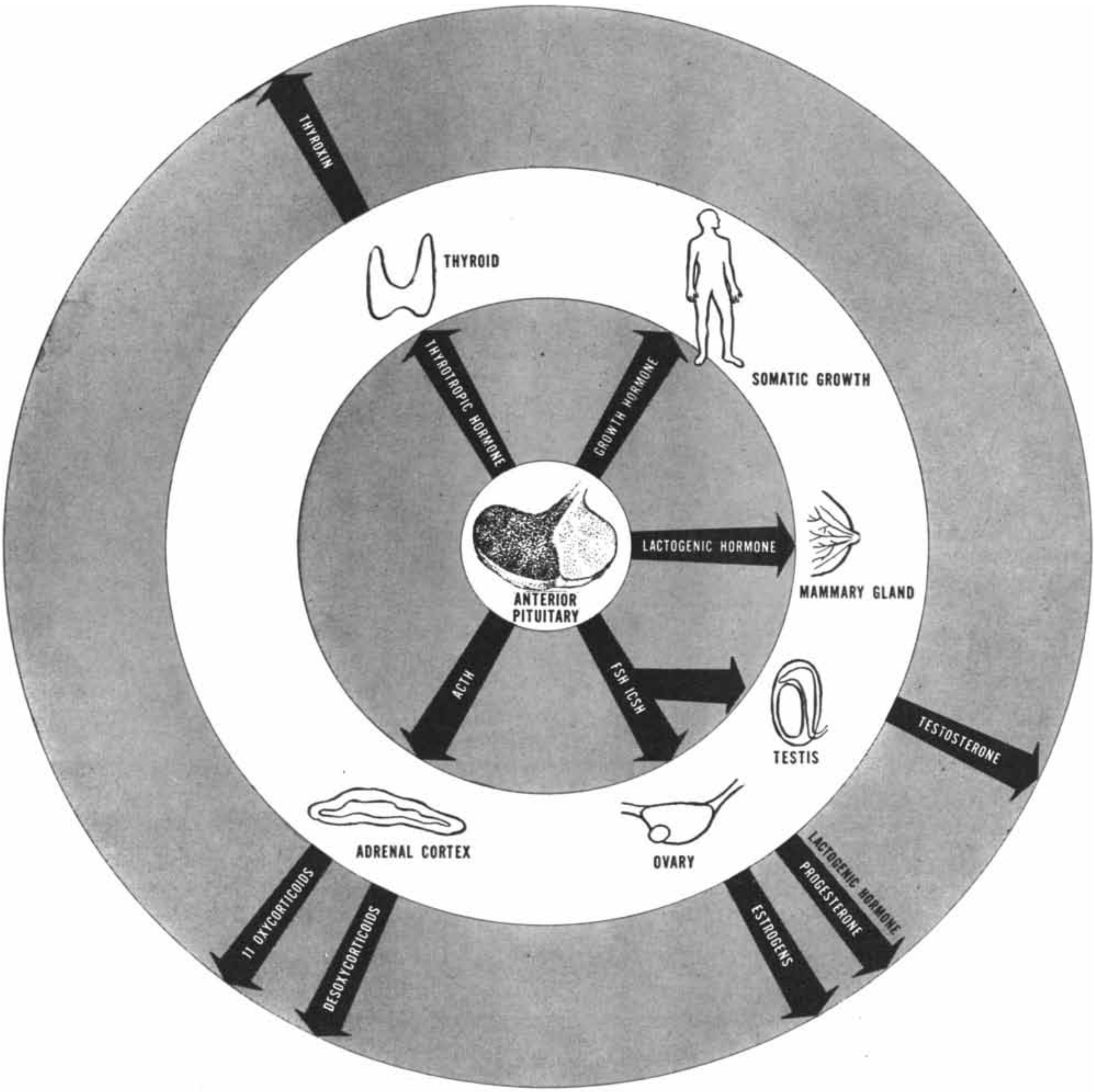


STARS OUTSIDE MAIN SEQUENCE have spectra indicating unusual proportions of elements. Second from the top is the spectrum of Theta Aurigae, which like the other three spectra has three prominent lines. Just to the right of the middle line, however, is a relatively strong line of the element silicon.

THE PITUITARY

Its anterior lobe, which manufactures the widely noted ACTH and other hormones, plays a major part in the orchestration of the endocrine system

by Choh Hao Li



THE ANTERIOR LOBE of the pituitary (*dark part of cross section in center of chart*) produces hormones that stimulate growth and the secretions of other glands. The glands in this chart are not drawn to the same scale.

THE very name of the pituitary is expressive of the misunderstanding that has shrouded its career. This master gland was discovered by Andreas Vesalius, the 16th-century founder of modern anatomy, in his dissections of the human body. He found it to be an ellipsoidal, pinkish-gray, primitively formed mucosal mass about the size of a cranberry. Lodged in the wedge-shaped sphenoid bone at the base of the skull, it is connected to the brain by a slender stem of tissue. Because of its position just above the nasal passages, Vesalius deduced that its function was to secrete phlegm into the nose, and he therefore named it the pituitary from the Latin word for phlegm.

Since Vesalius, many other functions have been attributed to the pituitary, now also known as the hypophysis from the Greek word for an undergrowth. Some early biologists toyed with the idea that it secreted cerebrospinal fluid; others thought it was the clearing house for transferring cerebrospinal fluid into the blood. At one point it was written off as having no function: its primitive structure—evolution has changed it so little that the general physiology of the pituitary in man is quite similar to that in reptiles—led some biologists to assume that it was merely vestigial.

The beginning of our modern understanding of the pituitary was made in 1886 by the great French neurologist Pierre Marie. Marie observed that people with acromegaly—enlargement of the face, hands and feet due to a resumption of growth after maturity—had always suffered destruction of the pituitary by tumor tissue. He erroneously inferred that the function of the pituitary was to inhibit growth, and that the resumption of growth was caused by the removal of this metabolic brake. Despite his error in interpretation, Marie's observation of a causal relationship between acromegaly and destruction of the pituitary served to put investigators on the right track.

They soon recognized that other metabolic disasters were associated with destruction or damage to the pituitary. Some of these diseases reflect hyperfunction (overactivity) and others hypofunction (underactivity) of the pituitary. True acromegaly occurs after the epiphyseal cartilages, which separate the bones in the growing child, have closed up upon maturity. At this stage any abnormal resumption of growth, having no outlet in the cartilage, takes place in the acra (extremities), including the hands, feet, chin, nose and the soft tissues such as lips and tongue. Another disorder caused by overactivity of the pituitary gland is pituitary gigantism. In this case—not the same as acromegaly—the whole body grows to giant size, with all the parts in normal proportion to one another. It results from a continuous growth of the individual, without the closing of the bone-joint structures, beyond the normal age of maturity. A third major expression of hyperfunction is Cushing's Disease, a generalized disturbance of the pituitary-adrenal system.

Underactivity of the pituitary is best exemplified by Simmonds' Disease, a disorder that sometimes follows damage to the pituitary by anemia during pregnancy and occurs four times as often in women as in men. This classical syndrome effectively reveals the boundaries of the endocrine dominion ruled by the pituitary. Simmonds' Disease is precipitated by total or near-total atrophy or destruction of the pituitary. The result is an endocrine disaster unmatched by any other disorder of internal secretions. Life gradually comes to a halt. There is a loss of body hair and teeth; genital atrophy; growing muscle weakness; lowering of the pulse rate, blood pressure, body temperature and basal metabolic rate. The victim becomes hypersensitive to heat or cold. The hungers of the body, including sexual desire and even the craving for food and drink, are lost. The individual has the appearance of accentuated senility. Toward the end the totally wasted patient appears to exist in a limbo, dedicated to death and indifferent to life.

Less ubiquitous but nonetheless disastrous are two other major diseases of hypofunction linked with pituitary destruction: pituitary dwarfism or infantilism, and Frölich's Syndrome, a eunuchoid-like condition.

THE discovery that these endocrine catastrophes were related to failure of the pituitary alerted biologists to the realization that the pituitary must be the source of substances of critical importance to the normal functioning of the human body. To find out precisely what the pituitary's responsibilities were, biologists began to investigate the effects of removal of the gland in experimental animals. Harvey Cushing, S. J. Crowe and J. Homans performed such operations on dogs in 1910. The chief difficulty, largely responsible for the long delay in learning what is now known about pituitary function, lay in the fact that surgical removal of the pituitary, called hypophysectomy, is an extraordinarily delicate operation. The operation itself was often fatal; it was not easy to keep an animal alive after it was deprived of its pituitary, and even when the animal survived the experimenter could not be sure that its symptoms were not caused by brain damage rather than by removal of the gland.

In 1916 Philip E. Smith, then at the University of California (he is now professor of anatomy at Columbia University), succeeded in removing the pituitary satisfactorily from tadpoles, and by 1926 he had developed a successful operation for the rat. Smith's classical experiments, and those of others, demonstrated that loss of the pituitary in growing or mature rats was followed by sweeping changes: cessation of general body and skeletal growth; a decrease in the size of the liver, spleen and kidneys; atrophy of the gonads, thyroid and adrenal cortex and cessation of estrus in the female; atrophy of the mammary glands and suppression of milk production; lowering of the metabolic rate and disturbance of the carbohydrate metabolism; loss of the ability to adapt. Young hypophysectomized rats remained sexually and otherwise immature, and in these animals life could be maintained only with difficulty.

But it was still not conclusively proved that these changes could be attributed only to the removal of the pituitary. To prove it beyond doubt, it was necessary to show that the animals' lost functions could be restored by providing a substitute for the excised organ. This proof was not long in coming. In 1930 Smith implanted pituitary tissue under the skin of hypophysectomized rats: the animals thereupon resumed their growth and recovered their other lost functions. Meanwhile other investigators began studies to determine the specific roles of the various parts of the pituitary—the anterior, intermediate and posterior lobes. They found that all of the major body functions described above were controlled by the secretions of the anterior lobe.

The emphasis of pituitary research now changed. Scientists focused on the problems of determining the nature and number of anterior pituitary secretions, isolating these substances, and defining the mechanism of pituitary influences. By this time it was clear that the substances responsible for the control exercised by the pituitary were hormones. What were the hormones of the anterior pituitary, and what was their relationship to the already familiar hormones of the adrenals, the thyroids and the sexual organs?

FOR a number of years Herbert M. Evans and Joseph A. Long of the University of California had been investigating the effects of cattle pituitary extracts on rats. In 1921 they had performed an historic experiment which demonstrated that injection of such an extract could cause normal adult female rats to resume growth. Rats given the extract for a long period grew to abnormal size. These investigators concluded that the pituitary might contain a growth-promoting factor. After Smith's successful experiments in reawakening growth in hypophysectomized animals by means of implants of pituitary tissue, Evans and Long found that they could also achieve this result by injecting their growth-promoting extract.

This work stimulated efforts to find other pituitary factors. Smith found evidence for four, two of them involved in the sexual cycle: 1) the follicle-stimulating hormone (FSH); 2) the interstitial cell-stimulating hormone (ICSH); 3) the adrenal-stimulating hormones (ACTH), and 4) the thyroid-stimulating hormone. P. Stricker and F. Grueter of the University of Paris proposed the existence of a lactogenic, or mammary gland-stimulating hormone. Thus a total of six hormones from the pituitary was postulated.

Until the hormones were isolated in pure form, it was impossible to state unequivocally the precise function of each, or to eliminate possible influences of impurities in extracts commonly used for experiment. Eventually, by methods developed in the laboratory of the writer and in other laboratories, five of the six hormones were isolated in pure form, and their chemical nature was studied. The thyroid-stimulating hormone, though not yet isolated in a pure form, is available in extracts for experimentation.

These pituitary hormones are identifiable as proteins with molecular weights ranging from 20,000 to 100,000; *i.e.*, the molecules are 20,000 to 100,000 times the weight of a hydrogen atom. Like all proteins, they are made up of amino acids, but some contain carbohydrates in addition.

A particularly intriguing finding is that the hormone counterparts in different species of animals, though apparently able to produce exactly the same biological effects, are not necessarily identical chemically. For example, the lactogenic hormone isolated from cows has a consistently higher content of the amino acid tyrosine than has the same hormone from sheep. There is a remarkable difference between the molecular weight of ICSH in sheep (40,000) and in swine (100,000), though the molecular weight of ACTH is identical for the two species. Despite these chemical differences, it is not yet possible to distinguish the biological effect of the hormone of one species from that of the other.

THE demonstration of the stimulating action of pituitary hormones added a radically new concept to the study of internal secretions. It became clear that with one exception the known hormones of the pituitary do not participate directly in physiological reactions. The pituitary acts like a generator or primer. Its secretions are called tropic hormones, meaning that they "turn," *i.e.*, change, something else. Each tropic hormone has a specific target organ. For example, the target of the adrenocorticotropic hormone ACTH is the adrenal glands; that of the thyrotropic hormone is the thyroid. The tropic hormone spurs the target organ to action. Awakened by the activating hormone, the target organ produces a second hormone which carries out specialized tasks. The one nontropic exception among the pituitary secretions is the growth hormone, which appears to participate directly in general growth processes.

Painstaking research has determined the functions of each pituitary hormone and shown how disturbances in its production cause disease. The interrelationships of the various hormones are, of course, subtle and complex. Yet the general responsibility of each can be described. The six hormones may be divided into two groups: 1) the gonadotropic hormones, which have to do with the sex cycle, and 2) the metabolic hormones, which tend the nutrition and regulate the chemistry of the body.

The gonadotropic hormones are FSH, ICSH and the lactogenic hormone. In collaboration with their target organs these hormones nurture the reproductive processes. In the female, FSH stimulates the development of immature ovarian follicles, in which ova begin their career. After the growing follicle has been brought to maturity through continued urging by FSH, ICSH instigates the mature follicle to form estrogens, the estrus-producing hormones, and gives the follicle impetus for further development as a corpus luteum. The growing corpus luteum is then brought to maturity by the lactogenic hormone, which at the same time stimulates the mammary gland. Upon maturing, the corpus luteum discharges an ovum and simultaneously produces the hormone progesterone, which has the function of conditioning the lining of the uterus for the reception and development of the fertilized egg.

The metabolic hormones are the thyrotropic, adrenocorticotropic and growth hormones. The thyrotropic hormone, of course, stimulates the thyroid gland to secrete and produce the thyroid hormone thyroxin. The metabolic well-being of the body pivots on the precarious chemical balance among these hormones.

THE rest of this article will describe mainly the effects of the growth hormone and ACTH. In rats the injection of the growth hormone produces remarkable results. For example, the pituitaries were removed from a group of young rats. Their growth stopped. Two weeks later the experimenters began to inject these dwarfs periodically with the growth hormone. After a year of this treatment, the rats had grown to about six times their original weight. Although they were giants in over-all appearance, their endocrine glands—the adrenals, the thyroid and the sex glands—were immature. On the other hand, all the bony structures of these infantile giants showed intensive development, and their soft tissues had a pattern of biochemical changes similar to those considered to be indicative of true growth.

For reasons which are not clear, it has not yet been possible to stimulate growth in human subjects, as it has been in rats, with injections of growth hormone. Yet it seems apparent that some day experimental conditions will be found for using this hormone to treat human dwarfism and to combat diseases characterized by wasting of the body's reserves of proteins and other organic compounds.

It is now known that the biological activity of the growth hormone can be modified by simultaneous injections of other hormones. For instance, daily injections of a small dose of thyroxin reinforce the effect of growth hormone in hypophysectomized rats. On the other hand, ACTH counteracts the growth hormone in such rats; it even inhibits growth in normal growing rats.

The mechanisms whereby these hormones influence the processes of growth are not known, but it seems clear that they must act by affecting the metabolism of proteins, since true growth is generally interpreted as the accumulation of proteins. Further research is certain to provide a detailed understanding of hormonal action which will give insight into the processes of both normal and abnormal growth.

The growth hormone and ACTH also play a part in the metabolism of fats and carbohydrates. Injections of high dosages of ACTH into normal rats produce an excess of sugar in the blood and urine—the familiar symptoms of diabetes. It has repeatedly been demonstrated that ACTH produces diabetic symptoms in man also. The English biochemist Frank G. Young, the Argentine physiologist Bernardo A. Houssay and others have recently shown that injections of the growth hormone can make normal cats and dogs diabetic. There is no evidence that this hormone has such an effect on normal rats, but this species difference is not surprising in the field of endocrinology. It is possible that genetic factors are involved in the action of these hormones. As for their effects on fat metabolism, it has been established that the two hormones, or indeed any pituitary hormone possessing metabolic activity, can produce an excess of ketones or an increase of liver fat in the body.

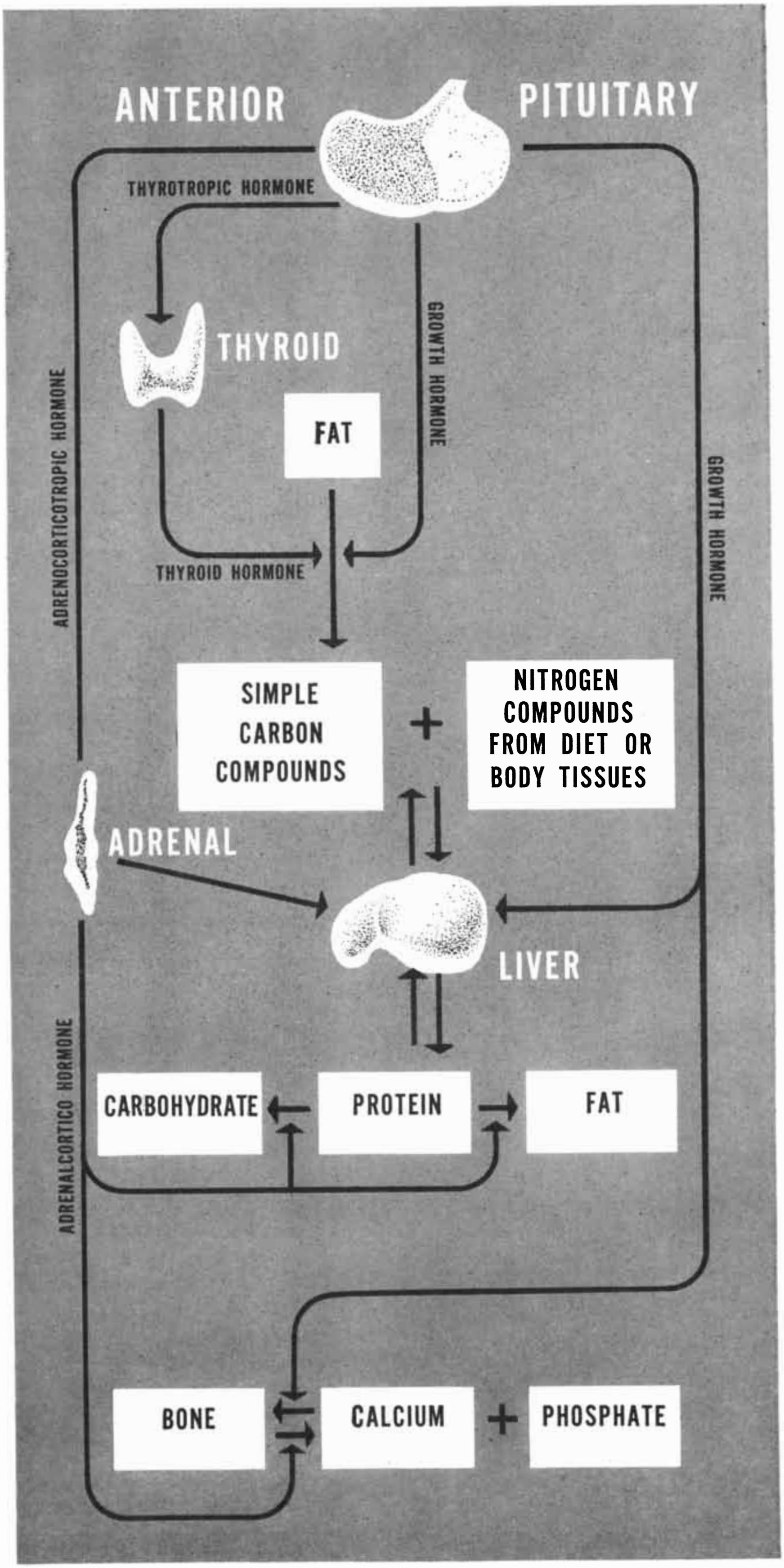
THE clinical implications of the results obtained from animal experiments with ACTH and growth hormone are great. Hormone therapy is, of course, an old story—insulin, thyroxin, androgens, estrogens and other hormones have been in wide clinical use for some time. But until a little over a year ago almost no therapeutic use had been made of the hormones from the master gland—the pituitary. The delay in such application can be attributed primarily to two factors. First, the pituitary hormones can be obtained only in minute quantities: the pituitaries of nearly half a million hogs are required for the production of one pound of ACTH. Second, the pituitary hormones have been isolated only recently, so recently that thorough animal experimentation has not been completed.

Yet a great deal of work has already gone into the development of the foundations for clinical use of ACTH, beginning with the success of P. S. Hench, E. C. Kendall and their associates at the Mayo Clinic in the treatment of arthritis with ACTH and cortisone and continuing with the investigation of their use for a multitude of other ailments, including some types of mental illness and rheumatic fever.

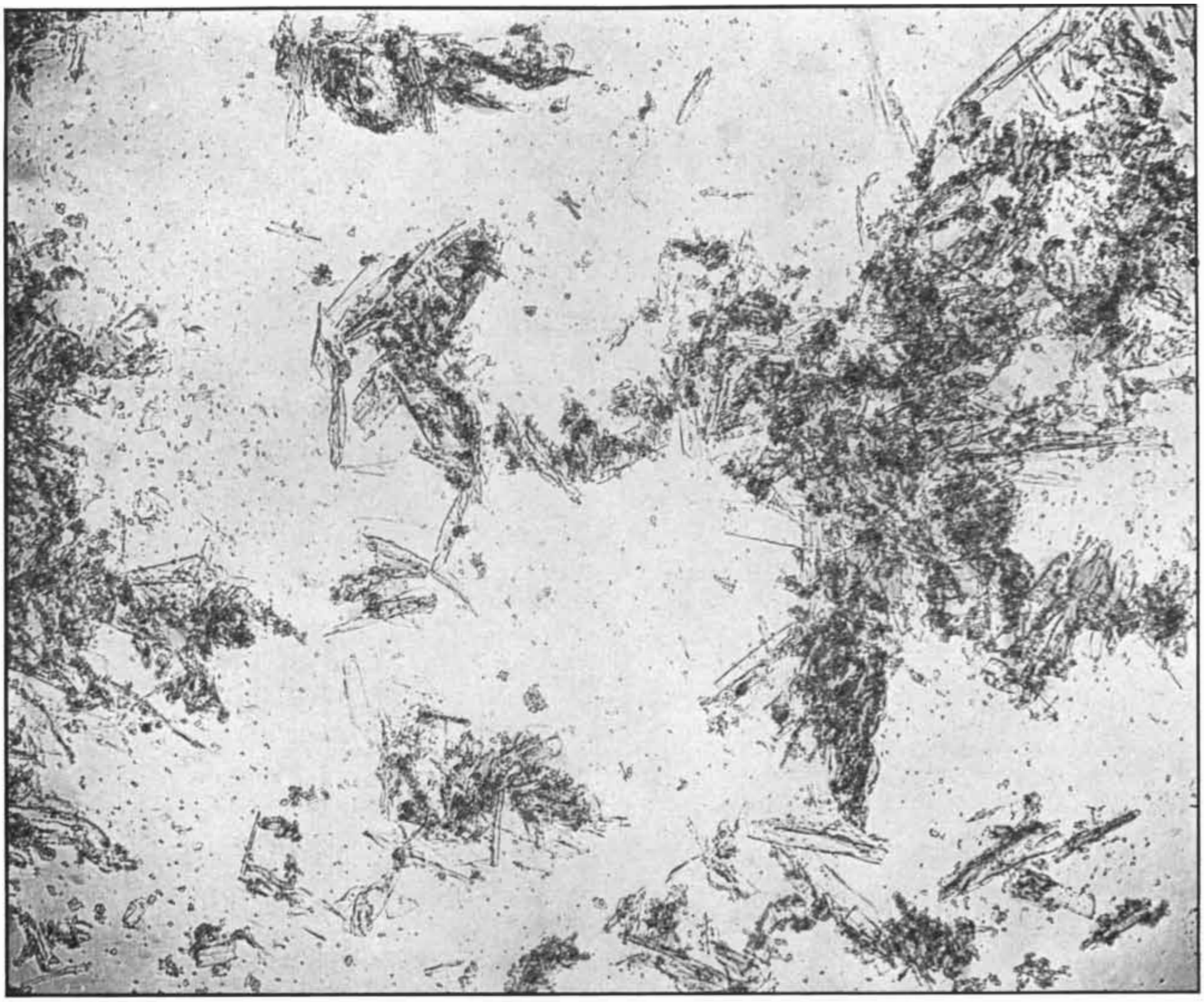
There is a good reason for pressing the expansion of sources of the pituitary hormones and for pursuing their use in clinical practice. This reason is that treatment with some of the secondary hormones is attended by certain dangers. Animal experiments indicate that administration of target-organ hormones often brings about an adverse reaction in the pituitary. For example, after rats are given large doses of estrogen, the pituitary increases in size, and there is evidence that the enlarged gland manufactures more lactogenic hormone. In other experiments, estrogen has produced pituitary tumors. Large injections of cortisone may cause the pituitary to produce less ACTH. In other words, there is some indication that an excess of the target hormone in the system causes a shift in the dynamic state of the producing pituitary cells. It is as though the pituitary must be active; if it is relieved of its normal duties, it begins to free-lance. The use of the primary hormones such as ACTH would tend to keep the system in better balance.

Up to now the method that has offered the most promise for increasing the supply of pituitary hormones is the development of more efficient techniques for extraction of the hormones from animal organs. But we must not overlook the possibility that these hormones may be synthesized in the laboratory.

RECENT experiments of the writer indicate that the biological activity of ACTH, and of FSH, resides in peptide fragments of these protein molecules. ACTH protein as isolated from pituitary glands has a molecular weight of 20,000. It exhibits some features of behavior that are unusual in a protein. For instance, treatment with acids and heat does not reduce its biological activity; in fact, acid-heat treatment actually can greatly enhance the hormone's adrenal-stimulating activity. It was soon discovered that peptide fragments obtained by splitting (hydrolyzing) the protein hormone retain the biological potency of the hormone itself; the peptide mixture proved



THE METABOLIC HORMONES of the anterior pituitary are distinguished from its gonadotropic hormones. The growth hormone enters directly into the metabolic process; two others stimulate thyroid and adrenal cortex.



THE GROWTH HORMONE of the anterior pituitary forms thin plates upon crystallization. These crystals were prepared in 1948 by Choh Hao Li, Herbert M. Evans and Miriam E. Simpson of the University of California. Five of six anterior pituitary hormones have been isolated. The thyrotropic hormone is available in extracts.

highly active in the treatment of rheumatoid arthritis patients.

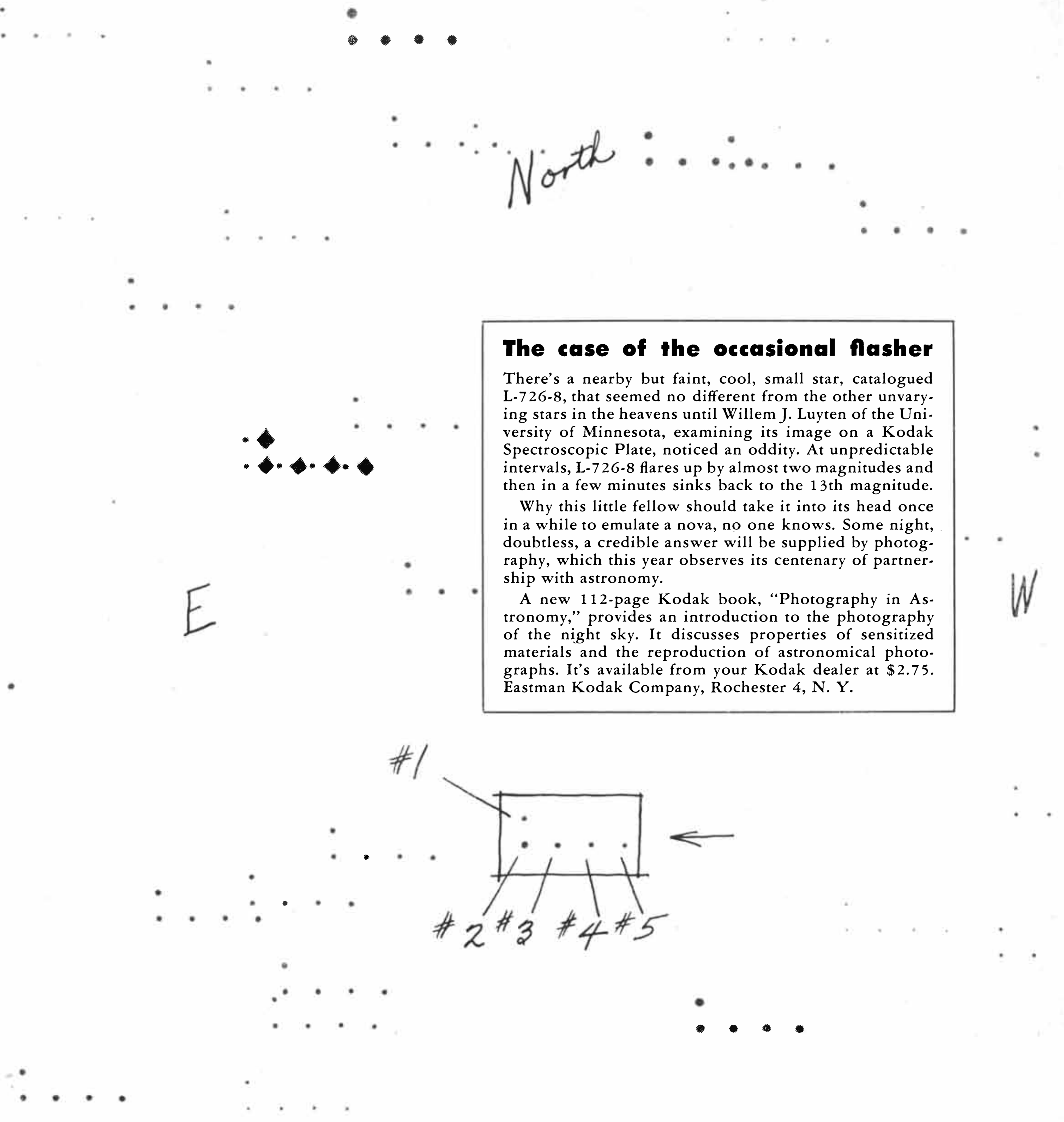
Now these active peptide mixtures contain an average of only eight amino acids and have an average molecular weight of 1,200. The hope for the synthesis of a protein having a molecular weight of 20,000 is nil, but the synthesis of a peptide from eight amino acids is possible. A number of laboratories in this country and abroad are now actively engaged in the search for methods for the isolation of the ACTH peptide and its final synthesis. It is not too much to hope that a synthetic process may be found for the manufacture of this and related pituitary hormones.

ACTH is the first biologically active protein that has been found to retain its physiological potency after partial hydrolysis. This observation not only raises the possibility of synthesizing this hormone but also suggests a search for similar behavior in other active proteins. Once a peptide possessing ACTH activity is synthesized, a broader investigation of the relationship between molecular structure and biological properties will be instituted.

FINALLY, we should not overlook the possibility that the anterior pituitary produces one or more hormones besides the six already known. As a matter of fact, there are some indications that the pituitaries of animals which have been receiving growth hormone for a long period secrete a "cancer-producing hormone." Normal rats, after treatment with growth-hormone injections for seven or eight months, often develop tumors, whereas hypophysectomized animals subjected to the same treatment never do. This suggests that the pituitary may participate in the production of tumor tissues. It is possible that the excessive stimulation of growth by the injections of growth hormone produces dynamic changes in the pituitary, causing it to secrete a cancer-producing substance.

The dynamic nature of the pituitary's functions has been demonstrated clearly by the recent experiments of Hans Selye of the University of Montreal, Cyril N. H. Long of Yale University and others. These investigators believe that the secretion and manufacture of anterior pituitary hormones can easily be modified by any type of stimuli. For example, various forms of stress will cause an increase of ACTH output from the pituitary, and thus enhance the activity of the adrenal cortex. Still to be investigated are the reasons for the increase in ACTH production under these conditions; it is clear, however, that the anterior lobe of the pituitary gland is marvelously able to adjust its functions according to the internal and external requirements of the body.

Choh Hao Li is professor of biochemistry at the University of California.



The case of the occasional flasher

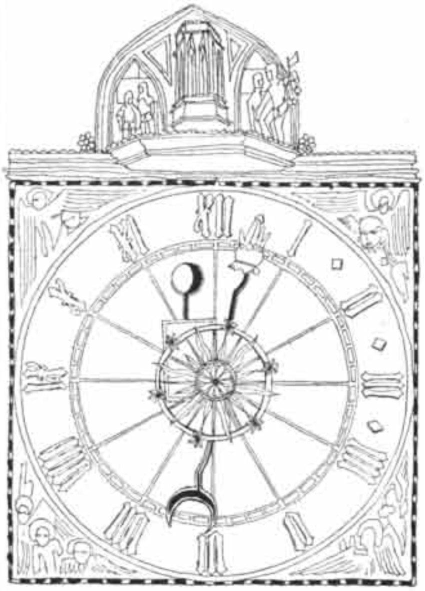
There's a nearby but faint, cool, small star, catalogued L-726-8, that seemed no different from the other unvarying stars in the heavens until Willem J. Luyten of the University of Minnesota, examining its image on a Kodak Spectroscopic Plate, noticed an oddity. At unpredictable intervals, L-726-8 flares up by almost two magnitudes and then in a few minutes sinks back to the 13th magnitude.

Why this little fellow should take it into its head once in a while to emulate a nova, no one knows. Some night, doubtless, a credible answer will be supplied by photography, which this year observes its centenary of partnership with astronomy.

A new 112-page Kodak book, "Photography in Astronomy," provides an introduction to the photography of the night sky. It discusses properties of sensitized materials and the reproduction of astronomical photographs. It's available from your Kodak dealer at $2.75. Eastman Kodak Company, Rochester 4, N. Y.

Multiple exposure by E. F. Carpenter on a Kodak Spectroscopic Plate, Type 103a-0. Five images of L-726-8 are marked. The very bright one is #2. Twenty minutes elapsed between the first and last; each exposure was two minutes.

Kodak
TRADE-MARK



SCIENCE AND

The Changing AEC

FOR the first time since the resignation of former Chairman David E. Lilienthal last February the U. S. Atomic Energy Commission is at full strength. The last vacancy on the Commission was filled by the appointment of T. Keith Glennan, president of the Case Institute of Technology. The Commission is now composed of Chairman Gordon E. Dean, Sumner T. Pike, Henry DeWolf Smyth, Thomas E. Murray and Glennan. Of the original Commission appointed in 1946 only Pike survives.

The new Commissioner is an electrical engineer who began his career with Electric Research Products, Inc., a subsidiary of the Western Electric Company, which introduced sound motion pictures. From 1935 to 1942 he served in Hollywood with Paramount Pictures, Inc., and Samuel Goldwyn Studios. During the war he was director of the U. S. Navy Underwater Sound Laboratory at New London, Conn., and from 1945 until he assumed the presidency of Case in 1947 he was an executive of the General Aniline and Film Company. He is 45 years old.

Even as the Commission attained a measure of stability, the most important office in its domain was in a state of change. Shortly after the appointment of Dean as chairman, Carroll L. Wilson, general manager of the Commission since 1947, resigned with the statement: "I regret I do not have the degree of confidence in the chairman of the Commission which I believe it is essential that I should have in order to serve him and the Commission effectively in administering the program." Wilson added that he believed the Commission under Dean had been invading the province of the general manager. Two weeks after his resignation and replacement by Carleton Shugg the Joint Congressional Committee on Atomic Energy approved a bill, requested by Dean, that would substantially change the general manager's role. The office of general manager is filled by Presidential appointment. If the new bill is passed, it will empower the Commission itself to hire or fire the general manager.

War Casualty

WHEN the National Science Foundation became law last May, the scientists who had worked toward its passage thought the dreary legislative campaign that had lasted five years was over and the chicken was finally hatched. But they had not reckoned with the House Appropriations Committee. Late in August the Committee rejected President Truman's request for $475,000 to start the work of the Foundation. The Committee members took the position that the organization of the Foundation must be postponed because it would not "provide early aid to our defense effort."

The scientists patiently went to work again. The Inter-Society Committee for a National Science Foundation was reactivated under the leadership of Howard A. Meyerhoff, administrative secretary of the American Association for the Advancement of Science.

The only hope of action at this session of Congress was that the Senate Appropriations Committee would restore the cut. The President asked for such action. Presidential assistant John R. Steelman wrote the Senate Committee: "The President has been preparing to nominate in the very near future 24 outstanding citizens drawn from the fields of science, engineering, agriculture, industry and public affairs to the National Science Board which is the policy-forming group provided for in the legislation to guide the Foundation. To fail to activate this very important agency, at this critical juncture as we speed the strengthening of other segments of our defenses, would be to pass over a unique opportunity to strengthen our scientific research efforts, which as you well know are of vital importance to the preservation of our security."

The Uranium Rush

THE U. S. obtains the bulk of its uranium from the Belgian Congo; its second most important source has been Canada. Recently the mining of uranium in the U. S. has increased to the point where the domestic output surpasses Canadian imports.

Up to now uranium mining in the U. S. has been largely limited to the Colorado Plateau, in an area of 30,000 square miles in Colorado, Utah, Arizona and New Mexico. At a recent meeting of the American Mining Congress in Salt Lake City, Jesse C. Johnson, raw-material operations manager of the Atomic Energy Commission, said that promising new deposits had also been discovered in Nevada, Wyoming, Idaho, Montana and Michigan. Some of the new finds in Michigan and Utah appear to be the first U. S. commercial discoveries of pitchblende, which may yield 10 per cent or more of uranium.

Color Television

LAST month the Federal Communications Commission took a step toward ending the long technical debate as to how color television will come to the radio spectrum. In a 184-page report the Commission indicated that among the systems so far submitted, it favored the mechanical color system of the Columbia Broadcasting System. The FCC ruled that the electronic systems of the Radio Corporation of America and Color Television, Inc. "fall short of Commission criteria." The Commission did not, however, take a final decision on the adoption of color-television standards. It postponed its decision to permit further work on development of a means to coordinate the CBS color system with the present black-and-white system, and allowed manufacturers until December 5 to submit other color methods.

The CBS color system is not compatible with present television receivers, since it produces a 405-line picture instead of the current 525 lines. But the Commission favored it because the picture is of higher quality than in the other color systems.

The Commission addressed a pointed query to the manufacturers of television receivers: Would they produce new sets that could receive the present black-and-white telecasts and also reproduce a black-and-white picture from the color broadcasts of the CBS system? (The latter could be converted to color by the addition of a color wheel to the set.) If so, the Commission might hold off its decision for some time to allow the further development of color systems. If not, the Commission would probably force the issue by deciding in favor of the CBS system immediately.

Birth of a Reactor

AT 2:30 a.m. on August 22 physicist Lyle B. Borst, standing in the control room of the new nuclear reactor at Brookhaven National Laboratory on

Long Island, raised and lowered his hands. It was the signal to remove the control rods from the reactor for the first time. Borst and nine other men tensely watched the recording instruments of the reactor. At 2:45 he turned to Robert Turner, head of the operating crew, and said: "I think you have a pile." A self-sustaining chain reaction was under way.

Although it is much smaller than the giant reactors that produce plutonium at Hanford, Wash., the Brookhaven reactor is the largest in the U. S. for research purposes. It is the sixth U. S. research reactor and the 10th in the world (not including possible research reactors in the U.S.S.R.). It had been three years and 11 days in the making, and the cost of the installation was $25 million.

The Brookhaven reactor is an air-cooled, graphite-uranium type. Its basic structure is a great cube built up of 60,000 graphite bricks machined in 2,600 sizes and shapes. The cube is surrounded by a massive concrete shield 38 feet from outside wall to outside wall. It is interlaced with channels for the aluminum-canned uranium fuel, the boron control rods, the cooling air and experimental substances. In regular operation the reactor will develop 30,000 kilowatts.

Dianetics

DURING the past four months many psychologists have been startled by the success of a new book entitled *Dianetics*, by L. Ron Hubbard. In the preface to the book, which bears the subtitles "The Modern Science of Mental Health" and "A Handbook of Dianetic Therapy," the author states that dianetics "will invariably cure all psychosomatic ills and human aberrations." One notable feature of his system is that readers of the book may themselves practice as dianeticians.

At the September meeting of the American Psychological Association in State College, Pa., organized psychology made its first anti-dianetic statement. The Association unanimously adopted the following resolution: "While suspending judgment concerning the eventual validity of the claims made by the author of *Dianetics*, the Association calls attention to the fact that these claims are not supported by empirical evidence of the sort required for the establishment of scientific generalizations. In the public interest, the Association, in the absence of such evidence, recommends to its members that the techniques peculiar to dianetics be limited to scientific investigations designed to test the validity of its claims."

Standards for an Atomic Age

THERE are three primary references for all physical measurements: the standard meter bar, the standard kilo-

"It took radiography to find the leak..."

SO writes the inspection manager of one of the nation's leading manufacturers of valves and fittings. "We had a problem of porous valve seat ring castings showing up at the final test of valves," the inspection manager continued. "With the aid of our x-ray apparatus, defective castings were found to be porous and gassy, causing the leaks through the ring.

"After a thorough research, it was found the foundry technique required some changes, resulting in sound castings as shown on right of radiograph. A saving was effected in eliminating the machining, assembling and disassembling of unsound rings."

This company's experience is typical of scores of others who have found that radiography has become a *development* tool. It not only diagnoses, but suggests treatment. It shows where savings can be made, designs improved, new techniques developed.

Is there a place for industrial x-ray in your business? A General Electric X-Ray engineer will be glad to talk it over. Or write for "Industrial Applications of the X-Ray" — General Electric X-Ray Corp., Dept. TT-10, Milwaukee 14, Wisconsin.

Find out how you can get x-ray inspection equipment under the GE Maxiservice Plan. No cash outlay. Monthly service charge covers everything. Write for folder.

GENERAL ELECTRIC
X-RAY CORPORATION

gram (both preserved in the International Bureau of Weights and Measures at Sèvres, France) and the mean solar day. In recent years the shortcomings of these standards have become increasingly apparent. The standards of length and weight cannot be reproduced independently, and there are limits to the accuracy of their reproduction. The standard of time varies with irregularities in the rotation of the earth.

Already the meter bar has been informally replaced as a standard of length by a wavelength of light emitted by the rare isotope mercury 198. Now R. D. Huntoon and U. Fano of the National Bureau of Standards, writing in *Nature*, suggest that all standards can be based on the properties of atoms. The three primary standards would be in terms of (1) the mercury-198 wavelength as the standard of length, (2) a frequency absorbed by the ammonia molecule as the basis for the standard of time, and (3) the ratio of the spin of the proton to its magnetic moment, which can be used as a basis for units of mass and units of energy. Of the three, say Huntoon and Fano, only the mercury-198 standard is now sufficiently accurate, but the accuracy of the other two standards can doubtless be improved.

Homing Lobsters

CERTAIN kinds of lobster appear to possess a well-developed homing instinct, like pigeons. This unexpected talent of the edible crustacean was recently discovered by two U. S. biologists in Bermuda.

In a letter to *Science* Edwin P. Creaser of Hofstra College and Dorothy Travis of Harvard University described their experiments in the waters about Nonsuch Island, near the mouth of Bermuda's Castle Harbor. From an area a quarter-mile square they had taken a number of spiny lobsters, a genus which lacks the large pincers usually associated with lobsters. They had then labeled the lobsters with plastic tags or punches in their tails and released groups of them at various places outside the area. Some of the lobsters were taken as far as two miles out to sea and released in 1,500 feet of water.

In about a month after their release 20 per cent of the lobsters, including representatives from every group, were recaptured in the area where they had first been caught. Some of them had made their way five miles around points of land and against shifting tides. Some of those which had been taken out to sea were recaptured only five days later. How the lobsters had accomplished these migrations, said the biologists, "remains an unanswered and puzzling biological mystery." There was no doubt, however, that learning the ways of lobsters would assist in catching and conserving them.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Because Revere salesmen and Technical Advisors call upon companies in practically every industry, they acquire a rather amazing fund of knowledge about many widely different products and processes. When no trade secrets are involved, knowledge thus acquired from one company often can be transmitted to another, with mutual benefit. Take the problem Revere found in the condensers of an East Coast electric utility. Cooling water comes from the harbor, with the result that the tubes quickly become coated with algae and other marine organisms, reducing the vacuum and hence increasing fuel consumption.

The utility is exceptionally well managed, and has a systematic program of tube cleaning. However, it was found difficult to clean the tubes effectively. Brushes and rubber plugs, pushed through the tubes, wore out rapidly, so that the operation was inefficient and costly. Though the condenser tubes were not made by Revere, we took an interest in this. A Revere customer makes special nylon-bristled brushes just for cleaning tube and pipe in dairies. The Technical Advisor suggested trying a slight modification of these. Results: over 300 tubes well cleaned per brush, a much longer life than anything previously used and a half-inch gain in vacuum, meaning dollars and cents saved in fuel.

There was another problem here, arising from the fact that the brushes are propelled through the tubes by an air-water pressure gun, operating at about 75 pounds per square inch. See illustration. Under that pressure a brush comes out of the far end of the tube like a projectile from a gun. It has to be stopped by something strong enough to take the shock, but not hard enough to damage the brush. Canvas and plywood were tried, without satisfactory results as either target or brush was injured, or both. Revere suggested making a target of foam rubber, and not only that, found a source of supply of rubber of the right consistency. This combination works perfectly, and is in part responsible for the record of 300 tubes cleaned per brush.

The average person would not think that an electric generating station would find good uses for nylon brushes, foam rubber, and plywood, but Revere through its contacts with many industries, was able to combine these three items into a practical solution to a particular problem. The electric company states that when next it buys condenser tubes, Revere will get the order. That, however, is not the point of this advertisement. The significant thing is that here we have an example of a supplier, Revere, recommending products other than its own, and acting as an advisor without fee. In the course of our daily contacts we often note other suppliers of materials to industry doing much the same thing, so we claim no special virtue.

The purpose of this advertisement is to use an example to point up our recommendation that no matter what you buy, no matter what you make, you take your suppliers into your confidence. You can benefit not only from their knowledge of their industry and its products, but also acquire non-confidential information about other industries and products. Facts thus obtained may be of considerable value to you, yet cost nothing to obtain. All you have to do is ask.

REVERE COPPER AND BRASS INCORPORATED

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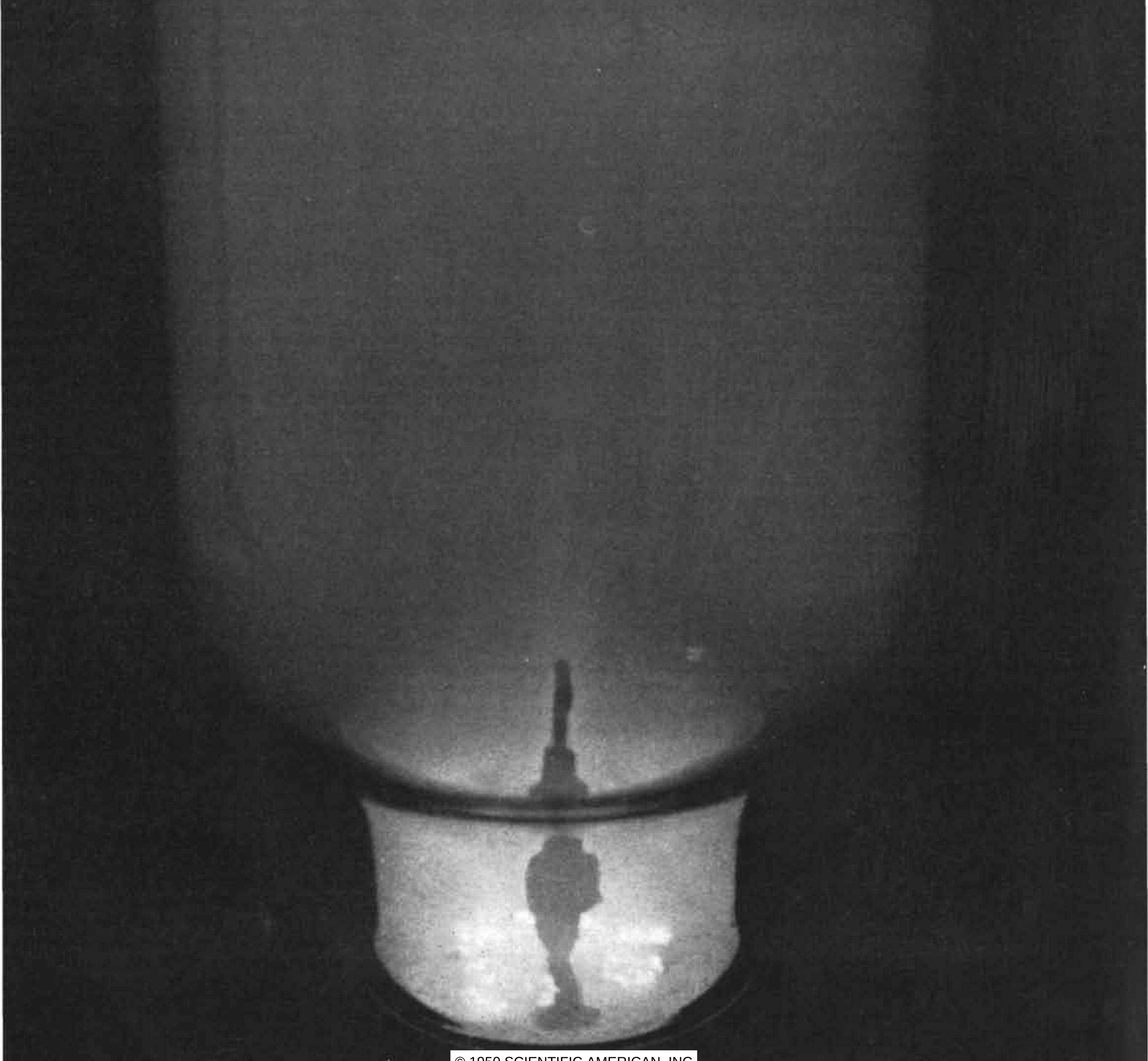
Executive Offices:

230 Park Avenue, New York 17, N. Y.

ELECTRONICS

A general account of the means by which the smallest fundamental particles are manipulated to accomplish many subtle tasks of our technological civilization

by J. R. Pierce



MODERN technology is made possible by some understanding of basic scientific laws or principles. Sometimes this understanding has come in the train of practical application; for instance, thermodynamics was strongly inspired by the empirical invention of the steam engine. In later times this order has come to be reversed. The most recent important contribution of physics to technology, the atomic bomb, is the outgrowth of long years of patient unraveling of nuclear physics; it would never have been made through mere garret inventing.

The development of electronics has combined both of these prods to progress; its scientific foundations and its applications have been closely intertwined, and each has inspired the other. To explain the electron tube as the outgrowth of years of science for its own sake would be to underestimate the importance of such a contribution of genius as Lee de Forest's invention of the audion, on which all our television, radio and long-distance telephony depend. On the other hand, much of our present detailed understanding of applied electronics has grown out of more basic studies, some aspects of which were available long before de Forest hit upon his invaluable invention without, perhaps, fully understanding its operation.

Electronics deals with the behavior of minute particles of electricity called electrons. The name actually came before the thing, for in 1858 William C. Richards wrote an epic poem in which he ascribed the wonders of electric telegraphy to a sprite he named *Electron.* It was not until 1891 that the British physicist G. Johnstone Stoney used the word electron in its modern sense to describe a fundamental particle of electricity, and not until 1897 that his fellow countryman Joseph John Thomson demonstrated the electron's existence.

The idea that electricity consists of little units goes back to that versatile British experimenter and theorizer Michael Faraday. But Faraday was concerned with the flow of electricity in liquids or solids, and electronics could not be born until men began to study electricity moving freely in space, that is, the motion of electrons in a vacuum. It was through the study of electrical discharges in crudely evacuated glass tubes that the effects of the electron were first detected and studied.

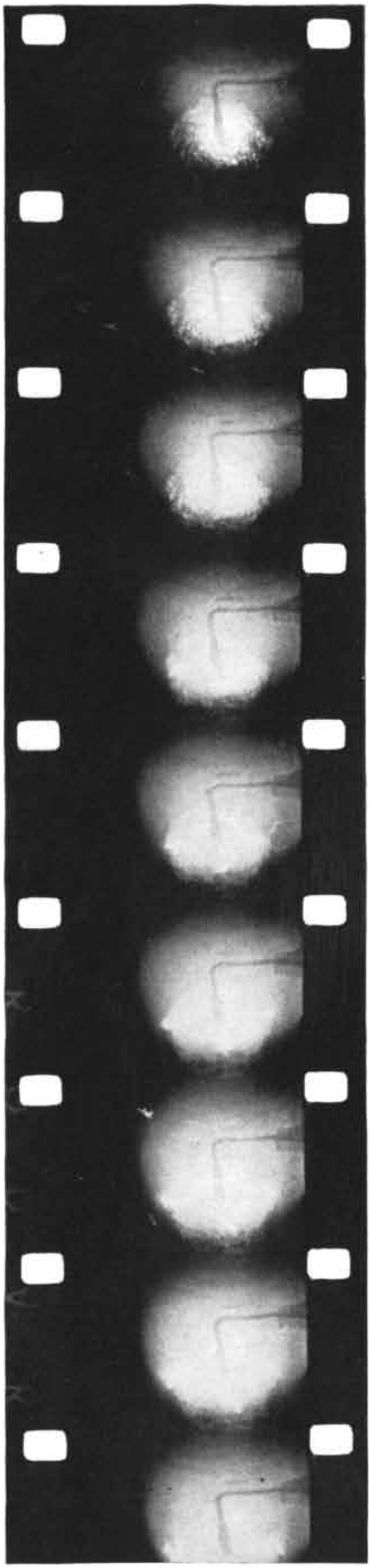
Geissler's Tube

We may well start with Heinrich Geissler (1814-1879), an itinerant German glass blower turned physicist who settled at the University of Bonn, where he was eventually awarded an honorary doctorate. Geissler was interested in vacuum pumps as well as in glassblowing, and he made some improved pumps for extracting the air from his long, oddly shaped glass tubes. He discovered that when a high voltage was applied between two electrodes he had sealed in the ends of a tube, the rarefied gas in the tube glowed brightly.

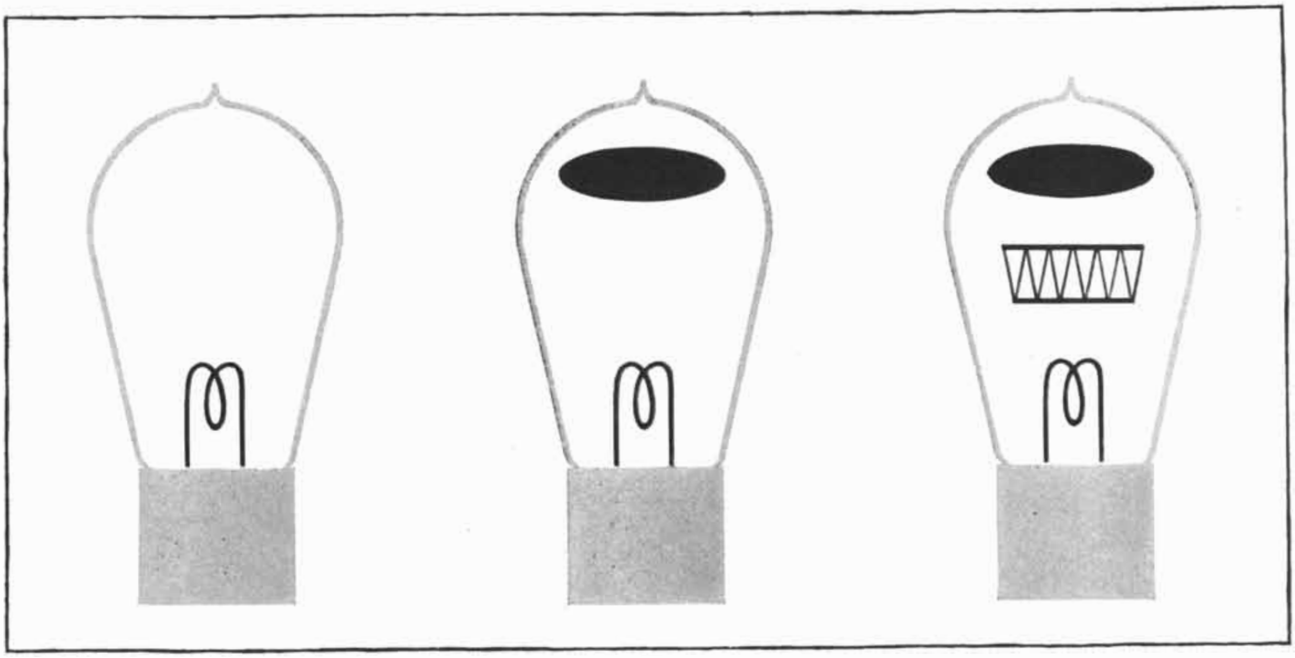
Geissler's tube was the ancestor of our neon signs. But Geissler did not understand the reason for the gas discharge in his tubes. Others began to explore this mystery, and among them was the indefatigable and ingenious experimenter Sir William Crookes. Starting about 1878, Sir William made several experiments with glass tubes similar to Geissler's but shorter and stubbier. As he pumped the air from his tubes, Crookes saw the same glow Geissler had observed. He noticed, however, that as the pumps worked longer and a higher vacuum was obtained, the glow became fainter and finally almost vanished. But now the glass wall of the tube opposite the negative electrode shone softly. Crookes realized that something—gas, particles, rays or whatever—was striking the glass.

To investigate this he put little metal obstacles in his tube. They cast a sharp shadow on the wall opposite the negative electrode. Crookes now knew that the something he was dealing with traveled in straight lines. He then placed a little metal paddle wheel in the path of this stream of something. The paddle wheel turned when the beam struck it. Crookes decided that the mysterious agent whose impact turned the paddle wheel must be a stream of tiny particles. He called this luminous, tenuous stream of particles a "fourth state of matter"—neither solid, liquid nor gas but something finer than any of them.

The curious thing is that he was right about the existence of a stream of par-



IGNITRON is a modern electronic tube in which the electrons flow from hot spots on a pool of mercury through a gas to a positively-charged electrode. In the photograph on the opposite page the mercury pool and its igniter electrode are at the bottom. The positive electrode is out of the picture at the top. This photograph and the strip at the right, which was made at 2,000 frames per second, were undertaken by H. W. Lord of the General Electric Company to analyze the behavior of the hot spots. Studies of pictures of this kind indicate that under certain conditions the spots attain a velocity of 40 feet per second. They also indicate that as the current flowing through the tube increases, the spots divide at currents averaging 15 amperes per spot. As the current decreases, spots die at currents averaging five amperes.



THREE BASIC ELEMENTS of electronic tubes are cathode, anode and grid. The cathode is a negatively-charged electrode which emits electrons. The anode is a positively-charged electrode which attracts electrons. The grid controls the flow of electrons from cathode to anode. Tube at left contains a simple cathode. Tube in center, containing cathode and anode, is a diode. Tube at right, containing cathode, anode and grid, is a triode.

ticles but incorrect in deducing them from the turning of the wheel. Twenty years later Thomson showed that whatever caused the paddle wheel to turn, it was surely not the impact of charged particles!

Crookes caused the stream of particles in his tubes to strike various substances and found that some of them glowed much more brightly than glass. (In modern television tubes the substances that glow so brightly when a stream of electrons strikes them are phosphors.) Crookes also found that a magnet could bend and twist the stream of particles, but apparently he did not understand what he saw.

In 1895 Jean Perrin, a French investigator, correctly deduced what the deflection of Crookes' stream of particles by a magnetic field meant. Uncharged particles, such as molecules of gas, would not be deflected, but charged particles in motion in a magnetic field would. Most important, the direction of deflection would depend on whether the charge was positive or negative and on the direction of motion with relation to the magnetic field. Perrin knew the direction of motion and the orientation of the magnetic field; from this he was able to determine that the particles' charge was negative. Crookes' "fourth state of matter" had been identified as a moving cloud of negatively-charged particles.

Were all the particles in the cloud of the same type? In 1897 Thomson began to investigate their nature. He cut the cloud of charged particles down to a well-defined beam by passing them through two lined-up apertures, and to this stream he applied both an electric and a magnetic field.

Now the two kinds of field act on a charged particle in different ways. An electric field, created by a voltage between two sheets of metal, urges a negative particle toward the positive electrode whether the particle is moving or not. The electric force involved in the particle's attraction toward the electrode is proportional to the charge on the particle times the strength of the electric field. A magnetic field, on the other hand, exerts a force on a charged particle only if the particle moves across the magnetic lines of force. Hence the speed of the particle now enters the calculation; the force deflecting it is proportional to the speed of the particle times the charge on the particle times the strength of the magnetic field. When either a magnetic or an electric field bends the path of a particle, the amount of bending varies inversely as the mass of the particle.

Thomson applied these facts to measure the physical properties of the particles. He first measured the deflection caused by a magnetic field of known strength. Since he knew the strength of the field, he was able to calculate the relation between the particle speed and the ratio of the charge of the particles to their mass. He then balanced the deflecting effect of the magnetic field by an electric field. This additional information told him the velocity of the particles. He could then calculate the ratio of charge to mass for the particles; that is, how much electricity they carried per pound. He found that this ratio of charge to mass was the same for all the particles, and that the particles were remarkably light. They were much electricity and little matter.

Although Thomson's experiment showed that these new particles, now called electrons, were very much alike, it was not yet demonstrated that they were all the same. To do this, it was necessary to measure the charge carried by the particles, and this was done in a number of ways. The most decisive was a series of experiments begun in 1909 by Robert A. Millikan, then at the University of Chicago. He caught electrons by ones, twos and threes on tiny drops of oil and measured the forces exerted on them by an electric field. Millikan's experiments showed conclusively that all electrons have exactly the same charge. Clearly all electrons must also have the same mass, for Thomson had shown that all electrons have the same ratio of charge to mass.

The experiments in bending the path of electrons suggested an interesting question. If magnetic and electric fields could deflect streams of electrons, was it possible that such fields might also focus an electron stream, as lenses focus a beam of light? By 1926 the German physicist H. Busch had proved that this was indeed the case. He showed that all symmetrical electric and magnetic fields act on streams of electrons much as lenses act on rays of light, and electron optics was born. From it has come such a great tool as the electron microscope.

But we are concerned here principally with the electron tube. The first question we must consider is the source of electrons. There are several ways in which an electron can be released from matter. In a gas-discharge tube the process by which electrons are knocked out of the negative electrode is very complicated and roundabout. The free, moving electrons in the tube run into molecules or atoms of gas. When the collision is sufficiently violent, an electron may be knocked out of the molecule, which is thereby left with a net positive charge. This positive ion is attracted toward the negative electrode of the tube. On finally striking that electrode, it can knock one or more electrons out of the metal.

Electrons can be knocked out of a metal or other substance by electrons as well as by positive ions. This is called secondary emission, the "secondary" electrons being the electrons knocked out, as distinguished from the primary electrons which do the knocking. One primary electron may produce several secondary electrons. This process is of great technological importance. Equally important is the release of electrons by radiation such as light or X-rays, a phenomenon called photoelectric emission and employed in the photoelectric cell.

But the form of electron release that has perhaps the greatest technological importance is thermionic emission, which means the escape of electrons from hot metal. This effect was observed, but not understood, as early as 1884 by Thomas Edison. He noticed in an early electric lamp that a flow of electricity occurred between the hot luminous filament and a cold electrode also sealed in the bulb. Edison showed the phenomenon to a visiting British electrical engineer, W. H. Preece, and paid no more attention to it. Preece took the news to Britain, where the physicist J. A. Fleming (who was later to make the first electron tube) and others showed some interest in it. In 1900 Thomson strongly asserted what proved to be the explanation of this effect, and his pupil O. W. Richardson later elaborated it in detail.

The free electrons in a metal are in continual motion. As the temperature of the metal is raised, the motion speeds up. If the metal is heated sufficiently, the electrons become so agitated as to boil right out past the barrier at the surface.

That barrier is important. Electrons must move very fast indeed to escape from tungsten, the metal of which incandescent lamp filaments are made; tungsten filaments must be heated white-hot to give much thermionic emission. In 1904 the German physicist A. R. B. Wehnelt discovered that if a metal is coated with certain substances, electrons can escape from it at much reduced temperatures. Later, through work at the Bell Telephone Laboratories and elsewhere, it became clear that oxides of barium and strontium are the most suitable coatings, and these are now almost universally used.

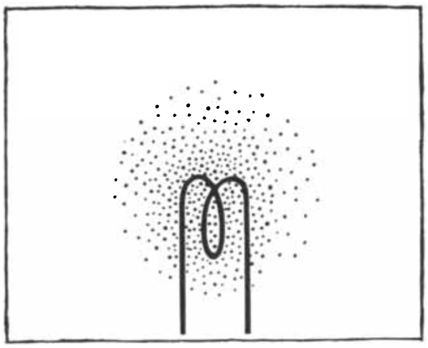
Electron Tubes

We have, then, a ready source of electrons—thermionic emission—and the knowledge that electrons are attracted by a positive electrode and repelled by a negative electrode. How can one make use of this knowledge? The answers were supplied by Fleming in the diode tube and by Lee de Forest in the audion, or triode.

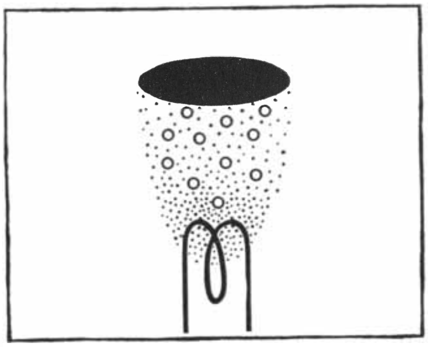
The diode, the simplest of electron tubes, consists of a hot, electron-emitting cathode and a cold, electron-collecting plate that serves as anode. If the plate is made positive with respect to the cathode, electrons will flow to it; if the plate is negative, no current can pass through the tube. Thus the diode can be used as a rectifier to change alternating current to direct current. In your AM radio a tiny diode changes the received signal, a high-frequency alternating current, into a unidirectional current whose strength varies with the sound. Other diodes are used in your radio set to change the alternating current of the house electric supply into the direct current needed to operate other electron tubes.

De Forest's contribution was the introduction of a third element of revolutionary effect. Like the diode, the triode has a hot emitting cathode and a nonemitting anode or plate. Between the two is an open electrode made of fine wire, the grid. The plate is kept positive at all times and the grid somewhat negative at all times. The negative grid repels electrons, but some of them can go to the attracting plate through the interstices of the grid. The number of electrons that reaches the plate per second, and therefore the strength of the plate current, depends on how negative the grid is made. If the grid is made very negative, the stream of electrons is completely blocked and the plate current is turned off entirely. If the grid is only a little negative, the plate current can be quite large. Thus the negative grid acts to control the plate current. The tube can in fact be used as an amplifier, for a small change in the electric potential of the control grid can cause a large power change in the plate circuit. The revolutionary achievement of the triode is this amplification; it has made long-distance communication possible and has given birth to a whole family of negative-grid tubes for a great variety of purposes.

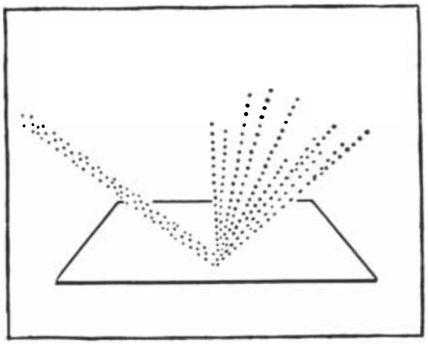
If a condenser and coil are provided between the plate and the grid, one obtains an electric oscillator. The amplifying effect of the tube tends to intensify any swinging disturbance in the circuit, and so produces a sustained electric oscillation. Oscillators are used to generate the radio signals in radio trans-



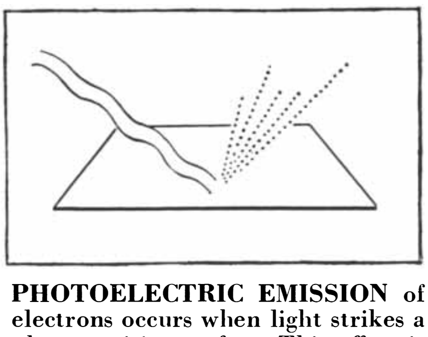
HOT CATHODE is a piece of metal heated so that electrons boil from its surface. Surface can be treated to enhance the emission of electrons.



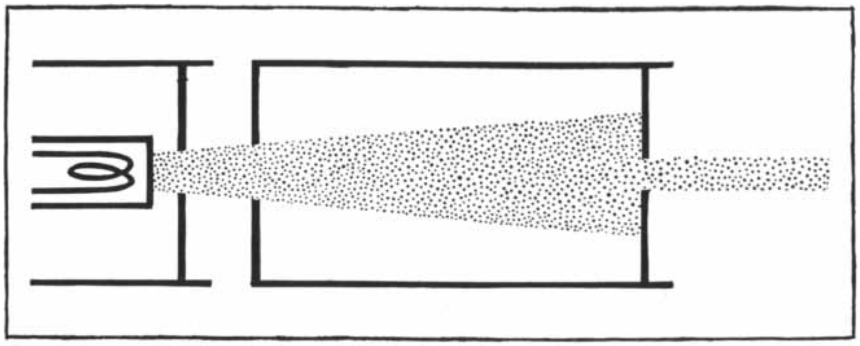
COLD CATHODE yields a few electrons to anode. If tube is filled with gas, electrons produce ions which knock other electrons from cathode.



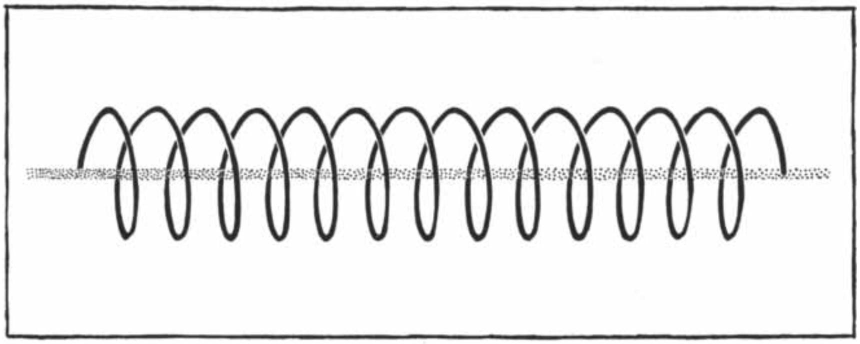
SECONDARY EMISSION occurs when fast-moving electrons strike a metal plate. Incident electron can knock out three secondary electrons.



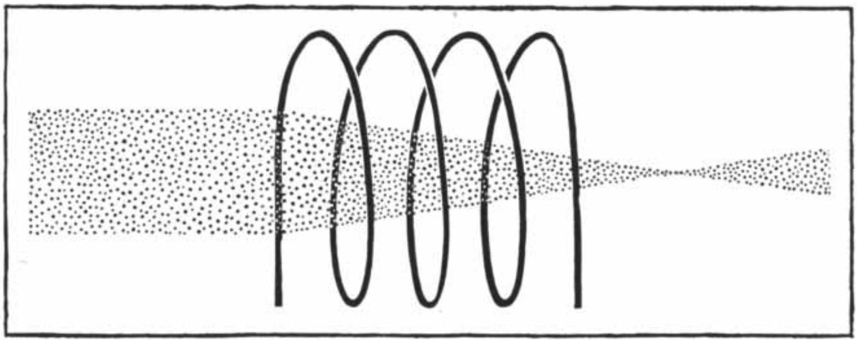
PHOTOELECTRIC EMISSION of electrons occurs when light strikes a photosensitive surface. This effect is utilized in the photoelectric cell.



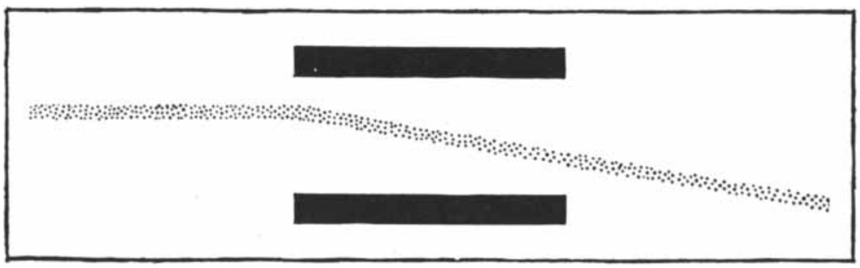
ELECTRON GUN is the fundamental means of producing a beam of electrons. In this schematic drawing the cathode is the electron-emitting surface at the far left. The electrons travel through a hole in the grid and through another hole in the anode. The third hole defines the beam more sharply.



LONG COIL may be used to focus beam of electrons. When current passes through the coil, it is surrounded by a magnetic field parallel to its axis. The field exerts no force on electrons moving parallel to the coil's axis, but electrons crossing the magnetic lines of force are turned back toward the axis.



SHORTER COIL may be used as a magnetic lens to focus electrons. Near the center of the coil the magnetic lines of force are parallel to its axis. Toward the ends of the coil, however, the lines of force bend away from the axis. An electron entering the coil away from the axis is thus forced toward it.



TWO PARALLEL PLATES may be used to deflect an electron beam. If one of the plates is made positive with respect to the other, the electron beam is bent toward the former. The charge on the two plates may rapidly be altered to move the electron beam (*see the tube drawing at the top of page 36*).

mitters, and negative-grid amplifiers intensify these signals before they are sent out.

The triode was the first important electron tube, and its relatives are still the most important and flexible of tubes. The triode itself has of course been greatly refined. In early tubes the electrons came from a white-hot tungsten filament. Now they come from the emissive coating on a dully glowing nickel tube or button, heated by an insulated tungsten spiral. In the early tubes the grid was a coarse structure far from the cathode. In one modern triode the grid has 1,000 wires per inch, each wire about a tenth the diameter of a human hair, and the grid is only one half of a thousandth of an inch from the hot cathode.

In some of the triode's descendants more grids have been added, making the tube a tetrode, pentode, hexode, heptode and so on. The additional grids make it possible to use the negative-grid tube at higher frequencies and increase its versatility and efficiency.

The diode and the triode use a broad flood of electrons which, like water spreading over a surface, avoids the heights (negative electrodes) and rushes down a declivity (toward the positive electrode). But we should remember that electrons can also be channeled in narrow, well-defined beams, and that these can be deflected electrically and magnetically. Surely these facts must be of some technological importance. Indeed they are. In the hands of Ferdinand Braun in Germany and of J. B. Johnson in this country they gave us the cathode-ray tube, the progenitor of today's television picture tube, and Philo T. Farnsworth and Vladimir K. Zworykin of the U. S. added other ingredients to create the tubes used in transmitting television.

Beams

In a television tube an electron gun is used to produce an electron beam. The electrons are emitted by a flat disk coated with emissive material and heated by a tungsten coil. Just beyond the disk a negative electrode with a circular aperture serves, like the grid of the triode, to control the intensity of the electron beam, and helps to focus the beam as well. A positive apertured electrode pulls the electrons through the aperture in the grid electrode and accelerates them to a high speed. Still another aperture limits the size of the beam. The beam that then emerges from the gun is focused to a fine spot by means of a magnetic or electric field, which serves as a "lens."

The electron gun that produces a beam, the magnetic or electric lens that focuses it and electric or magnetic deflectors that bend it form the ingredients of the cathode-ray tube and of the television picture tube. In these tubes a controlled beam of electrons is focused in a small spot on a fluorescent screen at the end of the tube, and the fluorescent material glows brightly under the impact of the electrons. The deflecting electrodes or coil, placed before the screen, can bend the electron beam and cause the bright spot on the screen to move horizontally or vertically.

In the cathode-ray oscilloscope the electron beam is swept smoothly across the fluorescent screen from left to right, tracing a bright line on the screen. At the same time the beam is deflected up and down according to the voltage in some circuit. Thus an exact picture of the variation of voltage with time can be obtained. The cathode-ray oscilloscope is the experimenter's most valuable diagnostic aid. In the television receiver, as the electron beam sweeps successive lines across the screen the television signal applied to the grid electrode varies the strength of the beam, thereby producing bright or dim spots on the screen; in this way the whole picture is repeatedly painted.

Television pickup or camera tubes, such as the iconoscope and the orthicon, are photoelectric cells that pick up the light image and convert it into electric current. Since the light available is often very faint, a device providing secondary emission of electrons is sometimes used to strengthen the current. The photoelectrons released from the photosensitive surface on which the image is focused by the camera lens are accelerated toward and strike an electrode treated so as to emit three to five secondary electrons for each primary photoelectron that strikes it. In turn, these secondaries can be accelerated to another secondary emitting surface, and so on. By such means the output current can be made a hundred thousand to several million times as great as the original current of electrons expelled from the photosensitive surface, which explains why television cameras can obtain satisfactory pictures in relatively dim light.

The image orthicon is a wonderful example of how the various physical phenomena of electronics can be brought together cooperatively in a technological device. In this tube a camera lens focuses a light image of the scene to be televised on one side of a thin transparent sheet of photosensitive material. Photoelectrons emitted from the other side of the sheet are accelerated by an electric field and focused by a magnetic field on the surface of a second very thin sheet of insulating material. The striking electrons cause a charge pattern on this surface, a pattern which corresponds faithfully in intensity to the light pattern falling on the photoelectric surface. But each electron that strikes causes several electrons to leave, so the pattern is positive rather than negative.

The insulating sheet on which the charge pattern is formed is so thin that the side opposite to that struck by electrons attains essentially the same potential. An electron beam scans this opposite side repeatedly, tracing out the whole surface. The surface takes up just enough electrons from this beam to make up for the secondaries lost on the other side and neutralize the charge on the surface. The rest of the electrons in the beam turn back. Thus as the beam scans the surface the returning current varies in intensity with the charge on the insulating surface and hence with the brightness of the picture. The returning current is amplified by a secondary emission multiplier to form the electric output of the tube.

So far we have considered the production and use of electron beams whose currents are best measured in millionths of an ampere. Can more intense electron beams serve some useful purpose? Of course they can and do, but there is more than electron beams to this story. It takes us into the whole field of microwave radio.

Tubes for Microwaves

The story of radio began with radio waves a few feet long, waves of very high frequency. Soon these were replaced by low-frequency waves miles in length. The generation of these long waves involved large coils and huge condensers. When, somewhat before World War II, experimenters began to work with waves only a few inches long, they had to use entirely new types of circuits, for the coils and condensers necessary to produce such short waves would be hopelessly small, delicate and inefficient.

One of the new devices developed to create microwave oscillations was the cavity resonator. A cavity resonator is a metal enclosure containing alternately a magnetic and an electric field. A change in the magnetic field produces an electric field, and a change in the electric field in turn produces a magnetic field. The electric and magnetic fields repeatedly change in strength and reverse in direction; energy in the resonator is continually transformed from electric energy to magnetic energy and back again, swinging back and forth billions of times a second.

Suppose that a steady electron beam is shot through a cavity resonator and is acted on by the rapidly fluctuating electric field. The electrons passing through are alternately slowed down and speeded up, as the changing electric field retards or accelerates them. As a result, the electrons that have been speeded up overtake the slower ones and form bunches; the originally smooth beam then becomes a fluctuating current.

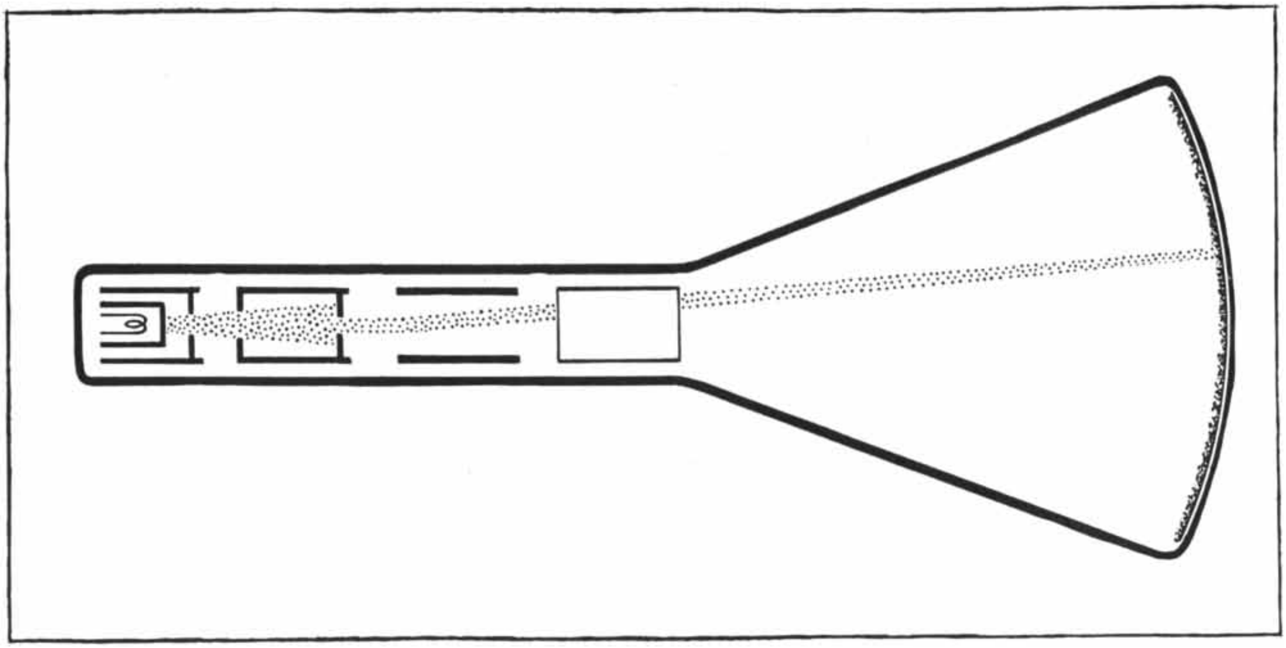
What we have come to in our piecemeal description is the klystron, the earliest of microwave amplifiers and one of the most versatile of microwave tubes. In a klystron amplifier a beam from an electron gun, perhaps focused by a magnetic field, is passed through two cavity resonators. The first resonator, excited by the microwave radio signal to be amplified, has an electric field proportional to the strength of that signal, and this fluctuating field acts to accelerate and retard the electrons in the beam. The beam then leaves the resonator and travels through a drift space in which the speeded electrons overtake the slowed electrons and the beam becomes bunched. When the bunched beam passes through the second resonator, it excites an electromagnetic oscillation and produces an amplified output signal.

During the war klystron oscillators were used in radar receivers. Now they serve as amplifiers in the radio relay link that carries television programs between New York and Boston. In short bursts or pulses klystrons have generated the most powerful radio signals ever made—microwaves having powers as great as 20 million watts!

A more recent microwave circuit is the traveling-wave tube. A stream of electrons is shot down the center of a long helix—a coil of wire much like a stretched door spring. The helix itself receives a microwave radio signal which travels along it at a speed a little slower than that of the electrons. The electric field of the radio signal acts on the electron stream to bunch the electrons into groups of greater than average density. The bunched stream of electrons in turn acts to strengthen the radio wave traveling down the helix. The action may be likened to that of a wind blowing over the surface of a rippled pond and raising the small ripples to sizable waves. The "electron wind" in a traveling-wave tube can multiply the power of the radio wave in the helix as much as 10,000 times.

The traveling-wave tube has even newer relatives, including the "double stream" amplifier. In this device two electron streams of different velocities are intermingled. Between them there takes place an interaction similar to that between the electron stream and the helix of the traveling-wave tube, and the resulting amplification can be even higher than that of the traveling-wave tube.

A more remote relative of the klystron is the wartime magnetron, which made possible microwave radar of very tiny wavelengths (in the centimeter range). The magnetron has resonators in the form of radial slots cut in the inside surface of a thick tubular anode surrounding a central cathode. A cloud of electrons drawn from the central cathode is bent and set into a whirling motion by a magnetic field. This whirling cloud



CATHODE-RAY TUBE may utilize two sets of plates such as those shown at the bottom of page 34 to move an electron beam in three dimensions. At the left end of the tube is an electron gun. To the right of it is one pair of deflection plates. Further along is another pair of plates at right angles to the first. By means of these four plates the beam can be made to paint an image on the fluorescent material which coats the end of the tube.

interacts with a signal in the surrounding circuit much as the long stream of electrons interacts with the radio wave traveling along the helix in the traveling-wave tube. By this means, powerful microwave oscillations can be obtained for short periods—powers of over a million watts lasting perhaps a few ten-millionths of a second.

For the production of continuous power at high frequencies a little short of microwave frequencies, there is another new tube: the resnatron. A recent tube of this type for operation at a frequency of 500 megacycles employs 48 separate electron streams shot through slots which act as grids, and it gives a continuous power of 500 kilowatts.

The tubes described so far are vacuum tubes. There are also modern counterparts of Geissler's gas tubes—gas diodes, gas triodes (called thyratrons) and other types as well. All gas tubes have two features in common. First, when the anode is positive they can easily be turned on by raising the grid or anode voltage a little, but once turned on, current will flow until the anode voltage is reduced to near zero. Secondly, a gas tube of a given size is capable of carrying a much larger current with less loss than is a vacuum tube.

If size and power were the measure of importance, then the most noteworthy of electron tubes would be the type that uses a mercury pool. In this device the cathode is not a hot filament or tube but a little bright spot that skitters over the surface of the pool of mercury. One of the most flexible of mercury-pool tubes is the ignitron. Current flow is initiated by applying a voltage to a resistive igniter electrode which extends into the mercury pool. The discharge can be stopped only by reducing the anode voltage to zero. The most powerful ignitrons are enclosed in metal tanks rather than glass bulbs. They can handle currents of several thousand amperes. Small ignitrons are used extensively in welding equipment. Large mercury-pool tubes, ignitrons and others, are used chiefly to change alternating current into direct current in the operation of electric railways and in the electrochemical industry, particularly in the production and refining of aluminum, magnesium, zinc and copper.

Electron tubes provide our technology with a variety of tools. Sensitive photocells can sense faint lights, and television tubes can seize on and reproduce whole moving scenes. Cathode-ray oscilloscopes can picture the workings of complicated circuits or apparatus. With the development of many special electronic devices, and particularly with the coming of electronic computers, a variety of special tubes have been developed to perform complicated functions. Negative-grid tubes are used in connection with all of these devices to amplify signals, and they perform a wide variety of other functions as well. Finally, under the control of these high-vacuum tubes, thyratrons and ignitrons can handle large currents, turning them on and off quickly, and can control the speed of powerful motors. In another field, vacuum tubes can send out radio and radar signals with powers of thousands and millions of watts.

Perhaps most important, however, electron tubes make it possible to amplify faint signals and to perform complicated operations at a speed and with a precision tremendously beyond the capability of any mechanical contrivance, even the finest instrument or watch.

The Impact of Electronics

Between 1930 and 1949 the annual business in radio tubes, which account for the bulk of the electron-tube industry, in the U. S. went from $120 million to $300 million, and the number of tubes manufactured from 52 million to 230 million. But statistics tell much less about the impact of electronics on our lives than do the radio and television sets in our homes. A world without electronics would be a dumb world to us. It requires a little imagination to recall the pre-radio world. In that world there was no morning weather broadcast to tell one to wear or not to wear a raincoat; there was no following of the day's news hour by hour. If people wanted music in their homes they had to play it, or listen to a tinny phonograph which rasped out coarse sounds and ground up records. They could go to the movies, but the movies were silent, for the sound that goes with the picture today is a product of electronics. The more distant of their friends, relatives and business associates were out of reach by telephone. No public speaker could be heard by an audience larger than could crowd within the reach of his voice.

There was radio of a sort before electronics. There was long-distance telephony, and in dry weather the telephone user could shout from New York to Denver. There were phonographs of a kind. Behind the revolutionary present-day improvements in all these devices is a particular common magic—the magic of amplification. The days before the audion initiated electronic amplification may be likened to the days when a man made his bicycle go by pushing on the pedals. The post-audion days belong with the automobile. The driver who steps on the gas merely controls the power of the machine; he does not push the car along.

In the making of a modern phonograph record the sound generates a tiny electric current, which need do no work at all. An electron-tube amplifier, deriving its power not from the voice or music but from the city electric supply, drives the cutting stylus that forms the groove in the record in a faithful reproduction of the tiny fluctuations of voice or music. Similarly in playing the record the phonograph pickup merely translates the wiggles of the groove into a tiny electric current; it is the powerful output of the amplifier that drives the paper cone of the speaker in and out in a faithful reproduction of the motion of the light stylus in the groove of the record. In telephony the electric current that operates the telephone receiver your listener holds to his ear in Los Angeles is not the current that leaves your instrument in New York. That current has been reproduced by amplifiers many times. In the radio transmitter the tiny current from the microphone controls the power output of amplifiers delivering tens of kilowatts to follow faithfully the small variations that distinguish speaker from speaker.

But amplification is not the sole service performed by the electron tube. It is used to transform low-frequency power into high-frequency power, and this affects our lives in many other ways. By means of high-frequency currents the inside of a person's body, a layer of glue between thick boards, a metal part suspended in an evacuated bulb can be heated in an accurately controlled manner. For the nuclear physicist the electron-tube oscillator produces the high-frequency, high-power voltages by means of which cyclotrons, synchrocyclotrons and linear accelerators speed atomic particles to energies of many millions of volts.

Besides the functions of amplification and production of high-frequency power, electron tubes perform certain other jobs in which their great speed is the main consideration. Electronic devices now are at least 1,000 times as fast as their mechanical counterparts, and inherently they are a great deal faster. Sometimes this speed may be used merely to achieve an economy in an old function. For example, electronic equipment in telephone exchanges, in place of the present electromechanical mechanisms, may give us speedier service in the future. The speed of electronic circuits can also lead to entirely new results. Many of the functions necessary in a television set are of this sort; they are neither amplification nor mere production nor control of high-frequency currents, and these functions must be performed so speedily that only electron tubes can do them. In another field, that of computation, electronic calculating machines have been used to solve problems in applied mathematics which would never have been attempted with electromechanical machines. In still another field, electron tubes are essential in the measurement and control of nuclear reactors.

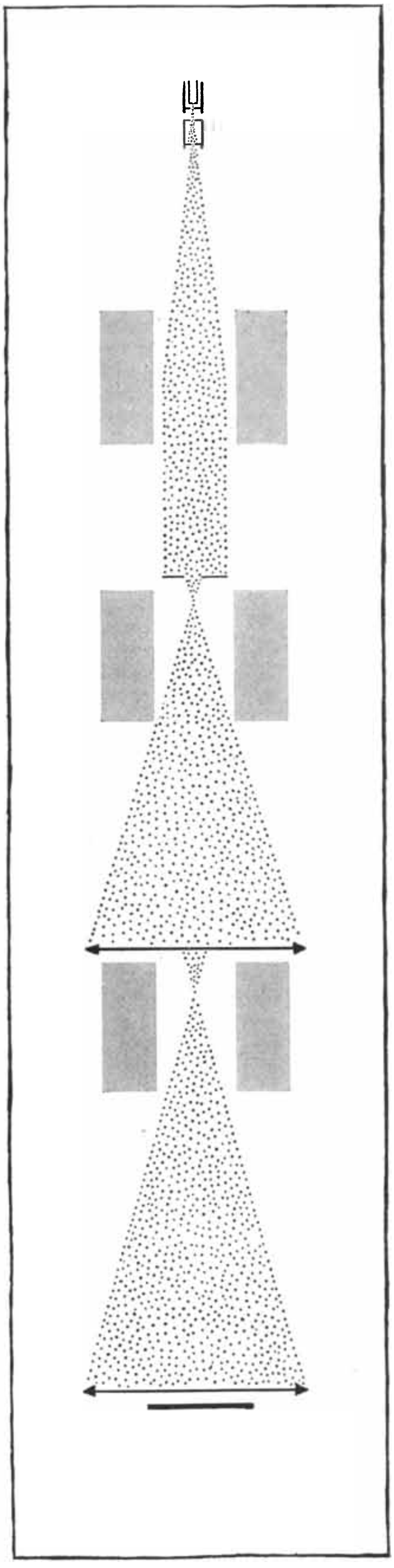
Year by year the scope of electronics becomes broader and the functioning of electronic circuits becomes more complex. New electron tubes continually turn the well-tried behavior of electrons to new and fruitful uses.

The Future

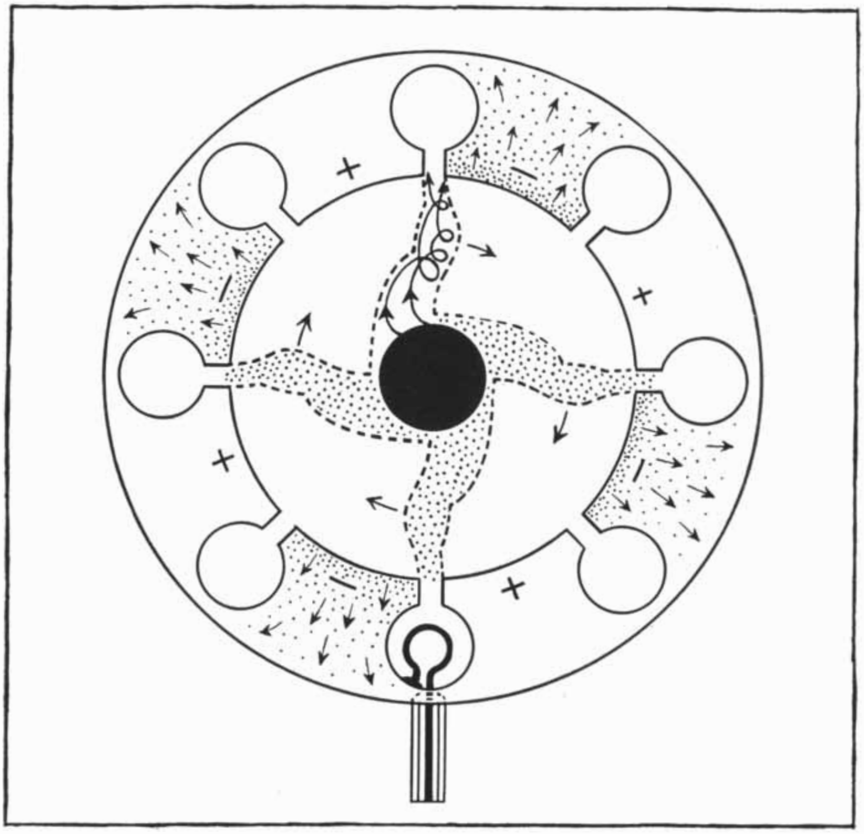
It is not always easy in these days of rapid advance to distinguish what has already been achieved from what is yet to come. Sometimes the newspapers herald almost as an accomplished fact a giant electronic brain that has only passed from being a gleam in an enthusiastic worker's eye to being a chronic pain in a discouraged worker's neck. What predictions can be made about future developments in electronics?

Some things we can see rather clearly in a general way. There will certainly be commercial color television, though we do not know its exact form. There will surely be more communications of a wider variety, and television for purposes other than home entertainment will be a part of this. Perhaps the first of these new applications will be television conferences among widely separated persons. Perhaps eventually new advances will make television with the telephone an economic possibility. All of this depends on the development of ways to send signals long distances more cheaply. It is not yet clear whether or in what degree this will be done by microwave radio from tower to tower, over wires or by radio waves of frequencies of perhaps 50 billion cycles per second traveling through a pipe called a waveguide.

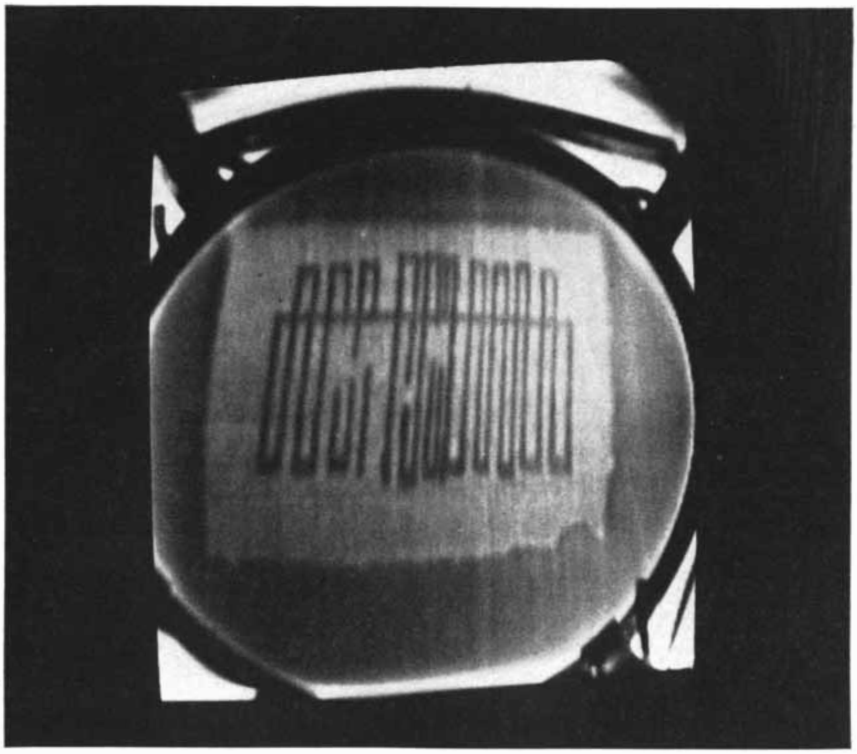
We may expect more vacuum tubes in devices such as business machines to give speedier operation. Electron tubes will appear in a variety of unexpected places; they have already shown up in the control systems of toy trains. Light-operated and perhaps radio-operated devices will appear with increasing commonness. Household devices may incorporate electron tubes as they become increasingly automatic.



ELECTRON MICROSCOPE utilizes several focusing coils to manipulate electron beam and produce vastly enlarged image of specimen.



MAGNETRON has resonant cavities in a metal ring. Around the ring is established a magnetic field whose lines of force are perpendicular to this page. The electrons describe curved paths between cathode (*center*) and ring, and give up their energy by interacting with electric field of cavities.



MEMORY TUBE, developed by Andrew V. Haeff of the Naval Research Laboratory, is a memory device for electronic computing machines. The tube can remember either numbers or pictures for hours or days, and reproduce them on demand. On the face of tube is a meaningless test pattern.

Beyond such matters lie possibilities whose realization may be governed more by economic and political considerations than by mere technical feasibility. Here prophecy can concern itself only with what could be, not what will be.

It is clear, for instance, that business machines and wires make possible a far-flung enterprise—a bank or chain of stores—with all its records and accounting concentrated in one center. New information, wherever filed, would be instantly available at any branch of the chain. In the case of a bank, we can imagine that an electronic auditor might ring an alarm in New York when a critical loan that could break the camel's back went bad in some remote hamlet. We can imagine branch stores that would merely exhibit samples, deliveries being made quickly from a central location; information as to whether an item was in or out of stock would be available at the branch in less time than it would take a clerk to hunt on a shelf.

And what of the miracle aspects of electronics? Will we have machines that respond to the human voice, an electronic fourth at bridge, an electronic chess opponent? Will electronic devices compose music as well as reproduce it? This is largely an economic question. Who, we may ask, will subsidize how many smart people to spend how much money in achieving such things?

Finally, what further contributions can we expect the technology of electronics to make to science? It has already helped the advance of knowledge in many branches, not only physics but also astronomy, chemistry, biology. Without electronic apparatus, electronic frequency standards, sensitive measuring equipment, electronic recording devices, photocells for measuring light intensity, particle accelerators, large-scale computers and the fast, cheap long-distance communication which electronics has provided to all sciences, much of the progress that these sciences have made would have been impossible.

I am thinking, however, of another more direct sort of contribution that work on electron tubes has made, and might perhaps make in a greater degree, to astronomy and physics. This has to do with the fundamental problem of the interaction between charged particles and electromagnetic fields. It involves, for example, questions about solar radiation.

Electronics and the Sun

It has long been known that a hot body emits a wide range of electromagnetic radiation: light, heat and, according to accepted and well-proved theory, radio waves as well. The hotter the body, the more intense the radiation emitted. Now man has always been strikingly aware of the light and heat emitted by so large and hot a body as the sun, but until recently the radio radiation from the sun escaped detection. In 1943 Grote Reber of Wheaton, Ill., using a receiver tuned to two meters, detected radio waves from the sun. In 1946 G. C. Southworth of the Bell Telephone Laboratories published measurements of solar microwave radiation at wavelengths of 10 centimeters and three centimeters. Southworth's measurements furnished an estimate of the sun's temperature independent of that by earlier light and heat measurements, and it roughly confirmed these earlier measurements, placing the sun's surface temperature at about 6,000 degrees Kelvin.

Very shortly afterward, however, a report published in *Nature* changed this picture in a startling way. Workers in Australia, on the basis of new measurements of the rising sun at a wavelength of 1.5 meters, found that the sun had a steady background temperature of one million degrees, with much higher bursts which they proved to be associated with sunspots. There is still a great deal of speculation concerning this intense radiation. Apparently it comes from the sun's tenuous outer atmosphere, the corona, which is transparent to light, heat and short microwaves but opaque to radiation of longer wavelengths.

Astronomers and astrophysicists believe that the million-degree background radiation represents the true temperature of the corona, but they are at a loss to explain why the corona is so hot or what causes the bursts of higher intensity radiation. Physicists familiar with the intense radio waves produced by the interaction of charged particles with electric and magnetic fields in magnetrons have suggested that these same ingredients, known to be present in sunspots, may account for the sun's bursts of intense radiation. In 1947 D. F. Martyn of Australia and Joseph S. Schlonsky of the U.S.S.R. proposed that the bursts might be explained by the phenomenon known as "plasma oscillation," first observed in gas tubes in 1929 by Irving Langmuir and Lewi Tonks. Plasma oscillation is a kind of oscillation of charged particles which does not require the presence of a magnetic field. Others have suggested that the solar bursts may represent types of interactions between clouds of charged particles in relative motion such as occur in traveling-wave tubes, particularly double-stream amplifiers, and which are related in a way to plasma oscillations. It is, for instance, attractive to think that perhaps the huge clouds of ionized gas ejected from the sun as solar prominences may, in rising and falling through the ionized solar atmosphere, produce just the signals that have been observed.

I think that a few years ago physicists would have said that Maxwell's equations and the laws of motion summed up all the interesting aspects of the interaction of charges with electromagnetic fields. Now the phenomena newly observed in the sun, which may be a particular case of such interactions, present some new questions that are very interesting indeed.

A theoretical treatment of the solar phenomena is, alas, extremely difficult. The astrophysicists cannot easily check their theories; indeed, the theories are at present scarcely in a condition to be checked. On the other hand, physicists and engineers who work in the more limited field of the interactions in electron tubes at least have a ready check of their theories, and they may actually be dealing with the same phenomena as the astrophysicists. The theories of interactions between clouds of charged particles in electron tubes and in gaseous clouds are essentially the same, and both are closely related to the theory of other physical phenomena. Among these one can mention the magneto-hydrodynamics of charged particles proposed by the Swedish cosmologist H. Alfven, the propagation of radio waves through the ionosphere, the operation of such alternating-current machines as induction generators, and perhaps various supersonic phenomena, the instability of laminar flow and various statistical problems of astronomy. An adequate comparison of these fields might simplify matters for all concerned.

Hence one might expect a cooperative effort by the workers in electronics and the physicists. Unfortunately, there seems to be little contact between the various groups. Such contact may be established in the future. At all events, the workers on electron tubes, though one stage removed from the field of pure science, can feel that they have helped in some measure to advance matters of a more philosophical nature.

J. R. Pierce has made important contributions in the fields of electron multipliers, electron focusing and microwave electron tubes. He is the author of The Theory and Design of Electron Beams *and numerous popular articles.*

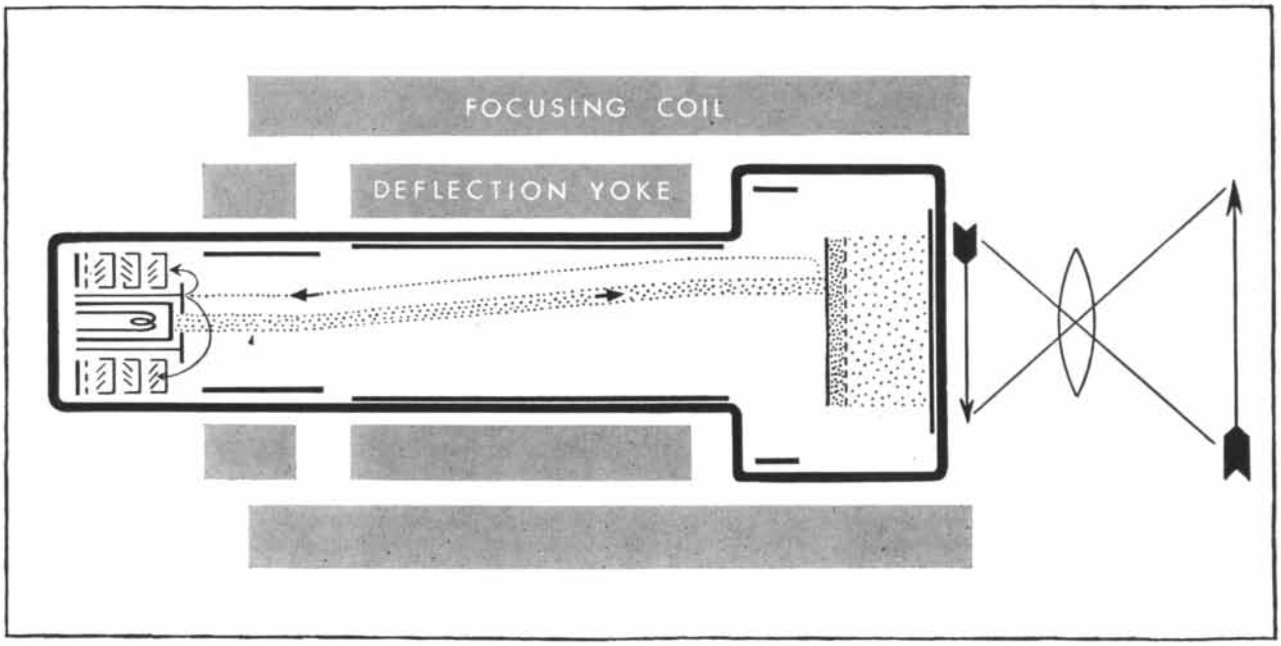


IMAGE ORTHICON is a television camera tube. At right end of tube an image is focused on a photoelectric surface. Electrons emitted from the surface in the pattern of the picture are then amplified by secondary emission. Part of an electron beam scanning a plate charged by these secondary electrons is turned back toward its source. The returned beam is amplified to yield an electric reproduction of the original image.

AUTUMN COLORS

In the fall the leaves of hardwood trees assume their hues of yellow and red. The latter is of special interest to chemists

by Kenneth V. Thimann

FOR those of us who live in the Northeast the summer may be short-lived, but it expires in a blaze of glory, and all the trees put on fancy dress for its passing. From the soft old-gold of the birches through the flaming scarlet of the rock maples to the rich crimson of the red oaks and sumacs, there is a wealth and variety of leaf color which compares very favorably with the flowers of our summer gardens. And the comparison is apt, for many of the pigments involved in autumn foliage colors are the same as those of the flowers.

The color changes involve both the fading or bleaching of the original pigments and the formation of new pigment types. The simplest case is represented by the yellow colors, which occur in the birches, poplars, elms and many other trees, as well as in almost every garden plant toward the end of its life-span. The yellow pigments that make their first appearance in leaves in the autumn were present all the time, but were hidden from sight by the somewhat greater amount of green substances—the chlorophylls.

To appreciate these and other color changes one must consider what actually happens when an object appears colored. When white light, consisting of all wavelengths of the spectrum from about 400 to 710 millionths of a millimeter, falls on a surface that contains pigments, the pigments absorb some wavelengths more than others. Suppose that the pigments are such that the shortest wavelengths (those that would appear to the eye as violet) are the most absorbed, a little of the blue is absorbed, and our eyes see the remainder—a mixture of red, yellow, green and some blue. This mixture does not add up to white but to yellow. To put it in another way: white minus violet equals yellow.

Every pigment has its own absorption spectrum, which is usually represented as a curve on a chart showing the extent of absorption of light by the pigment at each wavelength. The chart on the opposite page shows the absorption spectra of a complete leaf (in this case a spinach leaf), and of some leaf pigments—a yellow pigment called carotene and the two kinds of green chlorophylls, called (rather unenterprisingly) *a* and *b*, that are present in most leaves. Since the chlorophylls absorb light strongly in the blue and the red, and hardly at all in the green, the eye looking at a leaf receives principally green light, with some yellow and a little blue and violet. The result is a general sensation of green. Now the yellow pigments of the leaf, as the absorption spectrum of carotene indicates, absorb only blue and violet light, which are largely absorbed anyway by the chlorophylls. Consequently the yellow pigments do not very markedly change the visible color of the leaf, and this is the reason their presence is unnoticed. The absorption spectrum of a complete leaf, as the chart shows, is more or less the sum of the absorptions of the individual pigments (with minor differences), and the unabsorbed light which reaches our eyes is almost wholly limited to the green.

In the autumn, however, the chlorophylls begin to bleach, and now the yellow pigments become visible. The reason for the bleaching is only partly understood; in general it is a consequence of the breakdown of the proteins in the leaf cells that accompanies the leaf's aging. Because the chlorophyll is attached to some of this protein, its own stability gives out too.

BUT the real magnificence of the fall colors depends on the reds. It is evident that here a new pigment enters the scene, for no red is present in the typical summer leaf; although many young leaves formed in the spring contain some red pigment, they lose it as they mature. Only a few leaves, such as those of the copper beach and some corn varieties, remain red throughout the season.

The red pigments newly formed in the autumn belong to a class of pigments quite different from those in the summer leaf. This class is best known to us in the form of the pigments of flowers. The very first flower pigment to be studied, extracted by the Frenchman F. S. Morot over 100 years ago, was not a red but a blue. He obtained it from blue cornflowers ("bachelors'-buttons"), and it was named anthocyanin, which means, in Greek, blue flower. (Chlorophyll, correspondingly, means green leaf.) The word anthocyanin is now used for a whole family of pigments, some blue, some purple and some red. A curious feature of these pigments is that their color in the flower is not always the same as that of the pure pigment; for example, the dark red rose has the same pigment (cyanin) as the blue cornflower. The reason for the difference in appearance is that other substances in the plant cells modify the chemical form, and therefore the color, of the anthocyanins.

Anthocyanins differ from the green and yellow pigments in at least two important ways. In the first place, they are fully soluble in water, whereas the chlorophylls, carotenes and related pigments are soluble only in oils or organic solvents. In the second place, as a result of their water-solubility the anthocyanins appear in the watery sap of the plant, while the green and yellow pigments are found only in the little green chloroplasts inside the leaf cells.

The study of how anthocyanins are formed, though very interesting, has not been pursued with any great vigor. The reason for this is to be sought in the curiously spotty nature of scientific progress. The advance of knowledge is like the advance of the tide over a level beach: in places it runs up long creekbeds to penetrate startlingly far inland, while at other points it creeps with extreme slowness up an incline or may even leave uncovered long spits of land stretching into the sea. Although mankind is entirely dependent on plant products, it remains true that very little effort has been expended on studying the processes by which these are formed. We may know something (though little enough) about the bulk materials, such as sugars, starches and proteins, but when it comes to the more subtle products of plants, *e.g.*, drugs, dyes, vitamins and perfumes, our knowledge of the way in which they are formed is almost negligible. This is the more remarkable because the chemical structure of most of these has been thoroughly worked out, and even such a classical puzzle as the drug strychnine is now yielding up its long-guarded structural secrets to the organic chemists.

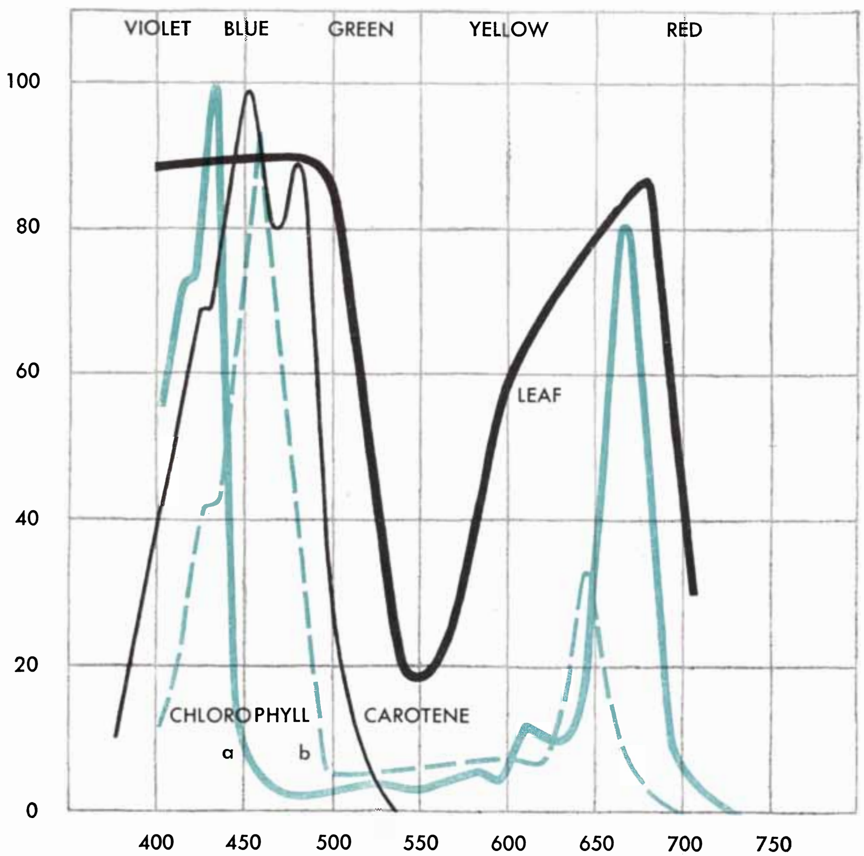
The anthocyanins have, like most plant compounds, been subject to extensive study by organic chemists; their chemical structure has been cleared up and many of them have been synthesized. Yet we still have a long way to go to explain how they are formed in nature.

TO STUDY the mechanism of their formation the right biological material must be selected. Flowers and autumn leaves are too transient; the best material is something that can be cultured for a long period and that forms anthocyanin throughout its life. Some work has been done with red-colored seedlings such as buckwheat or red cabbage, some with leaves that form red pigment in summer (especially corn), and, most recently, some with duckweeds. These last are very convenient because they can be grown in sterile culture solution like bacteria. The peculiarities of the duckweed plant were described by Eric Ashby in a recent issue of SCIENTIFIC AMERICAN ("Leaf Shape," October, 1949). In some members of the family, the little green leaflike fronds of the plant form purple pigment on the underside. It is the concentration of this pigment (which is of course an anthocyanin) that is measured. In our research on this material at Harvard University, the duckweeds are grown in a controlled medium in artificial-sunlight rooms, where the intensity of the light and the temperature can be accurately controlled.

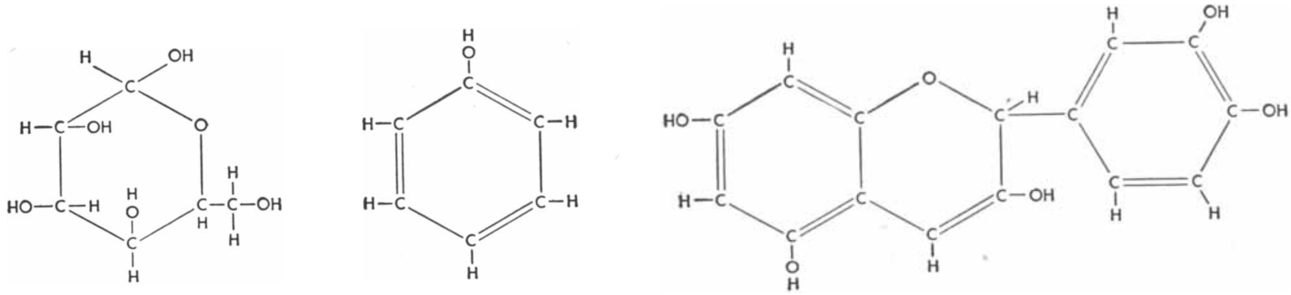
The conditions under which anthocyanin is formed by the duckweed are most instructive for the understanding of fall colors. In the first place, light is required; the brighter the light, the more pigment. In the second place, the temperature must not be too high. Every New Englander knows that cool bright weather in the early fall favors the development of brilliant foliage, and here the experiments bear out the common observation. In England, on the other hand, where the autumn is usually rather mild and cloudy, autumn foliage color is duller, limited mainly to the yellows and browns; anthocyanins make a very minor, often undetectable, contribution. Consequently when the English poets write of autumn, they concentrate on the "mellow fruitfulness," the harvests and the Bacchic revels; autumn leaves for them are symbols only of decay. Shelley wrote:

"... the leaves dead
Are driven like ghosts from an enchanter fleeing,
Yellow, and black, and pale, and hectic red,
Pestilence-stricken multitudes."

The laboratory experiments also cast interesting light on the role of sugars in the formation of pigments. At the end of the last century experimenters observed that if various aquatic plants were floated on sugar solutions in daylight, they reddened. If duckweed is grown on sugar solutions it produces an increased amount of anthocyanin. Traces of anthocyanin can be formed from sugar even in the dark, but light very greatly increases the pigmentation. It follows from this that not only is light needed for the for-



ABSORPTION SPECTRA of leaf pigments show why leaves turn yellow. The yellow pigment carotene is masked by the chlorophylls. When chlorophylls bleach in fall, the yellows become visible. Vertical coordinate: per cent of absorption. Horizontal: wavelength in millionths of a millimeter.



MOLECULAR STRUCTURES illustrate the problem of explaining how anthocyanins are formed. At left is the structure of the simple sugar glucose, one of the so-called aliphatics. In center is the structure of phenol, one of the aromatics. At the right is the structure of the anthocyanin cyanidin, also an aromatic. The structure of sugars may be remolded into the structure of aromatics, a feat that is now impossible in the laboratory.

mation of sugar by photosynthesis, but there is actually a light-induced reaction of another kind which forms pigments. Both light and sugar are necessary.

Now when sugar is oxidized or fermented in living cells, phosphate is always needed as well, for the sugar is broken down only after it has been combined with phosphate. When the influence of phosphate on anthocyanin formation was studied, it was found, surprisingly, that the depth of the pigment in duckweeds could be increased by cutting down the phosphate in the growth medium. With phosphate lowered to a few per cent of its normal value the pigmentation could be trebled. This is considered to support the idea that the pigment is formed through the accumulation of sugar by a process which takes sugar along a path quite different from that of its normal breakdown. The normal breakdown needs phosphate, but in the path leading to anthocyanin, phosphate apparently plays no part at all. Copper seems to play some role in this special path, for if a compound which combines strongly with the traces of copper that are present is added to the medium and the metal is thus denied to the plants, anthocyanin is not formed.

The effect of phosphate reminds one that scientific farmers have often observed that the leaves of crop plants become reddish or purplish as a characteristic response to a shortage of phosphate in the soil. It is one of the typical "hunger signs," and while such reddening may have several causes, phosphate deficiency is one of the commonest and the most important. The phosphate effect also recalls the fact, discovered by Raoul Combes at the Sorbonne many years ago, that many nutrients (of which phosphate is one) migrate out of the leaves into the stem as autumn comes on.

All of these observations and experiments add up to a general picture of a variant type of sugar metabolism which, with the aid of light, gives rise to the anthocyanins and perhaps also to other special products of the plant.

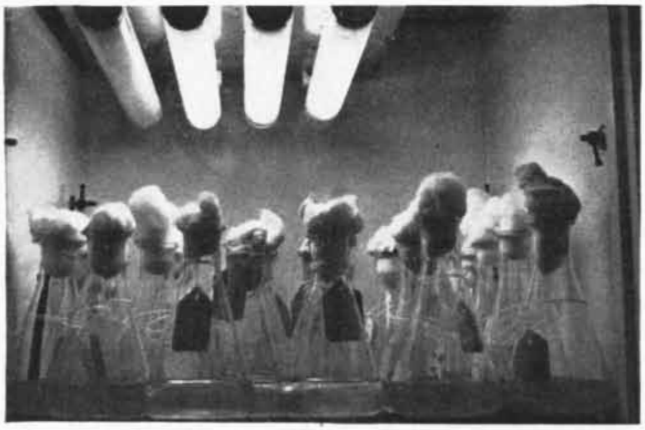
A complete explanation of autumn colors will have to involve at least four different factors: 1) the natural aging of the leaf, which causes phosphate and nitrogen compounds to go back into the stem; 2) the continued formation of sugars, provided the weather remains bright; 3) the presence of a specific chemical system or pathway, varying with the plant species, for the conversion of sugars into pigment, and 4) temperature. It may be that the low temperatures of autumn nights cause starch in the leaf to be converted to sugar and thus reinforce the second factor.

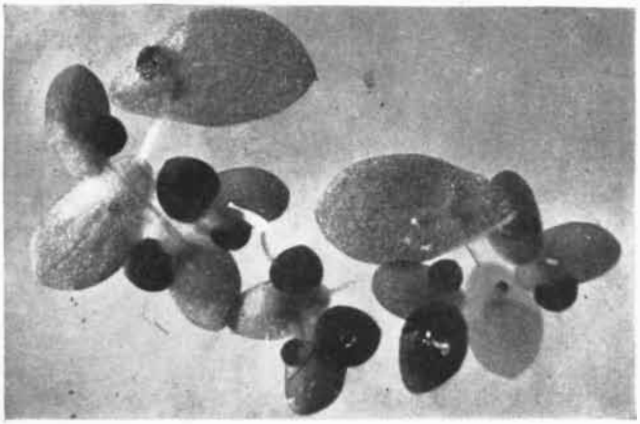
A FULL understanding of the pathway leading to the autumn color pigments might provide answers to much wider questions in organic chemistry and biology. The sugars, such as glucose, belong to a class of compounds called aliphatic; that is, they contain carbon atoms linked to each other in the ordinary way—a chain of six carbons, with the fifth carbon hooked back to the first through an oxygen atom and the sixth carbon at the side. The anthocyanins, however, belong to the class called aromatic, in which the carbon atoms are linked in the characteristic benzene ring of six, with electrons oscillating between them to give a taut and vibrating stability to the ring (*see diagrams above*). Oxygen atoms, when present, are linked to the side of the ring; a typical aromatic compound of this kind is phenol. Now the phenol arrangement occurs in all anthocyanins. The pigment of the duckweeds, and indeed of most red and purple leaves, is a compound of a phenol derivative, cyanidin, with certain sugars.

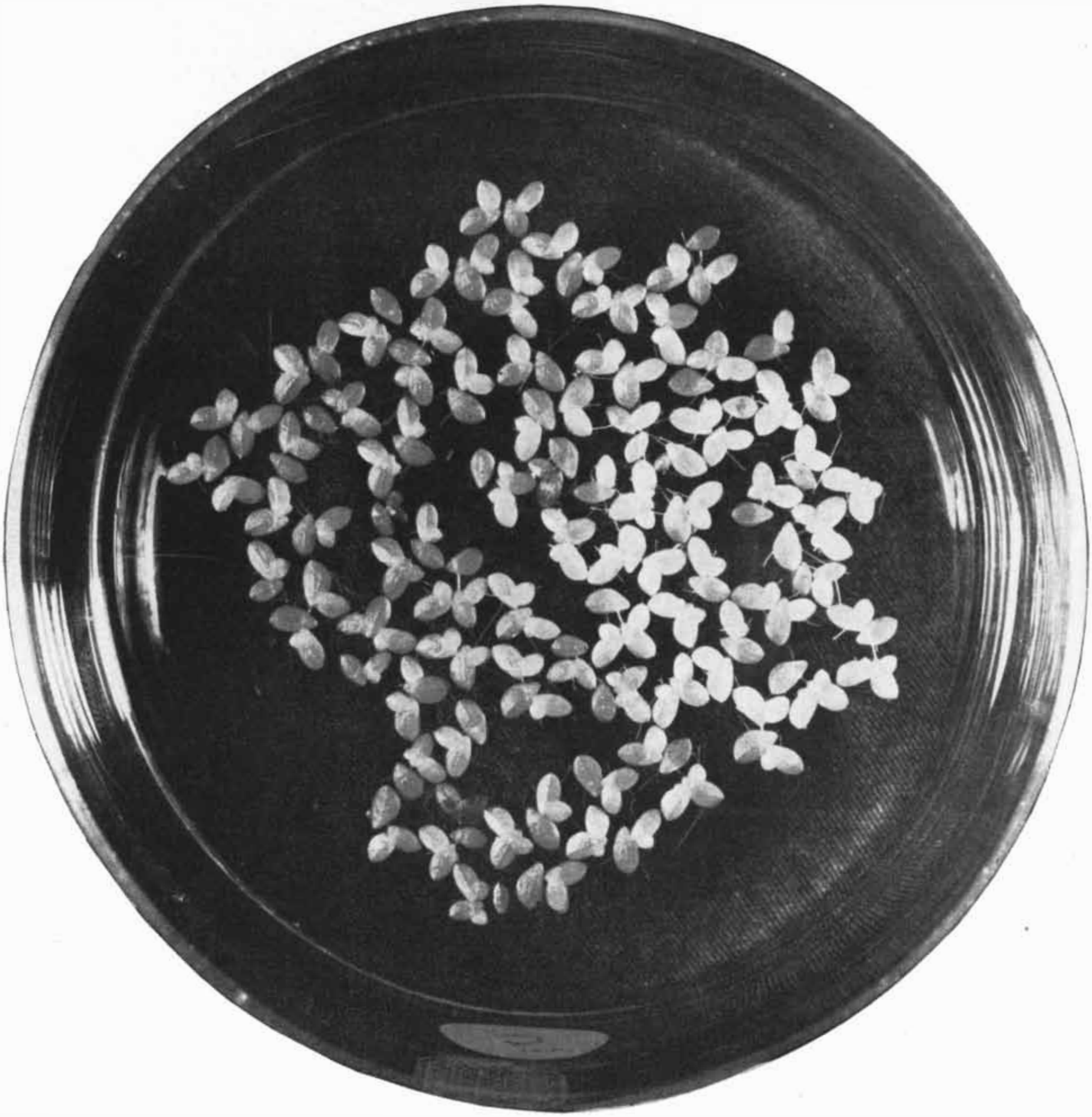
Just how aromatic compounds are formed in nature we do not know. The first products of photosynthesis, that great synthetic process which directly or indirectly supplies all the world's food, fuel, clothes, drugs, vitamins and so forth, are almost certainly aliphatic compounds—apparently sugars and the simple organic acids related to them. The aromatic compounds must therefore be produced by secondary reactions. If these reactions start from sugars, they involve a remolding of the aliphatic structure to join the six carbon atoms in a ring. Such remolding would represent a fundamental change that is virtually impossible to accomplish in the laboratory, but judging from the frequency with which aromatic compounds occur in nature, it must take place easily in plants. It is quite possible that it requires very extensive dismemberment and reassembly of the sugar molecules. In cyanidin the two six-carbon benzene rings are joined by a structure containing three carbon atoms. Since the breakdown of six-carbon sugars in nature involves splitting them into halves, each containing three carbon atoms, one may naturally suggest that the three-carbon bridging structure in cyanidin comes from a sugar. As yet this has not been proved. However, we find that anthocyanins and many other aromatic compounds very commonly occur in combination with sugars in the plant, which certainly suggests that they have a common origin.

The important aromatic compounds in nature include benzene itself, naphthalene, the lignin of wood, the photographer's developer quinol, some of the vitamins, a host of drugs (*e.g.*, morphine, strychnine, quinine) most of the natural dyes, and of course the anthocyanins of flowers and of autumn leaves. The parent substances from which all these are derived—benzene, phenol and naphthalene—are obtained chiefly from coal tar, a product of plants that died long ago. Upon these few naturally occurring compounds the vast structure of modern synthetic chemistry has been erected. It is not too much to say that benzene is a key substance for modern civilization. And it may be that the manner of formation of the anthocyanin pigments will provide a clue to the way in which nature produces benzene. Thus the study of autumn colors, like so many apparently minor problems in biology, leads us straight to the heart of the organism's activities, and a full explanation of the coloring, when we reach it, may yield explanations of many other biological mysteries.

Kenneth V. Thimann is professor of plant physiology at Harvard University.







THE DUCKWEED, a little plant that floats on the surface of water, is used in the laboratory study of anthocyanin pigments. It can be grown in sterile cultures like bacteria under controlled conditions of light and temperature (*upper left*). After a time a purple anthocyanin pigment forms on the underside of its leaflike frond (*upper right*). The photograph at the bottom of the page shows duckweeds growing in a culture dish.

PROBABILITY

Three centuries ago some sensible questions asked by gamblers founded a branch of mathematics. Today it powerfully assists our understanding of nature

by Warren Weaver

Probability is the very guide of life.
—Cicero, *De Natura*

OVER three centuries ago some gamblers asked the great Italian scientist Galileo why a throw of three dice turns up a sum of 10 more often than a sum of nine. In 1654 the Chevalier de Mere—another gambler—asked the French mathematician and philosopher Pascal why it was unprofitable to bet even money that at least one double six would come up in 24 throws of two dice. This problem of de Mere really started off the mathematical theory of probability, and the end is not yet in sight.

Probability theory has now outgrown its disreputable origin in the gaming rooms, but its basic notions can still be most easily stated in terms of some familiar game.

When you toss a die—one carefully made, so that it is reasonable to believe that it is as likely to land on one of its six faces as on any other—a gambler would say that the odds against any specified number are five to one. A mathematician defines the probability to be one-sixth. Suppose we ask now: What is the probability of getting a three and a four in one roll of two dice? For convenience we make one die white and one red. Since any one of six results on the white die can be paired with any one of six results on the red die, there is now a total of 36 ways in which the two can land—all equally likely. The difference in color makes it clear that a red three and a white four is a different throw from a white three and a red four. The probability of throwing a three and a four is the ratio of 2—the number of favorable cases—to 36, the total number of equally likely cases; that is, the probability is 2/36, or 1/18.

What is the probability of throwing a sum of seven with two dice? An experienced crapshooter knows that seven is a "six-way point," which is his way of saying that there are six favorable cases (six and one, one and six, three and four, four and three, five and two, two and five). So the probability of throwing a sum of seven with two dice is 6/36, or 1/6.

In general, the probability of any event is defined to be the fraction obtained by dividing the number of cases favorable to the event by the total number of equally likely cases. The probability of an impossible event (no favorable cases) obviously is 0, and the probability of an inevitable or certain event (all cases favorable) is 1. In all other cases the probability will be a number somewhere between 0 and 1.

Logically cautious readers may have noticed a disturbing aspect of this definition of probability. Since it speaks of "equally likely," *i.e.*, equally probable, events, the definition sits on its own tail, so to speak, defining probability in terms of probability. This difficulty, which has caused a vast amount of technical discussion, is handled in one of two ways.

WHEN one deals with purely *mathematical probability*, "equally likely cases" is an admittedly undefined concept, similar to the theoretical "points" and "lines" of geometry. And there are cases, such as birth statistics for males and females, where the ordinary concept of "equally likely cases" is artificial, so that the notion must be generalized. But a logically consistent theory can be erected on the undefined concept of equally likely cases, just as Euclidean geometry is developed from theoretical points and lines. Only through experience can one decide whether any actual events conform to the theory. The answer of experience is, of course, that the theory does in fact have useful application.

The other way of avoiding the dilemma is illustrated by defining the probability of throwing a four with a particular die as the actual fraction of fours obtained in a long series of throws under essentially uniform conditions. This, the "frequency definition," leads to what is called a *statistical probability*.

On the basis of the mathematical definition of probability, a large and fascinating body of theory has been developed. We can only hint here at the range and interest of the problems that can be solved. Two rival candidates in an election are eventually going to receive m and n votes respectively, with m greater than n. They are sitting by their radios listening to the count of the returns. What is the probability that as the votes come in the eventual winner is always ahead? The answer is $m-n/m+n$. A storekeeper sells, on the average, 10 of a certain item per week. How many should he stock each Monday to reduce to one in 20 the chance that he will disappoint a customer by being sold out? The answer is 15. Throw a toothpick onto a floor whose narrow boards are just as wide as the toothpick is long. In what fraction of the cases will the toothpick land so as to cross a crack? The answer is $2/\pi$, where π is the familiar constant we all met when we studied high-school geometry. A tavern is 10 blocks east and seven blocks north of a customer's home. If he is so drunk that at each corner it is a matter of pure chance whether he continues straight or turns right or left, what is the probability that he will eventually arrive home? This is a trivial case of a very general "random walk" problem which has serious applications in physics; it applies, for example, to the so-called Brownian movement of very small particles suspended in a liquid, caused by accidental bumps from the liquid's moving molecules. This latter problem, incidentally, was first solved by Einstein when he was 26 years old.

THERE are laws of chance. We must avoid the philosophically intriguing question as to why chance, which seems to be the antithesis of all order and regularity, can be described at all in terms of laws. Let us consider the Law of Large Numbers, which plays a central role in the whole theory of probability.

The Law of Large Numbers has been established with great rigor and for very general circumstances. The essence of the matter can be illustrated with a simple case. Suppose someone makes a great many tosses of a symmetrical coin, and records the number of times heads and tails appear. One aspect—the more familiar aspect—of the Law of Large Numbers states that by throwing enough times we can make it as probable as desired that the ratio of heads to total throws differ by as little as one pleases from the predicted value 1/2. If you want the ratio to differ from 1/2 by as little as 1/100,000, for example, and if you want to be 99 per cent sure (*i.e.*, the probability = .99) of accomplishing this purpose, then there is a perfectly definite but admittedly large number of throws which will meet your demand. Note that there is no number of throws, however large, that will really *guarantee* that the fraction of heads be within 1/100,000 of 1/2. The law simply states, in a very precise way, that as the number of experiments gets larger and larger, there is a stronger and stronger tendency for the results to conform, *in a ratio sense*, to the probability prediction.

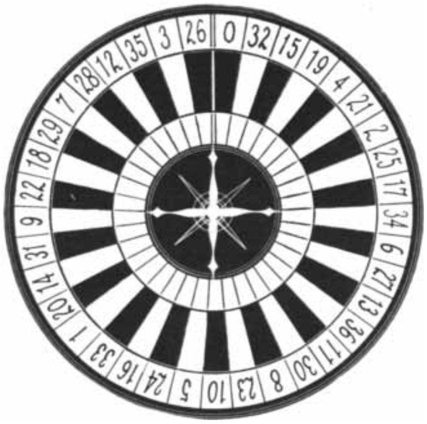
This is the part of probability theory that is vaguely but not always properly understood by those who talk of the "law of averages," and who say that the probabilities "work out" in the long run. There are two points which such persons sometimes misunderstand.

The first of these relates to the less familiar aspect of the Law of Large Numbers. For the same law that tells us that the *ratio* of successes tends to match the probability of success better and better as the trials increase also tells us that as we increase the number of trials the *absolute number* of successes tends to deviate more and more from the expected number. Suppose, for example, that in 100 throws of a coin 40 heads are obtained, and that as one goes on further and throws 1,000 times, 450 heads are obtained. The *ratio* of heads to total throws has changed from 40 per cent to 45 per cent, and has therefore come closer to the probability expectation of 50 per cent, or 1/2. But in 100 throws the absolute number of heads (40) differs by only 10 from 50, the theoretically expected number, whereas in 1,000 throws, the absolute number of heads (450) differs by 50, or five times as much as before, from the expected number (500). Thus the ratio has improved, but the absolute number has deteriorated.

The second point which is often misunderstood has to do with the independence of any throw relative to the results obtained on previous throws. If heads have come up several times in a row, many persons are inclined to think that the "law of averages" makes a toss of tails now rather more likely than heads. Granting a fair, symmetrical coin, this is simply and positively not so. Even after a very long uninterrupted run of heads, a fair coin is, on the next throw, precisely as likely to come up heads as tails. Actually the less familiar aspect of the Law of Large Numbers already mentioned makes it likely that longer and longer uninterrupted sequences of either heads or tails will occur as we go on throwing, although the familiar aspect of the same law assures us that, in spite of these large absolute deviations, the ratio of heads to tails is likely to come closer and closer to one.

ALL of these remarks, of course, apply to a series of *independent* trials. Probability theory has also been most fruitfully applied to series of dependent trials—that is, to cases, such as arise in medicine, genetics, and so on, where past events do influence present probabilities. This study is called the probability of causes.

Suppose we have a covered box about which we know only that it contains a large number of small colored balls. Suppose that without looking into the box we scoop out a handful and find that one third of the balls we have taken are white and two thirds red. What probability statements can we make about the mixture in the box?



ROULETTE WHEEL makes possible bets against several probabilities. At Monte Carlo red once came up 32 times in a row. This probability is: $1/(2)^{32}$, or about one in 4 billion.

This schematic problem, which sounds so formal and trivial, is closely related to the very essence of the procedure of obtaining knowledge about nature through experimentation. Nature is, so to speak, a large closed box whose contents are initially unknown. We take samples out of the box—*i.e.*, we do experiments. What conclusions can be drawn, how are they to be drawn and how secure are they?

This is a subject which has caused considerable controversy in probability, and in the related field of statistics as well. The problem of the balls as stated above is, as a matter of fact, not a proper problem. The theorem of probability theory which applies here (it is known as Bayes' theorem, and it was first developed by a clergyman) makes clear just how the experimental evidence of the sample justifies one in changing a previously held opinion about the contents of the box; but the application of the theorem requires you to have an opinion prior to the experiment. You cannot construct a conclusion concerning the probability of various mixtures out of the experiment alone. If many repeated experiments continue to give the same indication of one third white and two thirds red, then of course the evidence becomes more and more able to outweigh a previously held contrary opinion, whatever its nature.

Recently there have been developed powerful new methods of dealing with situations of this general sort, in which one wishes to draw all the justified inferences out of experimental evidence. Although Bayes' theorem cannot be applied unless one possesses or assumes prior opinions, it has been found that other procedures, associated with statistical theory rather than pure probability, are capable of drawing most useful conclusions.

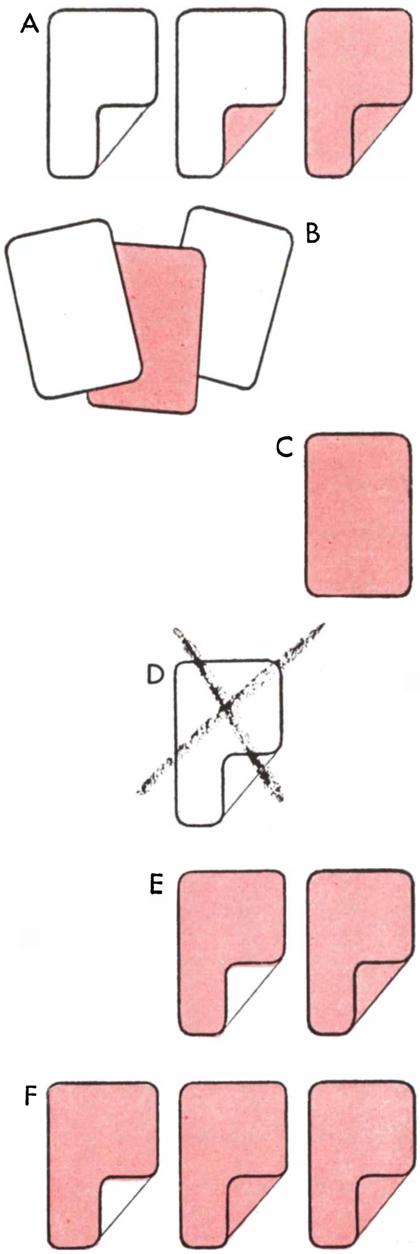
WHAT does a probability mean? What does it mean, for instance, to tell a patient: "If you decide to submit to this surgical operation, the probability that you will survive and be cured is .72"? Obviously this patient is going to make only one experiment, and it will either succeed or fail. What useful sense does the number .72 have for him?

The answer to this—and essentially to any question whatsoever that involves the interpretation of a probability—is: "If a large number of individuals just like you and just in your present circumstances were to submit to this operation, about 72 out of every 100 of them would survive and get well. The larger the number of individuals, the more likely it is that the ratio would be very close to 72 in each 100."

This answer may at first seem a little artificial and disappointing. It admittedly involves some entirely unrealizable conditions. A complicated intuitive process is required to translate the statement into a useful aid to the making of decisions. But experience does nevertheless show that it is a useful aid.

A theory may be called right or wrong according as it is or is not confirmed by actual experience. In this sense, can probability theory ever be proved right or wrong?

In a strict sense the answer is no. If you toss a coin you expect to get about half heads. But if you toss 100 times and get 75 heads instead of the expected 50, you have not disproved probability: probability theory can easily reckon the chance of getting 75 heads in 100 tosses. If that probability be written as 1/N, you would then expect that if you tossed 100 coins N times, in about one of those N times you would actually get 75 heads. So suppose you now toss 100 coins N times, and suppose that you get 75 heads



THREE-CARD GAME, classically known as The Problem of Three Chests, illustrates deceptiveness of probability. One card is white on both sides; the second is white on one side and red on the other; the third is red on both sides (A). The dealer shuffles the cards in a hat (B), takes one out and places it flat on the table. The side showing is red (C). The dealer now says: "Obviously this is not the white-white card (D). It must be either red-white or red-red (E). I will bet even money that the other side is red." It is a poor bet for anyone else. Actually there are three possible cases (F). One is that the other side is white. The other two are that it is one or the other side of the red-red card. Thus the chance that the underside is red is 2 to 1.

not just one or two times, as you expect, but say 25 times! Is probability now disproved?

Again no. For the event that has now occurred, although amazingly rare, is still an event whose probability can be calculated, and while its probability is exceedingly small, it is not zero. Thus one goes on, again making a new experiment which consists of many repetitions of the previous experiment. And even if miracles persist in occurring, these would be, from the point of view of probability, not impossible miracles.

Thus in a strict sense probability cannot be proved either right or wrong. But this is, as a matter of fact, a purely illusory difficulty. Although probability cannot be strictly proved either right or wrong, it can be proved useful. The facts of experience show that it works.

THERE are two different—or at least apparently different—types of problems to which probability theory applies. For the first type of problem probability theory is used not so much because we are convinced that we have to use it but because it is so very convenient. For the second type, probability theory seems to be even theoretically unavoidable. We shall see, however, that the distinction between the two cases, while of practical value, is really something of an illusion.

The first type has to do with situations which may be considered deterministic but which are so complex that the outcome is for all practical purposes unpredictable. In this kind of situation we realize that the final result has depended, often in a very sensitive way, on the interaction of a large number of causes. Many of these causes may be somewhat obscure in character, or otherwise impractical of detailed study, but it is at least thinkable that science could, if it were worth-while, analyze every cause in turn and thus arrive at a theory which could predict and explain what happens. When, in such circumstances, we say that the main final result "depends upon chance," we merely mean that, conveniently for us, the very complexity that makes a detailed analysis practically impossible assures an over-all behavior which is describable through the laws of probability.

Perhaps tossing a coin is again the simplest and most familiar illustration of this kind of case. There seems to be no essential mystery about why a coin lands heads or tails. The exact position of the coin above the table, the velocities of movement and spin given by the fingers, the resistance of the air, and so on—one can state what he needs to know in order to compute, by well-known dynamical laws, whether the coin will land heads or tails. But such a study would be very complicated, and would require very precise and extensive quantitative information.

There are many situations of this sort in serious everyday life, where we use probability theory not because it is clear that "chance" plays some obscure and mysterious role but primarily because the situation is so complicated, so intricately affected by so many small causes, that it is prohibitively inconvenient to attempt a detailed analysis. The experience of insurance companies, the occurrence of telephone calls and the resulting demands on telephone traffic and switching equipment, the sampling techniques used when one wishes to estimate the quality of many objects or the opinions of many individuals, the ordinary theory of errors of measurement, problems in epidemiology, the kinetic theory of gases—all these are practical instances in which the causes are too numerous, too complicated, and/or too poorly understood to permit a complete deterministic theory. We therefore deal with these subjects through probability. But in all these cases we would say, with Poincaré, that chance "is only the measure of our ignorance."

THE second type of probability problem at first sight seems very different. Most scientists now believe that some of the most elementary occurrences in nature are essentially and inescapably probabilistic. Thus in modern quantum theory, which forms the basis of our working knowledge of the atom, it seems to be not only impossible but essentially meaningless to attempt to compute just where a certain electron will be at a certain instant. All that one can do is reckon, as through the Schrödinger wave equation, the values of a probability position function. One cannot predict where the electron will be—one can only compute the probability that it will or will not be at a given place or places. And any attempt to frame an experiment that would resolve this probability vagueness, by showing just where the electron is, turns out to be a self-defeating experiment which destroys the conditions under which the original question can be asked.

It is only fair to remark that there remain scientists who do not accept the inevitable role of probability in atomic phenomena. The great example, of course, is Einstein, who has remarked in a characteristically appealing way that "I shall never believe that God plays dice with the world." But it is also fair to remark that Einstein, for all his great genius, is in a small minority on this point.

The problems that involve probability in this inescapable way are of the most fundamental kind. Quantum theory and statistical mechanics, which combine to furnish a large part of the basic theory of the physical universe, are essentially built upon probability. The gene-shuffling which controls inheritance in the living world is subject to probability laws. The inner character of the process of communication, which plays so great and so obvious a role in human life, has recently been found to be probabilistic in nature. The concept of the ever forward flow of time has been shown to depend upon entropy change, and thus to rest upon probability ideas. The whole theory of inference and evidence, and in fact of knowledge in general, goes back to probability.

We are now in a position to see that the two types of probability problems are, if we wish to be logically precise, not so different as we first supposed. Is it correct to think of the fall of a coin as being complicated but determinate, and the position of an electron as being essentially indeterminate? Obviously not. From a large-scale and practical point of view, one could doubtless deal quite successfully with coin-tossing on the basis of very careful actual measurements, plus all the analytical resources of dynamical theory. It remains true, however, that the coin is made of elementary particles whose positions and motions can be known, as science now views the matter, only in a probability sense. Thus we refine our original distinction between the two types of cases by saying that the second type, whatever the scale involved, is essentially indeterminate, whereas the first type involves large-scale phenomena which may usefully be considered determinate, even though these large-scale phenomena depend ultimately on small-scale phenomena which are probabilistic.

SCIENCE deals (as in mathematics) with statements about theory which are logically accurate, but to which the concept of "truth" does not apply; it also deals (as in physics) with statements about nature which can never in a rigorous sense be known to be true, but can at best only be known to be highly probable. It is rather surprisingly the case that the only time man is ever really sure is not when he is dealing with science, but when he is dealing with matters of faith.

There is, moreover, some justification for saying that in science probability almost plays the role that faith does in other fields of human activity. For in a vast range of cases in which it is entirely impossible for science to answer the question "Is this statement true?" probability theory does furnish the basis for judgment as to how likely it is that the statement is true. It is probability which, in an important fraction of cases, enables man to resolve the paradoxical dilemma pointed out by Samuel Butler: "Life is the art of drawing sufficient conclusions from insufficient premises."

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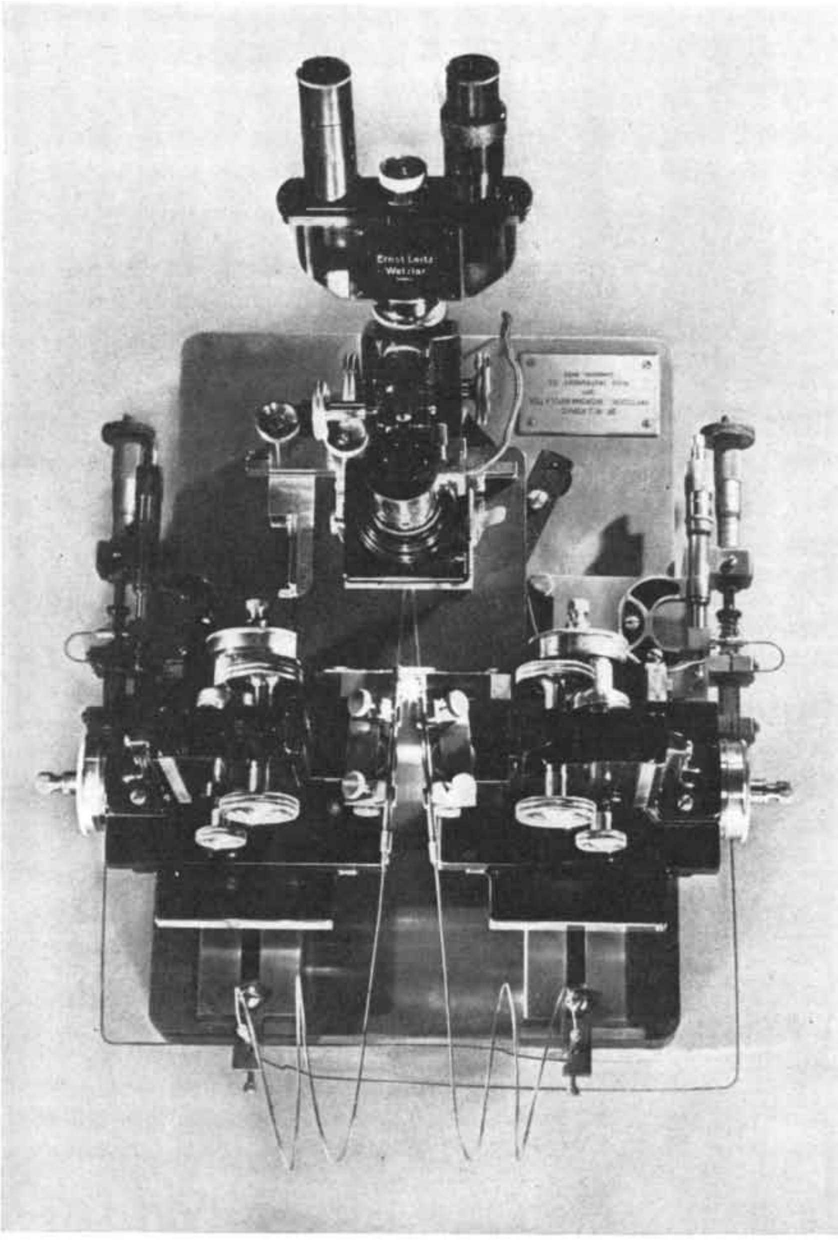
MICROSURGERY

The development of the micromanipulator makes it possible to perform operations upon individual cells without killing them

by M. J. Kopac



PRECISION MICROMANIPULATOR permits the insertion of two micropipettes into cells on the stage of a special inverted microscope. At the upper left and right of the photograph are micrometer-controlled syringes.

PROTOPLASM, the substance which Thomas Huxley described in 1868 as the "physical basis of life," is rather difficult to handle and measure physically. It is packaged in microscopic units—the living cells—so tiny that an operation on a cell with the point of the finest sewing needle by the steadiest human hand would be like trying to shave a man's face with a bulldozer. To work in the Lilliputian world of the cell, one obviously needs Lilliputian instruments. In recent years such high-precision instruments have been developed, and microsurgery on cells, known as micrurgy (from the Greek *micros,* small, and *ergon,* work), has become an important part of the study of protoplasm.

It is not too difficult to make delicate needles and pipettes of drawn glass that are fine enough to operate on a cell without killing it. The problem is to manipulate them with sufficient precision. This has been made possible by a device called the micromanipulator, a finely adjusted contrivance of screws and levers that controls the movements of the minute needles and pipettes with great delicacy under a high-power microscope (*see cover*). With a micromanipulator one can cut a cell into tiny fragments, remove the cell's nucleus or even its chromosomes, and inject fluids into either the nucleus or the cytoplasm. For many microoperations the microsurgeon uses two micromanipulator units, so he can operate simultaneously with two needles, two pipettes or a needle and a pipette.

THE creation of an apparatus for the microdissection of cells was suggested as early as 1844 by the Czech physiologist Johannes Evangelista Purkinje, who coined the word protoplasm as a name for the "formative material" of embryos and proposed to study embryonic material by taking it apart under a microscope. Apparently the first actually to build and use such a device was the physician Henry D. Schmidt of Philadelphia and New Orleans. In 1859 he described his "Microscopic Dissector," an ingenious instrument consisting of three separate units, each of which provided a three-way movement for a hand-ground steel needle. With this instrument, minute dissections were performed on small fragments of liver tissue. Although Schmidt's needles were large by present standards, he could tear individual liver cells, expose the cell contents and even liberate the nuclei.

In 1907 the physiologist Jesse F. McClendon devised a "mechanical hand" with which he could remove the chromosomes from starfish eggs at the time of maturation. His instrument placed a micropipette near the polar body of the egg, and the nuclear structures were then sucked out with a simple mouth pipette. The enucleated eggs, on insemination by starfish sperm, developed in the usual manner, showing no striking differences from normal eggs.

Meanwhile two bacteriologists, S. L. Schouten of Holland and Marshall A. Barber of the U. S., were independently developing important refinements in micrurgy. For the purpose of isolating individual bacterial cells and other microorganisms, they designed fine glass needles and pipettes and mechanical devices to control them, Schouten working with needles and Barber with pipettes. One of their very useful innovations was the hanging-drop technique, whereby a drop of water containing the cells is suspended from the bottom surface of a thin cover glass under the objective lens of the microscope. This method made microoperations possible even under the highest magnifications, and it is still commonly used. There is now available, however, an inverted microscope which eliminates several undesirable features of the hanging drop.

Barber left an impressive heritage to students of protoplasm. The Barber pipette holder was one of the earliest devices that permitted microoperations on living cells, and his directions for making microneedles and pipettes by hand are still followed by most investigators, although there are now several machines for making these delicate glass instruments. Barber also developed ingenious methods for microinjecting and withdrawing substances from cells, and was the first to report the removal of the nucleus from the living amoeba with little apparent immediate injury to the organism. The removal of the nucleus of an amoeba is a beautiful example of microdissection; it is one of the basic operations performed by all students in the Micrurgical Laboratory at New York University.

DURING recent decades a number of workers have added to the technique in various ways. They include J. A. Reyniers and his staff at the University of Notre Dame, who have made considerable progress in instrumentation; the late Charles Vincent Taylor of Stanford University, who made some classic studies of protozoa; Pierre de Fonbrune of the Pasteur Institute, who transferred the nucleus from one amoeba to another; William Seifriz of the University of Pennsylvania, who studied especially the colloidal properties of plant cells, and Tibor Péterfi of Germany, who developed many instruments and coined the term micrurgy. But perhaps the most influential of the pioneers in micrurgy was George Lester Kite, who in the summer of 1912 in the Marine Biological Laboratory at Woods Hole began some microdissection studies on living cells that launched an important new approach. It was Kite who pointed out that this technique was a means of establishing beyond doubt the reality of chromosomes, nucleoli, mitotic spindles and the other mysterious structures of the tiny, still largely unplumbed cell.

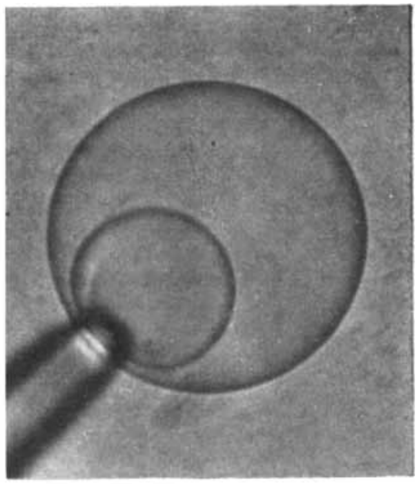
Kite's untimely death at the age of 37 was a devastating blow to biological science. But under his "inspiration," in the words of the official minutes of the American Society of Zoologists, other workers took up the problems he had begun to investigate "in the field where zoology, chemistry and physics meet." One of these workers was Robert Chambers, who had collaborated with Kite in a study of the nucleus during that summer of 1912 at Woods Hole. For nearly four decades Chambers (now New York University's distinguished professor emeritus) has carried on extensive investigations which have contributed much to our knowledge of living cells.

Chambers designed a new micromanipulator and a simple, workable method for microinjection. Copies of his equipment are now used all over the world. The Chambers micromanipulator, a beautifully designed instrument, may be used and even misused for years without becoming utterly unserviceable. It is perhaps the only type of micromanipulator that may be placed with confidence in the hands of beginning students of micrurgy.

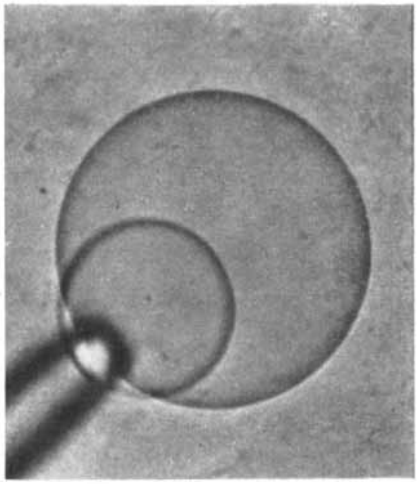
One of the outstanding results of Chambers' microinjection work has been the determination of the concentration of hydrogen ions in protoplasm. This is done by injecting *p*H indicator dyes into cells and measuring the concentration of ions by the change in color of the dyes. Important information about protoplasm has also been obtained by injecting water solutions of salts, but these results are less clear-cut than those with the *p*H dyes, because no one has yet been able to develop a micropipette that can measure with sufficient precision the amount of solution injected.

IT IS possible, however, to get quantitative results when the injected material is a water-insoluble substance, such as an oil. When oil is injected into a cell, it forms a perfectly spherical drop. The amount injected may therefore be determined merely by calculating the volume of the drop from its measured diameter. Another important feature is that there is no mixing of the oil substance with the protoplasm. Consequently the only place where any interaction between the protoplasm and the oil can occur is on the surface of the injected drop. Thus the area of the interaction can readily be calculated.

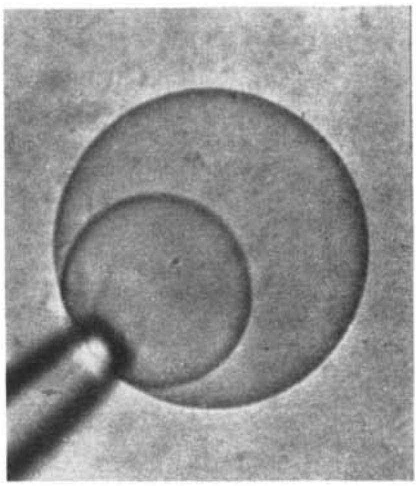
When oil is injected into protoplasm and the cell is caused to disintegrate, a dramatic event often follows: the oil drop spontaneously and rapidly crinkles and soon becomes a wrinkled mass totally unlike the original sphere. This peculiar effect has been a means of



TWO MINUTES after injecting oil drop (*large circle*) into protein solution, drop can only be partly retracted without crinkling (*small circle*).



FIVE MINUTES after the drop was first exposed to solution, it cannot be retracted as far. More protein molecules have unfolded on its surface.



TEN MINUTES after first exposure, retracted drop is still larger. Phenomenon shows progressive unfolding of protein molecules on the drop.

studying some extremely interesting properties of protoplasm.

The first question was: What is the cause of the crinkling? It never appears unless there is appreciable destruction of protoplasm around the oil. Several experiments quickly established that the reaction is due largely to the action of interfacial forces on proteins in the protoplasm. Proteins ordinarily are folded in spherical, rod or disk shapes. When exposed to surface or interfacial forces, these molecules frequently unfold to form thin platelets, usually only one fourth of their original thickness. The unfolding of the proteins of course increases their surface area requirements, and this forces more oil surface into contact with them. It is this spontaneous increase in interfacial area that produces the crinkling and spectacular deformation of the oil drop.

The unfolding of a protein from a three-dimensional structure to an essentially two-dimensional platelet is called surface denaturation. To study it further an apparatus was devised whereby the size of an oil drop could be increased or reduced at will. This drop retractor uses special syringes with which the oil drop, poised on the tip of a specially constructed micropipette, is enlarged or reduced. The three drop retractors and micromanipulators in use in our laboratory can regulate the diameter of a drop in steps of less than one thousandth of a millimeter.

When an oil drop is injected into protoplasm, a certain number of protein molecules will cling to its surface—some unfolded, some partially unfolded, and some in their normal three-dimensional configuration. The normal, folded molecules are most easily displaced from the drop's surface. As the drop is retracted, reducing its surface area, these molecules are expelled. Eventually only the unfolded protein molecules remain on the drop. They cannot be displaced; hence no further reduction of the interfacial area is possible. Now as the volume of the drop is reduced, its surface, like the irreducible skin of a drying prune, must crinkle.

The drop-retraction technique may be used to give quantitative data on the surface chemical behavior of proteins. As the drop is slowly retracted, just before the crinkling appears the drop quivers, due to extraneous vibrations always present in the laboratory. This signals the fact that the critical surface area, *i.e.*, the smallest area that will accommodate all the protein molecules trapped at the interface, has been reached. The critical area may then be calculated from the diameter of the drop at this point. The drop is enlarged to its original volume, and some time later the retraction is repeated and the new critical area is determined. The ratio of the critical area to the original area gives a measure of the fraction of the interface occupied by surface-denatured proteins at any time. These ratios may be plotted against time on a graph and this conveniently indicates the approximate rate of unfolding of the proteins.

THE effects of 75 different oils and other water-insoluble fluids on various proteins have been tested. The extent to which proteins unfold, at any given interface, depends on the type of protein, its concentration and the pH and salt content of the medium. It has also been shown that certain chemical agents may enhance the denaturation of proteins by a given oil. One of these agents is a drug known as stilbamidine; a small amount of it, added to a solution of plasma albumin, tremendously increases the surface denaturation of the albumin, particularly if the oil used is tricaprylin plus palmitic acid. On the other hand, there are agents that reduce the surface denaturation of proteins. Some of these agents, like protamine, may prevent the proteins from reaching the interface, while others, like propamidine, appear to strengthen the structures within the protein molecules so that their susceptibility to surface denaturation is reduced. Another interesting result is that the action of these agents—both the accelerating and the inhibiting kinds—is neutralized by the addition of nucleic acids to the mixture.

The drop-retraction technique is sensitive enough to be applied to some of the larger cells. One of these is the starfish oöcyte, which possesses a large, more or less structureless nucleus. It is possible to inject an oil drop into the cytoplasm and to maintain continuity between the oil and pipette without killing the cell. If the drop is later retracted, a crinkling effect will appear, but not before the interfacial area is drastically reduced. These experiments, demonstrating surface denaturation of proteins in the living cell, explain why oil drops never crinkle spontaneously in the absence of appreciable protoplasmic destruction. In their normal folded condition the protein molecules do not fully cover the interfacial area of the injected oil. When unfolded molecules are present, retraction of the oil drop permits them to cover the surface completely, and crinkling can then occur.

THE microinjection method promises to help in the investigation of the tiny bodies within the cell, such as nuclei, mitochondria and various other particles, many of which are rich in enzyme complexes whose functions biochemists would like to study. The problem is to develop media in which these subcellular particles may have a chance of retaining at least some of the properties they possess in the intact cell. One way to find such media is to inject test solutions into cells. If the test material causes extensive agglutination or disintegration of the visible particles in the cell, it is obviously unsuitable as a medium, but if it produces no visible changes, it may serve as a reasonably adequate environment for the isolated particles after the cell is fractionated. Another test would be to tear the cell in the experimental solution and see if the released subcellular particles retain their normal appearance.

For example, microinjection studies showed that a certain mixture of salts had no apparent toxic action on the cytoplasm of the amoeba. When the amoeba was torn with a microneedle in this medium, it was impossible to distinguish between the particles in the disintegrated portion of the cell and those in the surviving part of the living amoeba. However, when an oil drop was injected into this disintegrated protoplasm and then retracted, the proteins in the broken cell were considerably more susceptible of surface denaturation than those in living protoplasm. Clearly, then, the salt medium as tested was not ideal.

It is remarkable how little injury is produced by the injection of most oils into cells. For example, when a drop of oil is injected into a dividing egg of the sea urchin *Lytechinus,* it rarely inhibits division of the egg, even though the drop may have been placed in the path of the cleavage furrow. In fact, the oil drop itself, like the egg, is frequently pinched in two.

In general, little if any surface denaturation of proteins occurs when oil drops are introduced experimentally into living protoplasm. Just why this is so is not yet known. It may be that in living substance the proteins possess an integrating collective architecture that forms protein aggregates and prevents them from unfolding readily. Or the protoplasmic proteins may be associated with substances which either prevent the proteins from reaching the surface of the oil drop or which so reinforce their structures that surface forces are inadequate to induce extensive unfolding. The striking increase in surface denaturation of the protoplasmic proteins that follows the disintegration of a cell may be due to the breakdown of either or both of these protective devices.

Progress in the investigation of the physical properties of protoplasm, which was largely initiated by Kite's microdissection studies, has been frustratingly slow. But it is clear that these micromanipulative techniques have great potentialities, for they offer the most direct known experimental approach to living cells.

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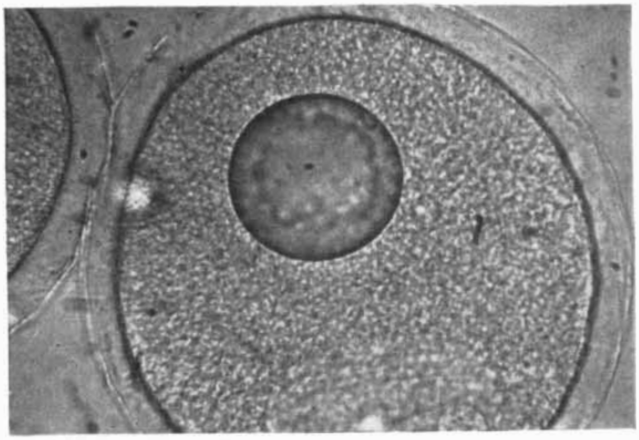
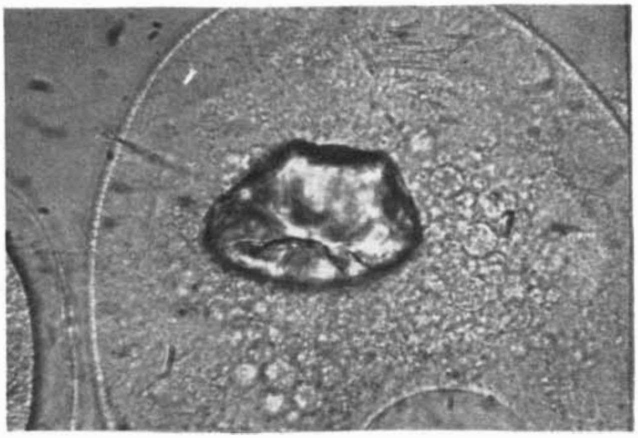
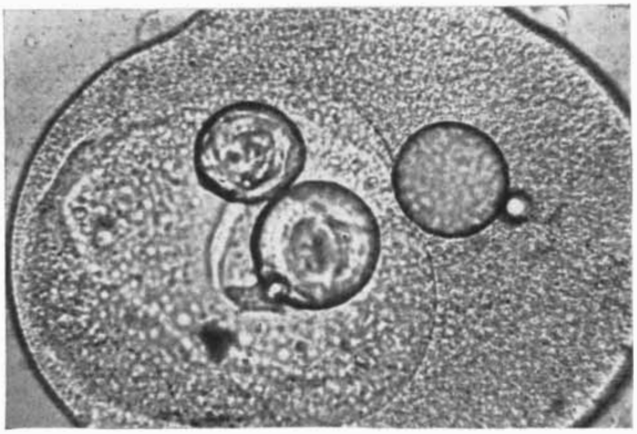


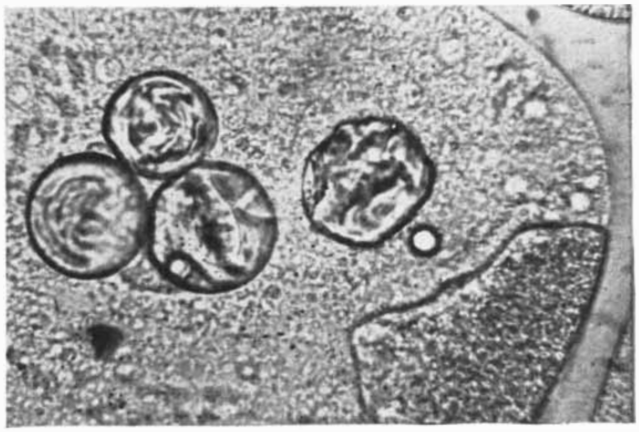
LIVING CELL contains a smooth spherical oil drop (*smaller circle near top*). The cell used in this experiment is the immature egg of the starfish. The drop was placed within the cell by means of a micropipette.



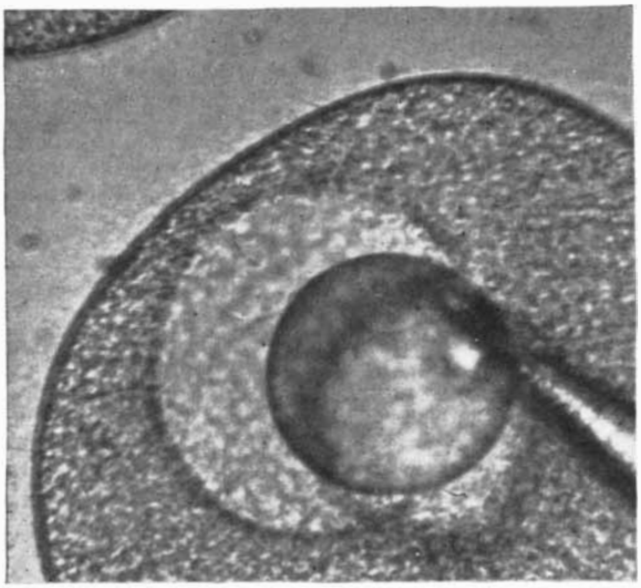
DEAD CELL contains a deeply crinkled oil drop. The crinkling, which is due to the unfolding of denatured protein molecules on the surface of the oil drop, was completed 30 seconds after the cell had been killed.



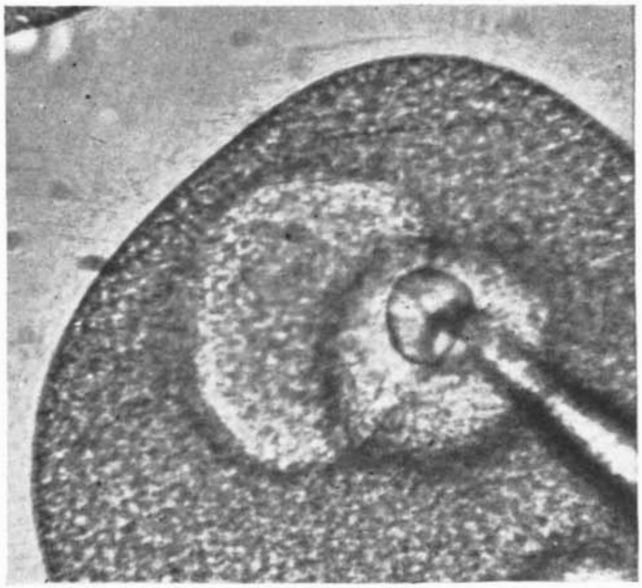
CRINKLED AND SMOOTH oil drops show that protoplasm must be appreciably broken down before crinkling occurs. Drops at left are in partly destroyed region of cell; drop at right is in region more or less intact.



CRINKLED drops show the progress of disintegration in the same cell as that at left. The third drop is also crinkled, as is a fourth drop which was injected into the disintegrating area after the process was under way.



DROP IS INJECTED into a starfish egg near the nucleus, one of the most sensitive regions of the cell. The nucleus is the light area behind the oil drop. The tip of the micropipette may be seen at the right.



DROP IS RETRACTED into micropipette until crinkling occurs. Around the crinkled drop is a region of protoplasm disintegrated by contact with the original drop. Denatured proteins in this region caused crinkling.

The Kuanyama Ambo

A tribe of the Bantu people in South-West Africa is an example of how a society generates social controls to meet the conditions of its existence

by Edwin M. Loeb

EVERY society is geared to a complex set of social controls which are an important part of its culture. The controls serve to keep the society adjusted to its total environment; they act to preserve the society's life and to furnish the society as a whole with the maximum of pleasure and the minimum of pain. In the insect world, where social organization is not uncommon, the controls are instinctive. In civilized society they usually are conscious, in the form of written or unwritten laws. Among primitive peoples they are often unconscious. In any society, primitive or civilized, those social controls that are unconscious change automatically, usually without the awareness of its people, to meet changes in the society's environment.

The most convenient place to study social controls is in homogeneous primitive societies, where the control mechanisms are relatively simple and easy to relate to the physical environment. Such a study was made in 1947-48 by members of the University of California African Expedition among the native peoples of South-West Africa. These natives may be taken as examples of various stages in the development of social controls. Four groups were investigated; in the order of their social development, from the most primitive to the more advanced, they were the Bushmen, the Hottentots, the Berg Dama and the Bantu. This article will deal particularly with one of the more advanced native societies: a tribe of Bantu called the Kuanyama Ambo.

The Bushmen probably were once widespread throughout Africa but now have been driven back by the more advanced races to the fringes of the Kalahari Desert. They are one of the most primitive groups known to man. The pure Bushman is quite childlike in appearance. He is short of stature, yellow-skinned, round-headed, hairless on face and body and has tufted ("peppercorn") head hair. He is especially marked by steatopygia—the growth of fat and muscle on the buttocks. Many Bushman features suggest the Mongoloid rather than the Negroid race. The language of the Bushmen consists largely of clicks (made by striking the roof of the mouth with the tongue, as in urging on a horse), which are considered a very early form of human communication. Still a hunting and fishing people thinly dispersed on the land, the Bushmen have no real chieftaincy and only the simplest social controls. Their unconscious controls have operated to enable them to adapt in a very primitive way to the change from the fertile areas where they once lived to the desert where they have been driven; *e.g.*, they have learned to store water in ostrich egg shells under the sand and drink the buried water through long "straws." Their conscious controls consist for the most part in instructions given boys and girls at the time of their tribal initiations, which are intended to teach the boys courage ("make men of them") and to test the girls for endurance. The Bushmen were once noted for their chiseled art, which may date back to the European Old Stone Age, but in their present habitat, which lacks stone cliffs for their drawings, they have unconsciously lost this art.

THE HOTTENTOTS, intermediate in physical appearance and height between the Bushmen and the Caucasians, appear to be Bushmen who mingled with Hamiticized Negroes farther north in Africa. From the latter the Hottentots received the precious gift of cattle-raising. They unconsciously also received from their neighbors the patrilineal clan system, which is well adapted to a cattle economy, since inheritance runs along the line of male herdsmen. The Hottentots, like the Bushmen, use clicks in their language, but to a far smaller extent. They have head men who supervise simple rules of conduct. They are, however, without any form of autocracy.

The Berg Dama, a true Negroid population unrelated to the Bushmen, were enslaved by the Hottenots very long ago. They still have Hottentot habitations, language and customs, and unconsciously wish to be actual Hottentots, but this, because of their appearance, will forever be impossible. Since their emancipation from slavery to the Hottentots, the Berg Dama have developed rather more elaborate social controls of their own.

The Bantu, who are Negroes with a white Hamitic admixture, divide into three groups: the Herero, a cattle-raising people who live in an area where agriculture would be difficult; the Okavango River people, who have acquired a few cattle in recent times and practice agriculture and fishing, and the Ambo, who live in the most fertile section of South-West Africa and have the most versatile economy, including cattle-raising, agriculture, fishing, hunting and food-gathering. All the Bantu have clan systems which automatically control the complex relationships of family, inheritance and social life. The Ambo, however, have the most elaborate system, formerly headed by a king.

Even a cursory comparison of these various peoples shows that as the complexity of economic life increases, so do the density of population and the intensity of social controls. The Bushman territory, with about 9,000 natives, is the most thinly populated; while Ovamboland, the home of the Ambo, has about 150,000 and is the most thickly populated area in South-West Africa. There is a similar gradation in political control, ranging from the simple hunting leader of the Bushmen to the kingship of the Ambo. Moreover, there is a considerable difference in the adaptability of these societies: the more advanced a primitive community is, the more rapid are the changes in its customs and its social control systems. The customs of the Bushmen presumably have remained largely unchanged for thousands of years, while the customs of the Kuanyama Ambo have altered rapidly in the past century.

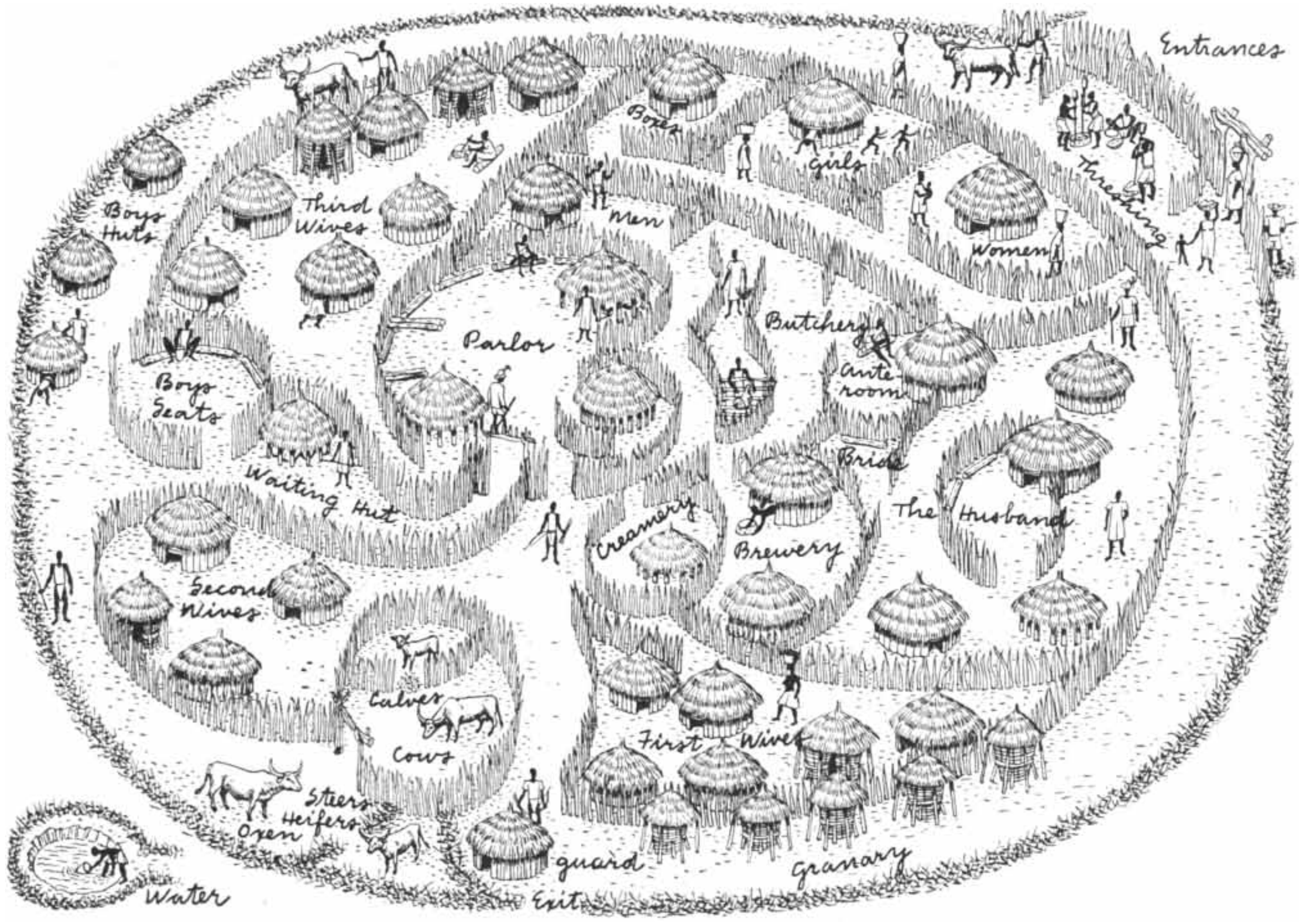
LET us now take a closer look at the Kuanyama Ambo. Their society offers a good illustration of the unconscious application of complicated social controls among a relatively primitive people.

The Kuanyama, the most northerly of the Ambo tribes, live partly in Angola and partly in Ovamboland, between 17 and 18 degrees south of the Equator. The Ovamboland territory is a high, sandy flood plateau, 3,300 feet above sea level. It has a subsoil sufficiently rich to permit the growth of grass cereals, concurbitants and legumes during the short but intense rainy season from January to March. The rainfall averages 17 inches a year, but is uncertain both in amount and in timing. This fact entails a rigid system of social controls relating both to horticultural practices and to religious rituals, since the ancestors are thought to produce or hamper the rainfall. The seasonal nature of the precipitation also makes the sex division of labor more pronounced. In the wet season the women carefully plant their crops in hillocks above the flood, and weed and transplant the growing grain. In the dry season the boys and young men take their cattle to pasture in the meadows of Angola, and the Kuanyama blacksmiths also go to Angola to fetch iron ore, since Ovamboland itself lacks minerals.

The Ambo live in stockaded, corral-like settlements called "kraal," each a self-governing city in miniature. This basic unit of social control is very directly related to economic circumstances, for the kraal's cattle and the produce from its 10 to 20 acres of surrounding garden are carefully guarded within the kraal walls. The inhabitants of a kraal are the husband, who is its head, from four to 20 wives, their children, relatives and servants. Each wife is responsible for storing and rationing particular food staples. The first wife, the most important both ceremonially and economically, has charge of the milk, butter and seasonal foods and has her sleeping hut near the sacred fire, which she attends. The fire must never be allowed to go out so long as the kraal owner and the king remain alive, else an omen of disaster is cast over the kraal.

The Kuanyama have a feudalistic system of government. It is now under European supervision, which has changed it somewhat; the account that follows will describe the society that existed while the Ambo still ruled themselves. At the head of all the Kuanyama Ambo was a king who lived in a royal kraal near Ondjiva in Angola, now in ruins but still called the "palace" by the Kuanyama. It was an immense structure surrounded by acres of gardens. Here the king kept his harem, at the head of which was the queen mother and her sisters.

The king was considered to be the physical embodiment of the native high god Kalunga, and was often called Kalunga. As surrogate of the god, he was entrusted by the divinity with the sacred fire, the sacred water and the sacred sheep—the three most precious embodiments of power among the Kuanyama—and these the king gave out to his people. He was the tribal rainmaker. Theoretically the king was the owner not only of all the land but also of all the cattle, the crops and the inhabitants of the country. He appointed a number of noblemen, selected for valor in battle, to rule over districts, and they in turn sold to each kraal owner the lease on his land. (Today the white commissioner of



KRAAL DWELLING of the Kuanyama Ambo is a big stockade divided into sections for various kinds of people and domestic functions. Once the king of the Kuanyama Ambo had a kraal with labyrinths to prevent regicide.

South-West Africa, who has replaced the king, appoints the district heads.)

Through a cannibalistic feast the monarch gained supernatural strength on his ascension to the throne, and he was anointed with the fat of a lion to bestow on him mystical identification with that totemic animal. The monarch usually obeyed the advice of the queen mother, but otherwise was "above the law." Descent was counted through the mother, and the king was permitted to marry only outside his own clan, but he could carry on love affairs with any women he pleased, except his own mother and her sisters. Special terms of respect were employed when speaking about the monarch, his dwelling, or his actions, and the penalty for touching his person or utensils was death.

REGICIDE, as long ago pointed out by the great English anthropologist Sir James Frazer, was a national custom in pre-Roman Italy and much of Africa. The Kuanyama had the proverb "He who kills the king becomes king," and the royal kraal was always being built into new patterns of stockaded mazes and labyrinths to protect the king from overenthusiastic brothers and nephews who were potential heirs to the throne. Since the rainmaking monarchs of Africa held in their persons the welfare of the land, it was deemed unwise to allow them to become old or sick, and fatal to permit them natural deaths. The Kuanyama ruler knew that a faithful attendant held himself in readiness to smother him with a small piece of the sacred lamb skin in case of dire illness, while a young girl who acted as fire-keeper was ready to be buried alive with her monarch and thus serve him in the next world.

There is, of course, a striking contrast between the glorious figure of Queen Victoria, with her diamond crown, her ermine robe, her glittering court and her position as "Ruler over England, Scotland, Ireland and Wales, and Empress of India," and the ragged, tottering, drunken apparition of the Kuanyama king as he stood prepared for coronation after his preliminary feast of mixed meat and human flesh. Over his shoulder he wore a tanned human skin (a relic of his cannibalistic meal), and other parts of his anatomy were draped with strips of the skins of the sheep, the lion, the leopard, the elephant, the badger, the puff adder, the giant mamba snake and various other animals. When the new ruler, so attired, stepped before his people to greet them, his subjects, reports an old chronicle, "fled in terror."

Yet this grotesque African figure can by no means be considered a shabby imitation of his European confreres. It is rather the European monarch who is a survival of the primitive king. The Kuanyama king Haimbili, who held sway over an African feudal aristocracy 100 years ago, exemplifies the primitive origins of the kingship institution. He presided over an elaborate court, complete with nobility, an army, page boys, secret police and hangmen. He announced when game was to be hunted; he opened the fishing season and received his share of the fish; he gave permission for the gathering of crops, out of which he also received his share; he even exercised certain powers of life and death for the control of the number of his subjects. But his powers were far from absolute. The Kuanyama ruler, like all primitive kings, was not a lawmaker; the edicts he issued were for the most part merely formal recognitions of natural events and unconscious controls. All the close relatives in his clan shared his prerogatives, and on the day of his coronation he was publicly given advice by his councilors. When he became too tyrannical, he was liable to assassination. And every Kuanyama ruler was compelled to kill his plebeian father when he came to the throne; though many must have objected to the custom, all conformed. It was not until 30 years after the missionaries had arrived that the last king of the Kuanyama, Mandume (1910-1917), took it upon himself to reform certain abuses, including abortions on unmarried girls and witch-killing.

In spite of malarial epidemics when there was plentiful rain, and famine when there was little, the growth of population became an increasingly acute problem among the Kuanyama. Various unconscious controls developed to protect the tribe against the overpopulation danger. By order of the king children born of unmarried mothers, and sometimes their parents, were put to death, on the ground that an unnatural child would ruin the country; children who grew their upper teeth before their lowers had erupted were also killed for the same reason. In the latter part of the 19th century, the marriageable age of Kuanyama men was postponed to about 28, and even then a man was not allowed to be a kraal owner with a retinue of wives until he had undergone a second marriage ceremony with his first wife at the age of about 38.

BRIDES of the Kuanyama Ambo wear marriage headdresses and aloe sticks representing porcupine quills. They are anointed with termite mud.

THE KUANYAMA system of justice also was subject to unconscious controls. The king and his nobles, who dealt with the graver crimes, such as theft, mayhem, murder and witchcraft, were often venal and sold decisions to the highest bidder or punished innocent people who had fallen into their disfavor. Yet the necessities of the native economy operated in a crude way to restrict these excesses and even to promote a system of social justice. The matrilineal system of inheritance, which did not permit a man to leave his herds to his sons but distributed them among his nephews and more distant relatives, prevented the accumulation of wealth in the hands of a few. A man who attracted attention by display of too many cattle was liable to fall under the displeasure of the court; his life might be endangered and his goods confiscated. The Kuanyama proverbs, which took the place of laws, exhibit a spirit of fair play: parents were looked after when they became old; the sick and blind were given food and shelter; peace within the kingdom was regarded as a blessing. Tranquillity, both here and hereafter, was the aim of social etiquette and moral law.

Another devious form of social control among the Kuanyama was exerted through the ceremonial songs sung at moonlight dances of the young people and at a spring cattle ceremony. The herdboys were rewarded or condemned, and unpopular members of either sex were ridiculed in mocking songs. A month before the spring communal marriage ceremony, the young people camped together and enacted the roles of married couples. The boys hunted in the daytime while the girls cooked and set up housekeeping; in the evening the couples often secretly but chastely slept together, *i.e.*, "bundled." When the boys came home with booty from the hunt, they raised a cry, and switched the girls with branches—especially those who had refused their "bundling" advances. Before settling down in marriage, Kuanyama girls now roam the country as "ash girls" or sacred spirits, assume male names and personalities, and take their turn beating their former lovers and snatching away their kerrie-sticks, the emblems of their manhood.

Much of the old tradition is gone forever from Ovamboland. Today many of the Kuanyama are Christians, and under the white man's rule controls are in a great measure exercised through laws. The Kuanyama have ceased warfare and training for warfare and have become gentle in nature.

OUR comparative study of the peoples of South-West Africa suggests these conclusions: The more advanced the economic life of a society and the smaller its dependence on its immediate organic environment, the greater is its density of population, the more elaborate and conscious is its system of social controls, and the more rapidly can it change its controls to meet new conditions. This, of course, gives the higher cultures added survival value. At the same time, even the highest present-day cultures still retain residues of unconscious controls, many of them useful. Thus the "bundling" of the Kuanyama, though it has never had explicit parental approval, survived among Alpine peasants and our puritanical New England ancestors, serving the useful purpose of allowing young people to get acquainted and choose their own mates. It still survives in a modern American counterpart—the "dating, courting and petting" complex.

The study of the unconscious social controls of primitive peoples is therefore not without value to civilized society, for through such studies psychology and anthropology can bring many of our unexplained emotions and actions to the conscious level.

Edwin M. Loeb is an anthropologist at the University of California.

What GENERAL ELECTRIC People Are Saying

T. R. HAND
Apparatus Department

C. J. FALK
General Engineering & Consulting Laboratory

QUALITY CONTROL: In industrial manufacturing, every production line will produce some rejects. To keep those rejects within economic limits, a technique known as scientific quality control has been developed.

Scientific quality control employs control charts which are based on mathematical probabilities. With knowledge of past production history, it is possible to predict with a known degree of risk whether present production conditions are producing too high a reject rate. The method has often resulted in reducing reject losses in a manufacturing process from 30 to 50 percent . . .

With scientific quality control, each inspector on a production line makes a mark on a tally sheet every time he rejects a unit. A separate tally sheet is provided for each test or characteristic which he is checking. At the end of a shift or at the end of the day, these tally sheets are collected from all of the inspectors and tabulated by the quality-control engineers. Each test is then individually analyzed to see whether that particular test is falling within the predetermined economic limits. If it is found that too many rejects have occurred and the upper control limit is exceeded, then the quality-control engineer informs the production supervisor that abnormal trouble is present and corrective action is indicated. In the meantime, rejects are still being produced . . .

Quality-control engineers at General Electric's Erie Works . . . realized how much more effective statistical quality control could be if the information presented by control charts was immediately available . . . The problem presented . . . was the development of a computer which would give instantaneous quality control.

The computer should count the rejects and total production on a production line and should analyze these counts immediately . . . The Quality Control Indicator is the solution to this problem . . .

At General Electric's Erie Works . . . a 60-percent reduction in rejects followed installation of the quality control indicator on a compressor assembly line. On this line, monitoring only five tests, more than $10,000 was saved the first year by reduction of scrap and rework expense. Greater efficiency also resulted, since a production supervisor could more easily direct his efforts where they were needed. Much closer quality control was achieved . . . and the customary rise in rejects during the vacation period did not occur after the quality control indicators were installed . . .

Quality-control engineers using the computer have called it the biggest step forward in scientific quality control since the beginning of quality control itself.

General Electric Review
July, 1950

★

W. R. G. BAKER
Vice President

COLOR TELEVISION: A new system of color television, which General Electric has submitted to the FCC, provides a method of transmitting color picture information within a frequency band no wider than that used in present-day black and white transmission and could be used with either the three-tube or the single picture tube systems advocated by other campanies at the recent FCC color hearings.

This new system is called "frequency interlace." Under ordinary conditions, announcement would not be made until field tests were completed, but since the FCC is currently studying other systems, it was necessary to reveal now that the system is being tested and that these tests to date indicate technical soundness.

Among the advantages over other known systems, frequency interlace would permit relatively low-cost TV receivers, reliable in operation, easy to adjust and maintain, and simple in construction. The system is inherently compatible with present black and white standards; it would permit color broadcasts to be received in black and white on present-day receivers or black and white broadcasts to be received on color receivers incorporating the new system. It would also permit reception free of twinkle, crawl, or flicker.

Syracuse, New York
July 27, 1950

★

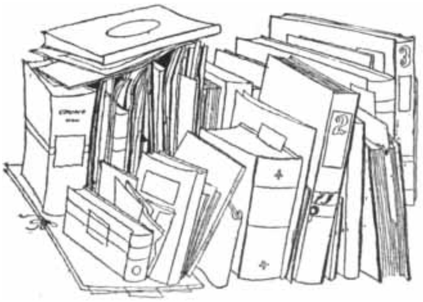
R. W. WIESEMAN
Apparatus Department

PERIODIC TESTS: The service record of a rotating electrical machine depends to a great extent on the performance of its winding insulation. Proper installation, suitable over-voltage and overload protection, normal operating conditions, and periodic inspection and testing all help the machine windings to function satisfactorily. However, windings in service are continually exposed to such adverse factors as conducting dirt, moisture, chemical action, mechanical damage, abnormal temperature, overloading, and overvoltages. It is, therefore, desirable to occasionally apply a conservative over-potential test, after inspection and cleaning, to determine the suitability of a winding for continued service. By making these tests at the beginning of planned station overhaul periods, time will be available to replace any defective coils with spare coils without loss of service time. In this way unexpected repairs made under costly emergency conditions may be avoided.

General Electric Review
August, 1950

You can put your confidence in—

GENERAL ELECTRIC



BOOKS

The economic feasibility of atomic power: a new assessment of the first importance

by James R. Newman

ECONOMIC ASPECTS OF ATOMIC POWER: An Exploratory Study under the Direction of Sam H. Schurr and Jacob Marschak. Princeton University Press ($6.00).

WHAT would it mean to the human race to discover a fuel that weighed nothing, cost nothing, was plentiful and yielded two and a half million times the energy released by an equal weight of coal? The cynic might reply that the only effect of the discovery in our age would be to multiply wars and spread human misery. It is possible, however, to envisage a less gloomy result, to speculate agreeably upon the constructive applications of this fabulous substance and the numerous benefits it might conceivably confer on society.

The fuel is, of course, now at hand, and prophecies as to its use, far from being purely fanciful, legitimately fall within the decorous province of practical thinkers. *Economic Aspects of Atomic Power* is a pioneer effort to appraise the economic feasibility of using the energy liberated in nuclear processes, the range of its industrial applications and the possible technological, social and economic consequences of its widespread utilization. It is a book which should receive the most careful attention from scholars, government officials, politicians and the more serious-minded of general readers; nothing comparable has yet appeared to illumine the many facets of this important subject.

The study was undertaken for the Cowles Commission for Research in Economics. The directors of it faced from the outset two serious limitations. The first was the dearth of information available on the purely technical aspects of atomic power; the second, the immenseness and complexity of this largely uncharted area of inquiry. Information was lacking not merely because some essential data are kept secret, but because the entire subject is relatively in infancy and most of the important questions of economic analysis are as yet unanswerable.

To reduce their analysis to manageable proportions, the authors found it necessary to confine their considerations to industrial applications based on a continually controlled release of energy within a permanent, stationary atomic reactor. Whatever the future possibilities of smaller mobile reactors, these are not dealt with in the Cowles report except to indicate that while atomic-driven automobiles and airplanes are not in prospect, atomic-driven naval vessels are today regarded as quite practical. There is also an interesting appendix showing that the factor of physical size, and certain economic factors, render unlikely the early development of the nuclear-powered locomotive.

The focus of the study is on those applications "that seem least remote today," which is to say (1) the generation of electricity by the heat obtained from a controlled chain-reaction, and (2) the transportation of low-temperature heat over short distances for such purposes as residential heating. Yet it should be borne in mind, as the authors point out, that precisely those applications likely to become practical first may not, in the long run, be important ones. Indeed, to use nuclear fuels for the production of heat, which in turn drives a steam or gas turbine generating electricity, may seem almost as unimaginative as to use electricity itself to no better purpose than to propel a surrey or ignite a Welsbach mantle. Nevertheless, no practical methods having yet been suggested for the more direct utilization of nuclear energy, the scope of the Cowles analysis is defined accordingly.

WHAT ARE the economic characteristics of atomic power? Subject to various qualifications and conditions, the conclusions of the report on this phase of its inquiry may be summarized as follows:

1. Stationary plants for the production of power through the consumption of nuclear fuel are technically feasible and economically promising, although designers admittedly still have a long way to go in finding appropriate new materials and devising an efficient nuclear engine.

2. The cost of generating electricity with nuclear fuel may be estimated at four mills per kilowatt-hour as a minimum, 10 mills as a maximum and 6.5 to 7.5 mills "intermediate." The highest figure may be taken as applicable to the first commercial plants; the intermediate, to those built five or 10 years after the earliest installations; the lowest figure represents the optimum cost that can be achieved with methods now imaginable, and it will be attained, if at all, only after many years of experience.

3. The three cost figures are derived from two major classes of data. First, it is known that a conventional coal-fueled electric plant of the most modern design with a capacity of 75,000 to 100,000 kilowatts operating at an average rate of 50 per cent capacity can produce electricity at a cost of four mills per K.W.H. (1946 prices). Taking into account the cost of power-generating equipment which would be common to both a conventional and an atomic electricity plant, and the fixed charges and operating costs other than fuel, the report concludes that "atomic power at best would be the cost equivalent of ordinary thermal power based on a costless fuel." Since one pound of nuclear fuel is the equivalent of approximately 1,250 tons of bituminous coal, for most practical purposes fissionable material may be regarded as a weightless as well as costless fuel. The initial fuel investment in an atomic reactor will not be negligible, and it will have to be written off in overhead charges. Thereafter, however, it is expected that the reactor can feed on natural uranium and thorium; in other words, the study is based on the assumption, by no means unreasonable, that the breeder technique is likely to prove successful. The second source of supporting data is the various studies of the costs of atomic power already published. It should be pointed out that at least two of the cost estimates on which the authors rely, *i.e.*, the so-called California and Thomas reports, have been severely criticized by other experts and would not be acceptable to them as a basis for their own assessments. While the Cowles report strikes its own independent estimates, it admits to having taken the studies referred to as "useful guides" to the general level of costs.

4. Although there is a paucity of accurate quantitative information on uranium and thorium deposits, the raw materials needed for atomic power plants are thought to be widely available. There are well-known rich deposits of uranium ore in Canada and the Belgian Congo; Czechoslovakian and German uranium sources, under Russian control, are reputedly ample; monazite sands, from which the highest grade thorium ores are derived, occur in abundance in India and Brazil; there is reason to believe that major uranium deposits have been located in the Union of South Africa. What is even more important, for the

U. S. and for many other countries, is that additional valuable sources of uranium, such as oil shales, are distributed all over the world. Thus it would seem "that eventually supplies of uranium and thorium may come mainly from mineral ores not formerly mined for these materials, primarily because they contain amounts which used to be considered too low for commercial exploitation." Much progress has already been achieved, and more is to be expected, in the mining and refining of these low-grade ores. Estimates have been made that U. S. reserves of "definitely minable" uranium and thorium would be sufficient to produce electric power at the 1946 level of output *for a period of 1,000 years.* If "probably minable" reserves are taken into account, the period is extended by an additional 10,000 years.

5. Under various circumstances, and in various localities, atomic power can compete favorably with coal even at a cost of five to seven mills per K.W.H. At selected points in several countries, including Norway, Sweden, Yugoslavia, Japan, Italy, Switzerland, the U. S. and the U.S.S.R., hydroelectric power is generated at four mills per K.W.H. or less; atomic power is therefore not competitive at those points. There are as many other localities where atomic power at four to six mills per K.W.H. would be competitive with water power. Among the countries where atomic power may turn out to be of the greatest significance are: Argentina and Brazil, which have negligible fuel resources and many important population centers far from potential water power; Denmark and the North African group of countries, which have negligible fuel and water-power resources; Great Britain, whose fuel supplies are dwindling, and Hungary, Italy, Austria and Switzerland.

6. Even with the use of breeder methods it might require several decades to build up fissionable stocks in the U. S. to the point where atomic power would furnish a significant part of the total energy supply. On the other hand, five or 10 years would suffice to produce stocks large enough to enable atomic power installations to contribute a substantial portion of current additions to power-plant capacity. But political factors may intervene to upset every calculation. Thus useful power may not be produced at all if the conditions required for such production are "found to be inconsistent with the maximum rate for breeding fissionable materials for use in the bomb." Since one may assume that the Chiefs of Staff as well as Congress will never be satisfied with the bomb stockpile, whatever its size and rate of growth, it is clear that continued world tension and extensive rearmament must profoundly affect the future of atomic power. In the happy, and unlikely, event that an international control system for atomic energy could be established, the prospects of atomic power development would of course be greatly enhanced. Even so, much would depend on the control policies, especially the restrictions adopted for reasons of security.

7. Finally, it should be noted that the basic cost comparison is not that of money costs but of "real costs," in the following sense: "To achieve a given level of present and future national consumption, and a given degree of national security, will it take more of a country's resources to produce an additional kilowatt-hour of power from atomic or from conventional sources?" Money costs may of course approximate real costs to the extent that private individuals and even government agencies "compete in markets and try to avoid losses." On the other hand, as soon as diplomatic, military and other politico-economic factors enter the situation, the straight comparison of money costs of energy from new and old sources must be regarded as only one of several clues to the future national development of atomic power.

AFTER this general survey of the economic feasibility of atomic power in relation to power from non-nuclear fuels, the Cowles report considers the effects atomic power might have on a selected group of energy-consuming industries. Among the industries examined are aluminum, chlorine, phosphate, cement, iron and steel, railroads and residential heating. For each of these potential users in whose manufacturing processes the cost of energy is a substantial percentage of total cost of production, the examination turns on three questions. First, would atomic power lead to cost reductions? Second, would low-cost atomic power encourage process changes "in which methods based on atomic energy would substitute for the direct fuel-burning or chemical methods used today"? Third, would changes occur in the location of certain manufacturing activities as a result of the geographical equalization of power costs? I found these analyses the most interesting and enlightening of the entire report.

The study suggests that atomic power may be of great importance in expanding and relocating the production of aluminum, now concentrated near water power; in the U. S. a new aluminum-producing center might develop in the Gulf Coast area. Atomic power would be more likely to reduce aluminum costs in France, Germany and Great Britain than in the U. S., the U.S.S.R., Canada or Japan.

Though atomic electricity would be of negligible significance in the manufacture of cement, brick and flat glass, if it were cheap enough it might induce process changes such as electrical firing instead of gas firing in glass furnaces and the heating of kilns by hot reactor gases.

It is possible that nuclear-powered hydrogen-reduction furnaces located near the major iron-ore region of northern Minnesota would permit delivery of iron to the Chicago-Gary market, and perhaps even the markets of the Pittsburgh area, at a lower cost than iron from the coke blast furnaces of the steel plants in those centers. This might bring about decentralization of the steel industry with corresponding economic repercussions. Countries such as Great Britain might apply atomic power to steel-making before the U. S., because their coking-coal reserves are more limited. And in countries such as India and Brazil, with vast iron reserves but meager or nonexistent coking-coal resources, atomic power combined with the hydrogen-reduction process could make an enormous difference in raising the per-capita level of steel output.

Extensive railroad electrification based on atomic power is not to be anticipated unless atomic electricity can be produced at the minimum estimated future cost. Diesel oil and coal will therefore continue as the major fuels, with the latter possibly used in "radically new locomotives."

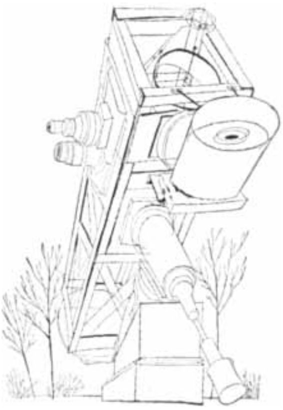
Space heating consumes a greater amount of energy than any of the industries covered in the Cowles analysis; "in 1945 the fuel consumed for this purpose accounted for almost 20 per cent of the total energy supply from mineral fuels and water power." The question is whether district heating based on "centrally-located straight heat-producing nuclear reactors" is a feasible substitute for the prevailing present system of separate heating plants in individual buildings. The authors are of the opinion that the concentrated demand required to bring nuclear district heating costs down to a competitive level exists in only a few large American cities, and even there nuclear heating would lead to no money savings; it would prevail, if at all, because of its convenience.

A general consideration is applicable to all the foregoing conclusions. In arriving at cost figures for atomic power in industry, one of the essentials involved is what is known as the "plant factor"; that is, the percentage of capacity at which the power station operates. Since fixed charges are an important element of atomic power costs, substantial cost reductions per K.W.H. are possible if capacity is more fully utilized. In not a few industries where there is a heavy, continuous energy demand, a higher plant factor might easily bring atomic power within competitive reach. For example, at 50 per cent capacity the minimum estimated cost of atomic power is 4 to 4.5 mills per K.W.H.; at 80 per cent capacity it is 2.7 to 3.2 mills, and at 90 per cent capacity it is 2.5 to 3 mills.

In sum, then, the use of atomic power by a number of principal industries may effect substantial changes in location, process, costs or combinations of these. While few of these changes measure up to the more extravagant popular notions of the revolution that atomic energy might produce, in at least one or two instances (iron and steel manufacture, for example) there are foreseeable effects of wide scope and significance.

IN THE last portion of their study the authors deal with the effects that the introduction of cheap atomic power, available anywhere, would have upon the economy of an entire nation or region. The findings are so conjectural, the supporting arguments so difficult, tenuous and theoretical, that I finished this section of the report with no more than a few vague impressions. I gathered, for example, after many pages of involved ratiocination, that atomic power may increase national income in the U. S. by one per cent or less; that it may stimulate invention and increase the demand for electricity or, on the other hand, may not do so; that it will be of greatest importance where conventional fuels are scarce, and of less importance where such fuels are less scarce. Atomic power, it is clear, is only one of a large number of technological, social, economic and political factors that will determine economic changes and the rate and direction of industrialization in many parts of the world. As the authors point out: "Atomic power may at most accelerate some processes, [but it may be] overshadowed by such factors as the rate of capital formation in slightly industrialized areas, population changes, the rate of spread of technological knowledge and skills, and government policies in relation to industry and international trade."

Economic Aspects of Atomic Power is an honest and valuable book. It is often cumbrous in organization; it also threatens, from time to time, to bog down in the usual execrable economists' jargon. (For some reason economists and social scientists persist in the extraordinary belief that their Eleusinian double-talk conveys authority.) Moreover, the book expresses many of its conclusions with such nervous reluctance to commitment that the reader will find it hard to discover just what it is that the authors are concluding. I assume that this same attitude of mind has steered the authors sharply away from any remotely controversial issues: the extent to which, for example, the lack of a coherent policy on the part of the U. S. Atomic Energy Commission with respect to the question of continued government monopoly versus private ownership may affect the future development of atomic power. All these shortcomings are fully redeemed, however, by the substantive achievements of the report, which include not only the laying of a sound foundation for all future studies in this field, but the opening to public scrutiny and understanding of a subject hitherto obscured by confused and contradictory pronouncements.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

IN ASTRONOMICAL telescopes the image appears upside down, backwards, or both. The astronomer soon comes to regard this as normal, and would be confused by a correct image of the moon or a planet. Leaving the image uncorrected saves added lenses, prisms or mirrors that would cause needless aberrations and loss of light.

In terrestrial telescopes, on the other hand, most users prefer normal, erect images. Vern E. Hamilton of Inglewood, Calif., has worked out an arrangement for turning the image right side up in the ordinary Newtonian reflector, although, as he says, the idea is probably not new. On the opposite page is a drawing of Hamilton's arrangement by Russell W. Porter, one of the last drawings Porter made before his death. Hamilton writes:

"In this telescope the conventional Newtonian diagonal is placed a little nearer to the principal mirror than usual, to allow the focal plane to extend farther beyond the side of the tube. After the cone of rays emerges from the tube it is turned back toward the principal mirror by a roof prism in the position shown.

"This arrangement completely erects the image, with top on top, left on left, and—much to be desired—with the observer facing the object. It also permits the telescope tube, if it is not too large, to be rested on the observer's shoulder instead of on a tripod. This design allows the relatively easily made reflector to compete with the more difficult refractor in such instruments as hand telescopes, spotting scopes and super-binoculars."

Porter added an insert to his drawing to explain the reflections that take place within a roof-angle prism invented by the Italian astronomer-microscopist, Giovanni Battista Amici, 1784-1863. This prism, not to be confused with others invented by Amici or with the roof-angle prisms of other inventors, is designated as the Amici roof-angle prism. Complex as it appears, a roof prism is simply the right-angle prism with its hypotenuse folded lengthwise to make a roof with slopes intersecting at right angles. The prism still turns the rays at a right angle and still reverts the image, but it adds to these an inversion, so that top comes out on bottom and left comes out on right. The prism's appearance is complicated by three small facets that have no optical function and are merely the stubs of edges and ends that lie beyond the useful field and so are ground off to decrease the prism's bulk.

"A workable substitute for a roof prism can be made from two first-surface mirrors," Hamilton points out. "Fasten them to an adjustable mount with the reflecting planes in a position that corresponds to the roof planes of a roof prism. Then, while viewing with the completed telescope some distant wires placed diagonally in the field, adjust the roof angle until the wires in the upper and lower halves of the image coincide. The joint at the roof ridge should be as good as possible, but need not be perfect, since it is out of focus of the eyepiece. Another substitute arrangement is to keep the two mirrors parallel to the regular roof planes and place them so that all the rays strike the first mirror, then the second mirror, and then the eyepiece. This arrangement has the advantage of having no roof-ridge joint to degrade the image, and the roof angle is not critical, since any misalignment merely rotates the entire field. The disadvantage is that it uses up more focal length and so requires a larger Newtonian diagonal.

"Of course these rough mirror arrangements will not equal a roof prism which has a perfect ridge joint and a light transmission of some 90 per cent, but they permit an *amateur* amateur to make in one evening a satisfactory roof-prism substitute good enough for most terrestrial uses. A professional amateur can obtain a larger roof than is practical with a solid prism. It may well be that substitutes of this kind will largely supplant roof prisms if recent developments to increase the efficiency of reflective coatings prove successful.

"A little time spent in tracing reflections through the optical train shows that the image will not come out like the scrambled monster in the left-hand drawing but normal, as in the other."

Instead of tracing reflections through a complex optical system on paper, it is safer and less confusing to set up the optical elements in dummy form and test the result. Experiment with a concave mirror, a flat, a roof prism and an astronomical eyepiece has verified the correctness of the Hamilton telescope. Anyone who builds this telescope should avoid crowding on high magnification, since this magnifies vibration and unsteadiness in proportion. Hamilton says that he learned to follow airplanes in flight, "after a fashion," with 28 power, but that 10 to 20 power is more practical for hand-held observation.

John M. Pierce of Springfield, Vt., has pointed out that there are but three positions in which a lens-type erector gives an erect and normal image with a Newtonian telescope: 1) with the eyepiece tube horizontal and on the right side of the telescope; 2) with the eyepiece tube horizontal and on the left side of the telescope and 3) with the eyepiece holder vertical and on top, and the top of the observer's head turned toward the object. However, in no possible position can a Newtonian with a simple lens-type erector give an erect and normal image with the observer facing the object. The Hamilton arrangement makes this possible and, in addition, eliminates the aberrations and extra length of a lens-type erector.

There is a considerable demand for terrestrial telescopes but relatively little literature about them, and that little is scattered and fragmentary. Among amateur telescope makers there must be at least one or two who have explored this subject widely, perhaps built and used a number of types of terrestrial telescopes and, in short, made a specialty of them. Such persons are urged to make available to their fellows what they have learned.

A QUARTER of a century ago Russell Porter set a fashion of answering the letters of fellow amateur telescope makers by scribbling replies and comments in the margins or on the back of the letters. This method, followed by this department when exchanging notes with workers, has the advantage not only of spontaneity and simplicity but of placing the answer where it belongs, so that the record is fully integrated. It is less easy to make the "gears" of a formal reply mesh with those of the original inquiry.

Thus today scores of papers with Porter's annotations, short and long, often accompanied with little sketches and personalia, are preserved as valued records and frequently turn up when piles of accumulated papers are sorted over. From 1925 on, this department weekly sent to Porter a fat batch of letters from amateurs; they were returned with interlineations in his clear round handwriting. No conventional trimmings were bothered with. Often these letters were forwarded to other workers, and from them gathered fresh marginalia—serious, humorous, cynical, even unprintable. Many of these round-robin "files" turned into slow-motion conversations, like a game of chess played by mail.

Not long ago, before Porter's death, one of these papers was reread and, in the belief that it would be interesting and useful to others, it was sent to Porter with a request that he make a drawing suitable for publication. The drawing appears on page 62. The exchange of notations ran thus:

Porter: "S'pose you wanted to make a very deep convex paraboloid, how'd you s'pose you'd go about it?"

The reply: "Not knowing, I cannot say."

Porter: "Well, I do it thisaway. The glass rotates while the template slides over it, back and forth. The linkage keeps the template always vertical. Throw on the abrasive and both glass and template automatically go paraboloid, the only curve we know of that can be made that way. Starting, say, with a hemisphere, or any segment of a sphere, and a *thin, circular* template, you can keep going and get any focal length you want. Of course, the above is a convex paraboloid but it works equally well on a concave one.

"The reason why this gadget works this way lies in the equation of the paraboloid and the fact that every section cut from a paraboloid, like *a, b, c, d, e,* is a parabola and all are identical.

"If you slide the spherical tool A down the side of a sphere it will touch only at B and therefore will begin wearing faster at that point than anywhere else along its edge. Conversely, the sphere will begin to wear away too. It's easy to show; just cut a piece of cardboard so it fits over the center of a tennis, croquet or billiard ball and slide it down, keeping it always vertical."

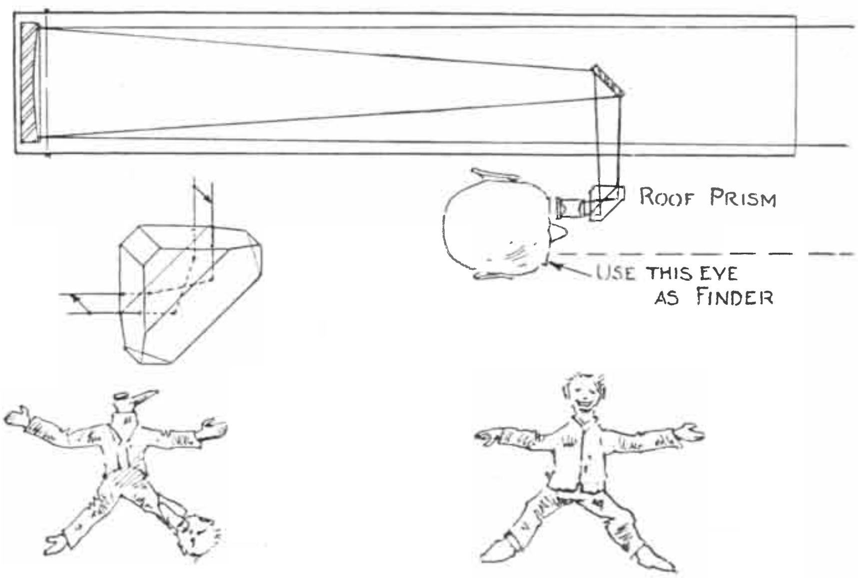
Later Porter wrote: "That convex paraboloid is to be used as a mold from which to cast concave plastic mirrors to be used for some kind of infra-red research, and the experiment consumed 111 hours of my time. After Anderson [maker of the 200-inch mirror] tested it and said it was 20 times better than the tolerance laid down I felt greatly elated, for he is not in the habit of exaggerating."

IDEALLY, when the amateur's telescope is not in use it should remain out of doors under an observatory dome, a runoff roof or at least a tarpaulin. But circumstances force what is probably a majority to keep their telescopes indoors and lug them outside for each use. Since even a six-inch reflector may weigh 100 pounds or more, this often results either in diminishing use or in such a reduction in weight that the instrument is shaky.

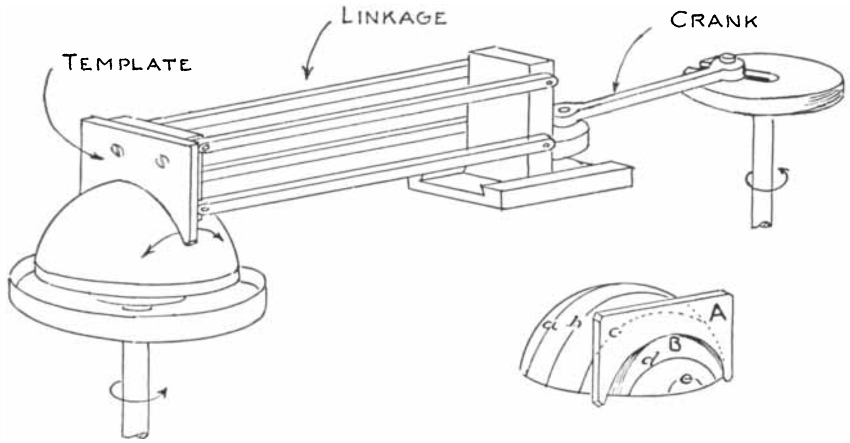
Edwin F. Bailey of the Astronomy Section of the Franklin Institute in Philadelphia hit on a happy solution of this dilemma. He used as his telescope base a 10-gallon expansion tank from a hot-water heating system. With the telescope unscrewed, this tank may easily be carried to the back-yard site. There it is filled with 83.3 pounds of water from the garden hose, which makes it quite heavy enough. After the observing period the water is let out of the tank. Tanks of this kind measure 11 by 18 inches and are tapped at the top for a ¾-inch pipe. In place of this tapping Bailey welded a two-inch pipe flange, and inserted a two-inch-length nipple to serve as the telescope-post attachment.

RECENTLY a newly organized amateur astronomical society in Australia asked this department for guidance in planning a workshop that would encourage its members to make their own telescopes. They asked, "What is required in the way of working space, machine tools and, in short, the whole setup?"

Copies of their letter were transmitted by this department to several American amateur astronomical groups, with the suggestion that copies of the replies be made available in these pages to others who may be planning similar organiza-



The Hamilton terrestrial telescope



This linkage will automatically produce a paraboloid

tions. From replies that were made available the following excerpts are extracted.

From Leo N. Schoenig, shop superintendent of the Amateur Astronomical Association, Pittsburgh, Pa.: "Our set-up at Buhl Planetarium consists of a rectangular space 24 by 33 feet in dimensions, or an area of 726 square feet. This is divided into a general workshop 16 by 24 feet, rough- and fine-grinding and polishing rooms each 9 by 11 feet, and a testing tunnel 6 by 24 feet. The space was arranged for our needs when the Planetarium building was erected in 1939.

"At the start we held a tool shower, and the members responded well. Thus we have in the general workshop a metal lathe, drill press, bench grinder, vises, an anvil, a gas furnace for making castings, patterns and scrap metal, a large layout table for general construction layouts, 10 lockers for individual members, and numerous hand tools. In the rough-grinding room: eight spindles for grinding, a workbench, electric plate and additional lockers. In the fine-grinding room: a grinding machine, four polishing spindles and a large bench for mirror storage. In the testing room, or tunnel: a table for supporting mirrors and a movable stand for the testing equipment."

Schoenig confirms the assumption that the true purpose of the anvil he cites is as a substitute for the famous hydrant mentioned in *Amateur Telescope Making*, page 287, with its use extended to other mirrors.

From H. L. Freeman, executive secretary of the Los Angeles Astronomical Society: "We have about 750 square feet of shop area in the Griffith Observatory, divided into a large general shop, a small polishing room, a small office and a hall for testing. Telescope-making activities are carried out in the main room, which contains a quick-change, nine-inch-swing, 54-inch bed lathe and its accessories; two drill presses, of which one is a high-speed precision type; a power-driven vertical spindle carrying a horizontal steel lapping wheel, for surface-grinding glass to rough plane surfaces; a power-driven, two-spindle grinding and polishing machine, with pans for submerged polishing, capable of working 12-inch mirrors; three pedestals for hand grinding; a heavy workbench with bench grinder; a sink, a two-burner gas plate, a compressed air outlet for spray painting, a mercury vapor lamp and flats for testing, storage cabinets and hand tools.

"In the polishing room is another polishing machine, a sink with hot and cold water, and a gas plate for melting pitch. No activities not connected with polishing are permitted in this room. Entry is forbidden to anyone coming from the grinding shop, and entry by others is discouraged.

"In a hall is the Foucault equipment, which is big enough for mirrors 18 inches in diameter with a 20-foot radius of curvature. The easel that supports the mirror being tested slides on a heavy metal track in a curtained tunnel. The design provides for direct reading of the radius of curvature of the mirror from the knife-edge at the observer's seat. The distance is shown by a spring-driven steel tape attached to the easel and to the knife-edge stand where the tape passes under a reference mark. Fore-and-aft movement of the easel is provided by a hand wheel at the test stand.

"The knife-edge stand is independent of the easel-track arrangement and rigidly bolted to the concrete floor and wall. The knife-edge mechanism is solidly bolted to the stand. No tremor of the pinhole image is perceptible under any circumstances. The knife-edge may be adjusted 8 inches vertically, 10 inches longitudinally and 6 inches laterally, a wide range that facilitates locating the reflected pinhole image. Vertical motion is controlled by friction wheels running on upright columns, and lateral and longitudinal motion by micrometer screws with half-nuts. When the half-nuts are lifted, approximate adjustments may be quickly made. When they are re-engaged, fine adjustment is immediately available. Gross fore-and-aft travel is registered by a reference mark traversing a plate graduated with .025-inch divisions which represent one revolution of the screw. This in turn carries a disk marked off into .001-inch divisions. This screw has complete adjustment against backlash.

"The light source is a 32-candle-power six-volt bulb supplied from the power line through a transformer. Its light reaches the pinhole after passing through a tube containing two achromatic condensing lenses placed to focus on the pinhole to which the light is finally guided by a right-angle prism. This prism permits bringing the knife-edge to within less than one half inch of the pinhole, which is chosen by rotating a disk containing a selection ranging in diameter from one fourth to .0015 inch.

"The knife-edge is a ⅜-inch square opening, so that the returning light beam can be intercepted in two dimensions, laterally and vertically. For Ronchi testing a plate carrying a slit can be inserted in this opening. Our Foucault test device has proved most satisfactory and is absolutely free from vibration.

"Nearly all our members have telescopes or are making them. We sell telescope mirror-making kits, abrasives and polishing materials to members at a modest increase over costs. Since our Society is a nonprofit organization and pays no salaries, the profits from such sales are used in the purchase and upkeep of shop equipment, to defray the costs of awards and prizes and to add to our building fund, which ultimately will enable us to build our own quarters and observatory. Mr. Ingalls is correct in saying that most of the amateur groups built up their facilities by patience and hard work." The statement here verified by Freeman was made because it has sometimes been supposed that amateur telescope-making organizations to which planetariums have furnished free quarters are otherwise supported by these institutions.

Los Angeles was the first community that organized a telescope-making group, after the pioneer Telescope Makers of Springfield, Vt.

From Allyn J. Thompson of the Optical Division of the Amateur Astronomers Association, New York: "The A.A.A. has its rooms in the American Museum of Natural History and its Optical Division has quarters in the adjacent Hayden Planetarium. Partly through our dues money, but chiefly through funds earned in annually conducted mirror-making classes for the public, the members of the Optical Division have purchased all their own equipment, tools and so on, except for some oil drums which are partly filled with water and used as pedestals for mirror making.

"The group of you, 10 or 20 persons, will pool funds and efforts to set up a society and a shop. Preparation should be made for the years to follow. Who will run the show? Be particularly careful about any investment of authority. What are the rights of the members? Will others, strangers to you now, be permitted to join later, and what will be their rights? What steps will you take to screen undesirables, and how will you recognize them as such? What about new members who are green about machine work? Among you now or destined to enter later will be some who have a natural aptitude for optical work, mechanical work, or both, and who will acquire exceptional skill or knowledge in their favorite hobby. Use should be made of this talent. The vain ambitions of others should not be allowed to hamper or fetter it. A program embracing the aims and purposes of the club should be prepared. It should not be irrevocable.

"Your group will need an electric plate for melting pitch. A spherometer for checking mirror radii is desirable, but accurately made templates are a good substitute. The Foucault testing device can be made by the members; use a slit if possible. An optical flat is desirable for checking plane surfaces and can be made by a member of your group. A fluorescent lamp is satisfactory for interference testing.

"It is best if all mirror-making materials are stocked by the club rather than obtained at random by the individual members. May I suggest for abrasives Carborundum No. 80, Aloxite Nos. 120, 220, 400, 600, emery No. 305 (finest) and, for polishing, Barnesite.

"Essential equipment in the machine shop may consist of a lathe, drill press, milling machine and vises. The lathe should not be less than nine-inch, with 36-inch bed. The more completely it is equipped the more useful it will be. Two or more lathes and two or three vises, one for heavy duty, will be better. Such auxiliary equipment as a band saw to handle wood or metal, a jig saw and a table saw is valuable. Measuring tools and essential bench tools should be provided. Additional tools, such as drills, taps and reamers, will suggest their need later. It is best for members to provide their own lathe tools.

"Omitted from the list because they are nonessentials are a spindle for small lens work, a grinding machine for mirrors and lenses, and a woodworking lathe. Storage space and receptacles for materials and equipment of the club and its members should be provided.

"Running water and drainage facilities should be provided for the optical room. Thought should be given to safe disposal of the sludgy wastes of glass grinding. To dispose of ours we have to run way out to a room used by the attendants. The Carbo from the emptied water pails almost always runs back uphill away from the drain and gets in the porter's mops, and then upstairs, and the whole Planetarium has a No. 60 surface."

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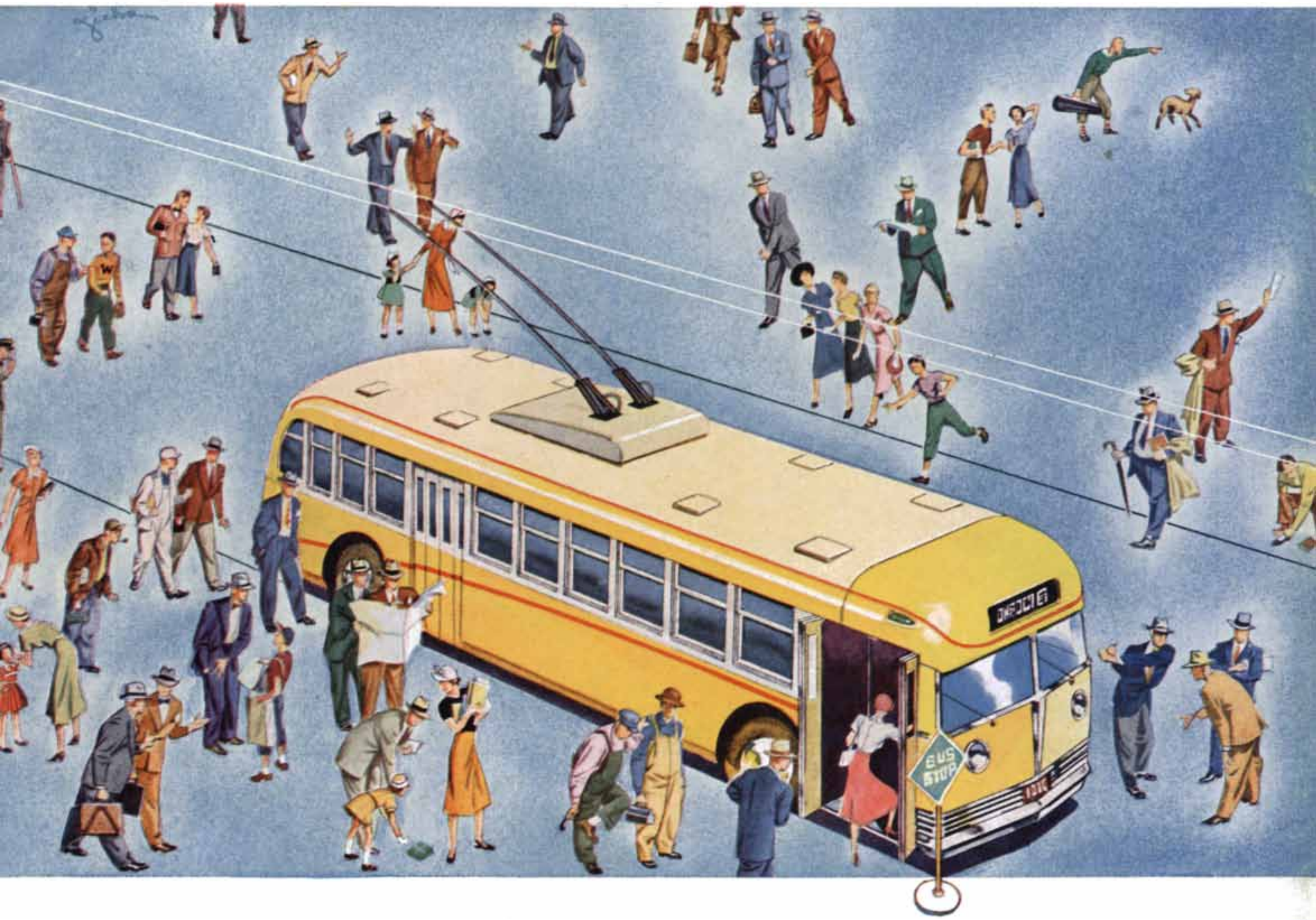

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