SCIENTIFIC AMERICAN

TOPOLOGY

FIFTY CENTS

January 1950

Photo by O. L. Snider from Shostal

A new day for poultry!

One of the reasons why poultrymen are now raising better, healthier chickens is because feed manufacturers are putting an "ounce of prevention" as well as plenty of nutrition *right in the feed.*

For example, when an ounce of MEGASUL* *25% Nitrophenide,* developed by Cyanamid's Lederle Laboratories Division, is incorporated in every 500 pounds of chicken feed, it helps flocks to build up virtually complete immunity to coccidiosis, a serious poultry disease.

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*Reg. U. S. Pat. Off.

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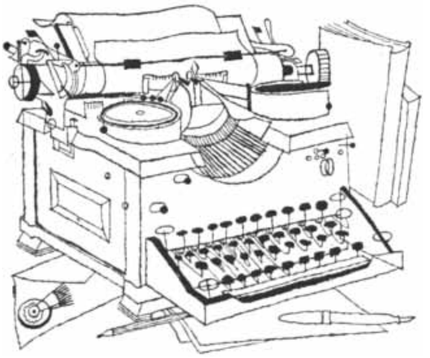

LETTERS

Sirs:

The article by J. H. Simons in your issue of November, 1949, entitled "Fluorocarbons" contains the following passage: "There is no question of the abundance of the raw materials. Carbon, as everyone knows, is sufficiently plentiful. And fluorine, according to all estimates, is roughly as abundant as carbon."

I had to read that last sentence three times before I could believe my eyes. Who in heaven's name has ever estimated that fluorine is "roughly as abundant as carbon" on this particular planet?

When you consider all the coal, the petroleum and the carbonaceous shale that exists throughout the world; when you consider the thick beds of limestone (mostly calcium carbonate) that underlie major portions of entire continents and form whole mountain ranges; and when you consider the corals in the tropical seas, the vegetation on the land and the vast amount of carbon dioxide in the atmosphere itself; and finally balance all these sources of carbon against the handful of relatively rare minerals that contain fluorine, one wonders how any person could make such a statement.

JOHN A. RITTER

Paoli, Pa.

Sirs:

Your correspondent can be answered easily but perhaps not as concisely as one might desire.

The difficulty is that the composition of the earth in terms of chemical elements is difficult to estimate, and different answers are obtained by different people depending upon the kind of estimate they make. In the *Handbook of Chemistry and Physics* published by the Chemical Rubber Publishing Company we find the chemical composition of the earth including the atmosphere given as .077 per cent fluorine and .027 per cent carbon. In other sources we find somewhat different numbers, but I believe that most unprejudiced sources give numbers in such a range that my statement that the two elements have about the same abundance is correct.

Although your correspondent mentioned coal, petroleum, vegetation and limestone as all containing carbon, which is true, he perhaps fails to appreciate the fact that fluorine is very widely distributed and is found in small percentages in practically all the minerals of the earth. It is found in and associated with limestone and other sedimentary rocks and is also found widely distributed in igneous rocks. It is present in a considerable concentration in all of the phosphate minerals, and deposits of impure fluoride are widely distributed and quite plentiful.

J. H. SIMONS

The Pennsylvania State College
State College, Pa.

Sirs:

The very interesting and generally accurate article on Woods Hole in the August, 1949, issue of *Scientific American* opens with two statements that, if not incorrect, are misleading. There can be little doubt that the statement that the name "Woods Hole" is a corruption of the original name "Woods Holl" is an error. To be sure Woods Holl was claimed to be the original name by E. N. Horsford (1818-1893), professor of chemistry at Harvard and famous for the Horsford's Acid Phosphate and the Rumford Baking Powder of my childhood. In his later years Professor Horsford was much interested in Norse language and legend. He believed the Norsemen to have settled along Vineyard Sound. In their language he found the word "holl" meaning hill, and he observed that a hill forms a conspicuous landmark at each of the places along Vineyard Sound that have "Hole" a part of their names. He inferred that Norsemen having used Holl as a place-name, the Indians had learned it and passed it on to the early English settlers.

On the insistence of Professor Horsford, the Post Office Department and the Old Colony Railroad adopted Woods "Holl" as the official name of this village, and to avoid any possible mistake that name, Woods Holl, and the date, 1879, were inscribed on a stone now lying in front of Community Hall, that was placed at the side of the main street where it crossed the culvert which at that time connected the Eel Pond with Great Harbor. It was there when I first entered Woods Holl in 1889. Some time in the '90s the name came to the attention of the U. S. Commission on Geographical Names and that body decreed the name to be spelled "Woods Hole," and so it has been ever since. As pointed out in a letter in your November, 1949, issue by Gairdner B. Moment, we have at Woods Hole, at Robinson's Hole and at Quicks Hole a narrow passage joining two large bodies of water, Vineyard Sound and Buzzards Bay; and at Holmes Hole, now Vineyard Haven, a narrow inlet connected the harbor with a lagoon south of the village.

The statement that Spencer F. Baird (1823-1888) was U. S. Commissioner of Fish and Fisheries when appointed Secretary of the Smithsonian Institution is true. That appointment was made in 1878 after the death of Joseph Henry. But that statement is misleading without the qualifying fact that Professor Baird had been Assistant Secretary since 1850, when he was appointed to relieve the aging Secretary. About 1870, when Baird was touring the New England coast to study the birds and fishes in which he was interested, he dropped in at Woods Hole.

Mr. Baird returned to Washington with at least two distinct impressions: 1) the advantages of Woods Hole as a place to study marine zoology, and 2) the distress in the population caused by the disappearance of the cod from the inshore fisheries. He resolved to do something about it, persuaded the Congress to create the U. S. Fish Commission as an independent bureau, and in 1871 was appointed the first Commissioner, without pay at his own request.

ROBERT PAYNE BIGELOW

Massachusetts Institute of Technology
Cambridge, Mass.

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50 AND 100 YEARS AGO

JANUARY 1900. "Sklodowska Curie has endeavored to determine the atomic weight of radium. She subjected to fractional distillation a mass of purified radiant barium chloride obtained from half a ton of uranium residues supplied by the Austrian government. She further treated the chloride by fractional precipitation in alcohol. The highly active substance obtained was used for determining the atomic weight by means of the silver nitrate reaction. The values thus obtained varied from 140 to 145.8, as against the atomic weight of inactive barium 137.7 found at the same time. This of course leaves the atomic weight of 'radium' indeterminate, but it is clear that radium is not allotropic barium, since no allotropic forms of an element have different atomic weights. And further, whatever be the atomic weight of radium, it must be greater than that of barium."

"M. Curie and Mme. Curie have forwarded a note to the Paris Academy of Sciences, in which they state that radioactive chloride of barium possesses the property of converting oxygen into ozone —which is proof that the radiation represents an expenditure of energy."

"The importance of determinations of the resistance of the air to moving bodies, in connection with the problem of aerial navigation and numerous other practical applications, has led to a series of experiments by M. l'Abbé le Dantec and M. Canovetti. Experiments show that the resistance depends on the form of the surface, and the resistance of a surface of given area is proportional to its contour. Canovetti finds that the resistance of the air on an area of one square meter moving with a velocity of 1 meter per second is 90 grammes for a rectangle and 80 grammes for a circle. In a double cone, the resistance is reduced to 15 grammes, or less than a fifth of the original resistance."

"An Austrian savant has declared that the human brain contains a 'name center.' A striking case which would seem to confirm this theory recently occurred at Cleveland. A brakeman was shot and could not remember the names of persons or things, although he could perfectly well describe the functions of all articles exhibited to him. The surgeon probed for the bullet and found it in the exact spot necessary to affect the remembrance of names, according to the Austrian's theory. When the pressure on the brain had been relieved, the patient remembered names as well as he had done before his injury."

"Prof. Virchow has just celebrated the fiftieth anniversary of his labors as Professor Ordinarius in the University of Berlin. He is now in his seventy-eighth year."

"In his presidential address, delivered before the British Association, Mr. Horace Brown gives an account of the experiments which he has carried out in order to determine the conditions under which the carbonic oxide of the atmosphere is absorbed by the leaves of plants. He considers that the gas penetrates only by the mouths or pores of the leaf, and finds that in the case of the plant under consideration, a variety of the catalpa, the gas must pass at the rate of 150 inches per minute. Mr. Brown has also made determinations to find out what proportion of the solar energy is utilized for the vital processes of the plant. This proportion is much greater in diffused light than when the leaf is exposed to the direct light of the sun. In the former case he estimates that 95 per cent of the energy absorbed may be utilized; in the second case, that of exposure to direct sunlight, only 28 per cent of the energy was utilized. He estimated that 6.5 per cent of the total energy of solar radiation consists of rays which are capable of being absorbed by chlorophyl."

JANUARY 1850. "It has been truly observed that the progress of science for the last century has outstripped all calculation, and left even the wildest imagination far in the rear. Is this astonishing progress to continue; and will nature in years to come yield to man her long treasured secrets as willingly as she does now? If so, what mortal shall venture to limit the boundaries of human knowledge, or the power of human skill? 'There is indeed,' says a late writer, 'no reason why the earth should not supply us with water hot, as well as cold, any more, perhaps, than why mechanical attrition or compressed air should not keep us warm, and the electric fluid light our streets and houses, convey our messages, set our clocks going, and possibly also perform some of our hard work.' "

"The remarkable feat has just been accomplished of effecting a communication by railway between London and Paris in the space of 8½ hours. This is probably the quickest trip by more than four hours that has ever been accomplished between the two capitals."

"Patent granted to Chas. Goodyear, of New Haven, Conn., for improvement in processes for the manufacture of India rubber."

"The immense beds of bituminous coal found in the valley of the Ohio fill the mind with wonder and surprise, as it reflects on the vast forests required in their formation. That coal is of vegetable origin no one who has read much on the subject, or personally examined the coal beds, will now deny. The product of its chemical analysis, being altogether vegetable, and the artificial formation of coal from wood by Sir James Hall, have silenced all doubts on the subject. The only mystery now is, how such vast quantities of vegetable matter could be accumulated and grow on the spot where they were buried. The climate at that period must have been more warm and more humid than at present."

"It is the fortune, or misfortune, of every age, we cannot tell which, to be the witness of great events that never transpire. In the line of navigating the aerial ocean above us, how many triumphant lucky inventors have arisen, some to delude themselves, and some to delude others. During the past two years, in London especially, and from there to the ends of the world, nothing was heard of from time to time but the great 'Electric Light.' A Frenchman discovered one kind, an Englishman another, and a Scotchman another; all were to make short work of gas companies. At one time the price of stocks fell considerably, and there was no little panic in the gas market. It has turned out after all, that the old kind still maintains its position, while the jeers of its younger opponents have been converted into an expiring moan. The steam engine, the steamboat, and many other good inventions, had once supreme judges of wiseacres, who wagged their heads in portentous dignity at the folly and credulity of man."

THE COVER

The six-colored twist of paper on the cover is a Moebius band, a celebrated curiosity in the active modern branch of mathematics known as topology (*see page 18*). The Moebius band has only one side and one edge; the fly shown in the painting can crawl to any point on the side without crossing the edge. The band is divided into six colored areas, each of which has a common boundary with every other. On a plane or spherical surface it is impossible to draw more than four such adjacent areas. The edge of a thrice-twisted Moebius band has a configuration similar to that of a trefoil knot, shown looped about the scissors at the lower right. The transparent object in the center of the painting is a Klein bottle, the three-dimensional analogue of the Moebius band which has only one surface. Here the bottle has a hole in its side that enables the surface to pass through itself; it therefore has one edge as well as one side. Topologists also deal with a theoretical Klein bottle that passes through itself but has no hole and no edge. The map of the East Prussian city of Koenigsberg, upon which these objects have been placed, presents one of the classical problems of topology. Koenigsberg is situated on the banks of the Pregel River and on two islands in the river. Seven bridges connect the islands to each other and to the banks. It is impossible to cross all seven bridges without crossing one of them twice.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

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What GENERAL ELECTRIC People Are Saying

J. H. HOLLOMON,

Research Laboratory

NUCLEATION: Such diverse problems as the kinetics of phase transformations, the formation of cracks in solids or of bubbles in liquids, and the formation of reversed domains during demagnetization have been treated in terms of the concepts of nucleation and growth. By nucleation is meant the formation of a new and distinct region separated from its surroundings by a discrete boundary. Nucleation is involved in the formation of a small droplet of water from water vapor, the formation of a small region of body-centered cubic iron within a face-centered cubic matrix, and the formation of a region of ferromagnetic material having one-spin orientation in a matrix in which the orientation of the spins is different.

The problem of nucleation, then, is pertinent to some of the most interesting transformations occurring in nature, and by control of the rate of nucleation the transformations can be controlled. Recently, for example, it has become possible to modify the weather over large geographic regions by simply inducing the nucleation of ice from a cloud of water droplets. Recently also metals have been significantly supercooled by preventing the formation of nuclei over a wide range of temperatures.

American Society for Metals, Cleveland, October 15, 1949

★

A. H. SHARBAUGH,

Research Laboratory

EXPLORING MOLECULES: One of the outgrowths of the intensive research in the radar field during World War II has been the opening of a promising new field: that of exploring the molecule with radio waves . . . With a microwave spectrometer we cause radio waves about ½-inch long to pass down a long hollow pipe which is filled with the gas we wish to study. At the far end we measure the radio power with a crystal detector and show the pattern on a television tube. Every time we tune the microwave source through an absorption line we see a sharp dip in the trace on the oscilloscope or television tube. By tuning over the available frequency range, we find out experimentally all the frequencies where the energy is absorbed as well as how strongly it is absorbed.

One advantage that microwave spectroscopy holds over the kinds of spectroscopy practiced at shorter wavelengths, as in the region of visible light, is the ability of the microwaves to distinguish between absorption lines that are very close together. This quality, known as resolution, is several thousand times better than the best optical instruments . . .

By using a crystal oscillator checked with WMV, the Bureau of Standards station at Washington, D. C., we may generate standard reference markers throughout the frequency range of the spectrograph. By means of these we can measure experimentally our absorption lines to about 1 part in a million. Not quite all this accuracy is retained in the molecular geometry because of uncertainties in Planck's constant and the fact that the molecule may be slightly flexible and disturb our measured interatomic distances. In spite of these limitations, we may calculate from experimental data the distances between atoms to an accuracy of 1/1000 of an angstrom unit or 1/100 of a millionth of an inch!

The fact that these microwave absorption lines are extremely sharp and very stable opens up the avenue to some interesting applications. One of these is the use of the spectroscope as an analytical tool for chemists. The frequency range currently used in microwave spectroscopy is from about ½ cm. to 2 cm. in wavelengths and, even in this relatively small region so far investigated, there is room for 5 million noninterfering rotational absorption lines. In principle, it is believed that a thousand or more different complex organic molecules could be determined from a sample weighing less than 1 ten-millionth of an ounce without harming it in any way and without using up the sample . . .

Although microwave spectroscopy primarily yields information about the structure of the molecule as a whole, it may also be used for studying the rotation of internal groups of atoms within the molecule.

General Electric Science Forum, WGY, September 28, 1949

★

C. G. SUITS,

Vice President and Director of Research

ATOMIC POWER: It is probable that about $200 million will have to be spent in the process of building successive experimental power plants before we will have a proper basis for judging the future economic possibilities of atomic energy. Because of the great array of unanswered technical questions, there can be no assurance at present that the final result will be successful. If a profitable atomic industry ever develops, it is certainly decades in the future. This financial risk is obviously one which cannot be supported by any private capital in the world, so that it is clear from the outset that only the resources of the national government can sustain the required effort. Not only does the great cost of the development make it necessary for the national government to foot the bill, but the fact that fuel for atomic power plants is also the explosive material of atomic bombs makes it necessary for the federal government to control the security and accountability aspects of the project in great detail. All atomic energy work is thus the responsibility of the Atomic Energy Commission and is carried out in laboratories operated by its contractors.

National Academy of Sciences, Rochester, N. Y., October 25, 1949

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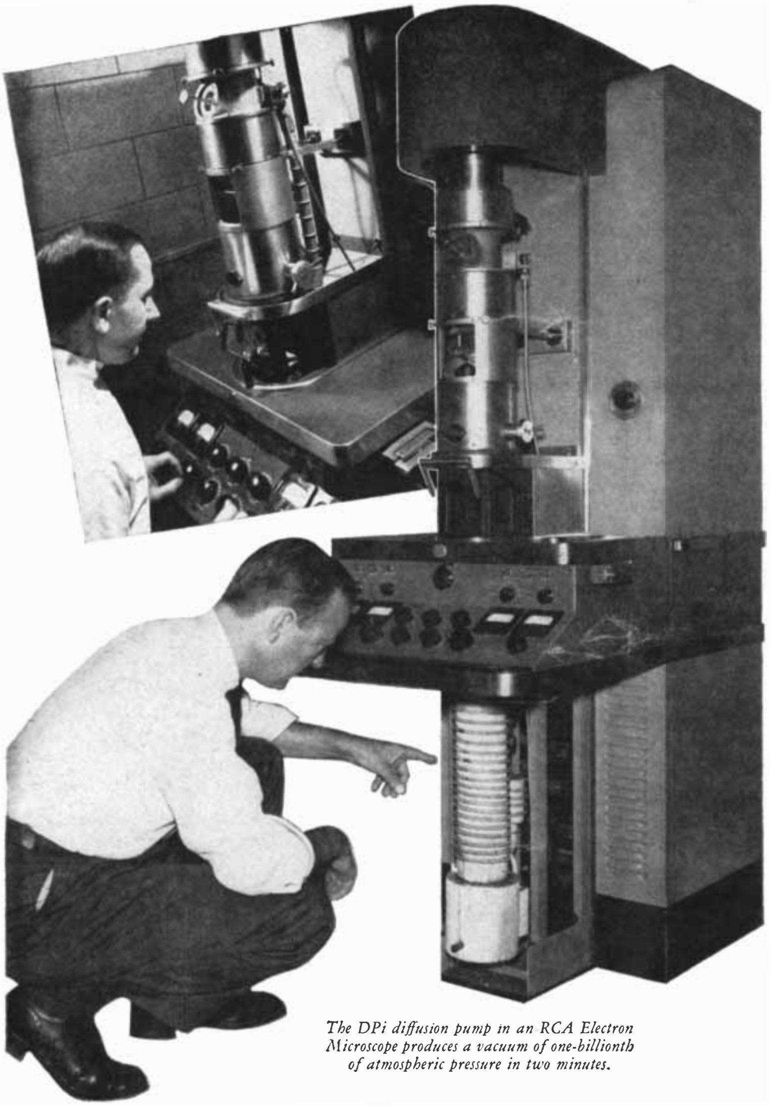
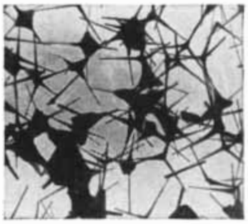
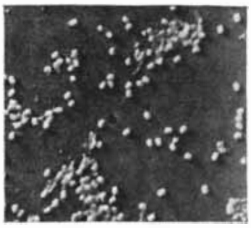
GENERAL ELECTRIC



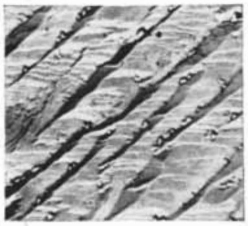
The DPi diffusion pump in an RCA Electron Microscope produces a vacuum of one-billionth of atmospheric pressure in two minutes.



ZINC SMOKE PARTICLES
J. Hillier, RCA

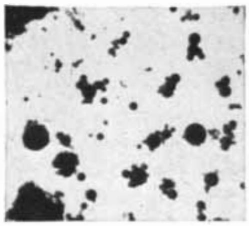


VACCINIA VIRUS
D. G. Sharp, Duke University

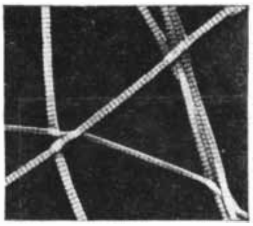


POLISHED AND ETCHED QUARTZ
R. D. Heidenreich, Dow Chemical Co.

PROTEUS BACILLUS
R. Wyckoff, National Institute of Health



SILICA SMOKE PARTICLES
A. L. Schoen, Eastman Kodak Company



COLLAGEN FROM ADULT HUMAN SKIN
Gross and Schmitt, Massachusetts Institute of Technology

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SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR JANUARY 1950 VOLUME 182, NUMBER 1

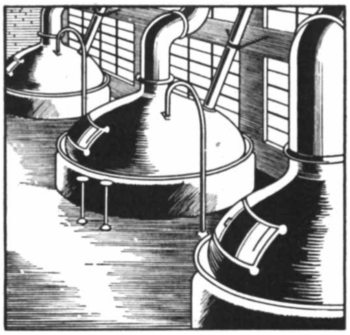
ARTICLES

DEPARTMENTS

BUSINESS IN MOTION

To our Colleagues in American Business . . .

The brewing industry has been in an expansion and modernization stage since the end of the war made copper freely available to it once more. New breweries are being built, and older ones enlarged, in order to meet the increasing demands of the public. As a result, the coppersmiths who fabricate brewing equipment have given Revere large orders for copper sheet and copper tube, which they turn into such items as brew kettles, mash tubs, lauter tubs, wort tanks, cookers, water heaters, and piping. Because the brewing of beer is necessarily done on a large-volume basis, the equipment is correspondingly huge. Orders for several hundred thousand pounds of copper are not unusual.



Though the brewing people thus are large users of Revere copper, they are not direct customers; the Revere customer is the coppersmith who fabricates to brewers' specifications. Nevertheless, Revere keeps a friendly hand outstretched to the brewer. Lately we have talked with quite a few brewmasters, and have found the same outstanding loyalty to copper that existed before the war and which has, in fact, been a feature of the brewing industry from its beginnings centuries ago. One master brewer, for example, said: "In planning the mammoth new installations for our $12,500,000 expansion program, copper was chosen because it is the most ductile metal for the fabrication of specially-designed brew kettles and related equipment; in keeping with time-honored traditions."

Brewing is, in fact, a remarkable mixture of tradition and science. Beer and ale are among the oldest of man's beverages, and all the evidence indicates that copper, probably man's first metal, has been used since the beginning. This ancient art relied upon the rule of thumb, experience, for centuries. It is now under a large measure of scientific control as well, the brewmasters' high talents being supported and confirmed by laboratory checks of materials. It is therefore especially gratifying to Revere that copper continues to be the metal preferred by brewers.

There is an old saying: "Be not the first by whom the new is tried, nor yet the last to cast the old aside." What is important, however, is not newness and not oldness, but suitability. A material may be new as tomorrow's sunrise, yet suitable for only a few applications. It is part of every manufacturer's task to study the old as well as the new, and be certain he is neither unreasonably wedded to tradition, nor unwisely eager to change for the sake of change. In making such studies he can and should call upon his suppliers, who, like Revere, are always glad to provide the latest and fullest information about their materials.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

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

SCIENTIFIC AMERICAN

JANUARY 1950 VOL. 182, NO. 1

UN v. Mass Destruction

Negotiations for the control of atomic weapons begin hopefully in 1950 with the Great Powers' agreement to explore several fresh approaches

by Trygve Lie

ONLY time will tell to what extent the discussions on atomic energy that took place during the recent session of the United Nations General Assembly may foreshadow a constructive turn in the consideration of this problem. It appears to me that there is good reason to hope for such a turn during 1950.

The debate on the problem of international control of atomic energy and prohibition of the atomic bomb began with confirmation that at least one other country besides the U. S.—the U.S.S.R.—was manufacturing atomic explosives. During the debate the positions of both sides were restated with force and at considerable length, but without any apparently significant modification on either side. The great majority still favored the plan based on the proposals originally made by the U. S. The minority supported the proposals of the Soviet Union. In the end the General Assembly voted 49 to 5 with 3 abstentions to ask the permanent members of the Atomic Energy Commission (Canada, China, France, U.S.S.R., United Kingdom and U. S.) to continue their consultations and "to explore all possible avenues and examine all concrete suggestions with a view to determining whether they might lead to an agreement."

The Soviet Union voted against this resolution, preferring one of its own which provided, among other things, for resuming consideration of the problem in meetings of the full membership of the Atomic Energy Commission. However, the Soviet Union joined the other Big Powers in replying affirmatively to the appeal of President Carlos P. Romulo of the General Assembly to renew their efforts to reach agreement and to approach constructive new suggestions with an open mind.

Thus the world can rightfully expect a resumption this year of genuine negotiation between East and West on the problem of atomic energy. This in itself is important, for an absolute stalemate on this question has existed for more than two years. During that time there has been no real negotiation between the majority and the minority. Real negotiation requires what General Romulo called an open mind and some flexibility of position. Now we are to have exploration by the six Powers of "all possible avenues" and examination of "all concrete suggestions."

We must not expect important immediate results. There may be few results, or even no apparent results at all, for some time. The problem of control of atomic energy is one of the most difficult problems of all on the road to world peace. The differences between the majority and the minority on the control plan go to the heart of the Great Power conflict that has so poisoned all international relations since the end of the war.

MANY less difficult differences between East and West still defy solution or adjustment. This is true both outside the UN and inside it. Outside the UN there is even yet no peace settlement for Germany, Japan, or for Austria. Inside the UN the Security Council does not yet have the military forces pledged to it by the members under the Charter; no progress has been made since the Big Powers disagreed two years ago on the size and composition of these forces. On the problem of regulating and reducing the so-called "conventional armaments" (everything but weapons of mass destruction), there has been even less serious exploration and less agreement than in atomic energy. The problems of control over other weapons of mass destruction such as biological and poison-gas weapons have not been considered at all. There are also important political differences between East and West involving the Balkans, Korea, the admission of new members, and human rights in Bulgaria, Rumania and Hungary. Finally, there are the repeated charges of war-mongering and aggressive policy that have been exchanged.

It is too much to expect that a comprehensive agreement on a system for the international control of atomic energy could be reached in such an atmosphere. The differences I have listed, and the mutual fears and distrust that accompany them, are all linked together. The atomic problem cannot be isolated from the other problems of creating and maintaining a peaceful world. But by the same token, progress toward settling any of the differences, either inside or outside the UN, will make it less difficult to settle the others. The difficulties that now appear so large will tend to disappear in proportion to the extent that tension is reduced and that those enemies of peace—distrust and fear—fall back before the spirit of understanding and mutual confidence. Thus agreements on such apparently unrelated matters as a peace treaty for Austria and the admission to the UN of all the 14 countries now waiting outside the door because of vetoes or abstentions in the Security Council would undoubtedly help the atmosphere of the coming atomic negotiations. Similarly, real progress in the atomic negotiations would undoubtedly improve the prospects for a settlement of the German problem.

I believe that the world enters the year 1950 with a somewhat better chance of making progress toward these goals than has existed at any time since the first part of 1947. We should be careful not to place our hopes too high, but in recent months there have been signs of a returning spirit of negotiation and of efforts at adjustment. There were, for example, the discussions among the UN delegates of the Great Powers that led to the ending of the Berlin deadlock. There was the resumption of meetings of the Council of Foreign Ministers, a forward step even though it did not produce immediate results on the problem of Germany. There have been the continuing meetings of the Foreign Ministers' deputies working toward agreement on an Austrian treaty. There have been the renewed efforts at conciliation in the UN, with full participation by the Great Powers, of the long-standing Balkans dispute between Greece and her three northern neighbors. There is the fact that, although the Marshall Plan continues to be opposed by the Soviet Union, the UN program of technical assistance for economic development, based on a U. S. proposal, was adopted unanimously by the General Assembly, with the Soviet Union joining in support of the program. And finally there is the agreement to resume exploratory talks on atomic energy.

I DO NOT propose to suggest here any specific "possible avenues" or to make any "concrete suggestions" for the solution of the atomic problem. I leave that to the statesmen and the scientists of the Great Powers who know most about the problem. I prefer to limit myself to a statement of the general UN context in which the problem must be considered and to suggest certain general approaches in the light of that context.

First, I think all of us need to refresh ourselves constantly when faced by such problems as these by going back to the beginning. Why have the nations of the world undertaken to seek agreement on the international control of atomic energy? We must be careful not to confuse the means with the end. The nations have not embarked on this undertaking in order, on the one hand, to establish international ownership and management of atomic facilities in all countries, accompanied by continuous inspection, or, on the other hand, to provide for national ownership and management with international control and periodic and special inspections. The fundamental purpose is to protect mankind from the use of atomic energy for war and to promote its use for the purposes of peaceful progress. Each side contended that its plan was the best way to achieve that end. The majority believed international ownership and management was the only effective method of insuring the world against secret manufacture and stockpiling of atomic bombs for use in war. The minority believed that a majority of nations, out of hostility, jealousy or for other motives, could prevent minority nations from developing atomic energy in their own way for peaceful progress unless national ownership and management of this key source of future industrial power was retained. This is the heart of the differences between the majority and minority plans. No one can deny that it is a basic difference. There are also many important differences on such matters as the powers of investigation and inspection of the control organ and on methods of enforcement against violators.

We must not forget, however, that there are important areas of agreement. Both sides start with the same answer to the same basic question as I have just given it: the universal desire to protect mankind from the use of atomic energy for war and to promote its use for the purposes of peaceful progress. Both have agreed that atomic weapons and all other weapons of mass destruction should be eliminated from national armaments. Both have agreed upon the establishment and terms of reference of the UN Atomic Energy Commission. Both have agreed that there should be an international system of control over atomic energy with a control organ that operates without veto in its day-to-day operations. Both have agreed that there should be international inspection of some sort to help prevent violations of the control system and to discover them if they occur, even though there appear to be important differences about the nature of this inspection.

The renewed negotiations of the six permanent members of the Atomic Energy Commission are being undertaken on the basis of this area of agreement, about which we hear comparatively little, as well as on the basis of the area of disagreement, about which we hear so much. The members have also agreed to give serious consideration to four possible avenues of approach toward breaking the deadlock suggested by General Romulo: 1) a short-term armistice in atomic production accompanied by an inspection system; 2) an interim prohibition of the use of atomic weapons with adequate safeguards; 3) further compromises between the existing majority and minority plans for a control system; 4) a new approach to the central problem of control itself.

WE MUST not overlook the related problem of the control of other weapons of mass destruction. When the Atomic Energy Commission was created in 1946, the General Assembly entrusted it with responsibility for working out proposals for the elimination from national armaments not only of atomic weapons but "of all other major weapons of mass destruction." The Commission, however, has never discussed these other weapons, such as biological and chemical poisons. Some of these weapons may be even more destructive of human life than atomic weapons. We do not know by experience what they might do. Unlike the atomic bomb, they were not used in the Second World War, although we know they existed then and have been further developed since. Even a preliminary study of the problem of establishing international controls for such weapons and providing safeguards against violations might lead to conclusions shedding new light upon what is necessary and attainable in the international control of atomic energy.

The Commission on Conventional Armaments is also continuing this year its pursuit of agreement on steps toward the regulation and reduction of all armaments and armed forces not considered to be weapons of mass destruction. Here again, the study of control problems such as inspection and verification in the area of conventional weapons might help to solve the problems in atomic energy control.

I do not know whether any or all of these approaches would be fruitful. I do suggest that they are worth trying.

In the final analysis we must not forget that although science discovered and harnessed atomic energy, only the art of politics can prevent the use of atomic energy for the destruction of man instead of for his advancement. The solution of the problem of attaining agreement on effective international control of atomic energy will be a political solution—based, of course, upon scientific facts, but possible only if the necessary political understandings are reached. So those of us who believe that agreement must be reached no matter how many months or years it takes must dedicate ourselves to extending the area of political understanding between East and West at every opportunity and in every possible way. We must do this not only in the atomic negotiations, but in all other negotiations involving the two sides.

I KNOW there are people who talk of the inevitability of a third world war, and whose efforts seem to be directed to pointing out how irreconcilable is the gulf that splits the world today rather than to seeking ways to bridge it. I do not believe there are many with such a suicidal bent of mind. All of us should know by now that another war with the weapons of mass destruction now available would destroy all existing political, economic and social systems and set civilization back by a thousand years.

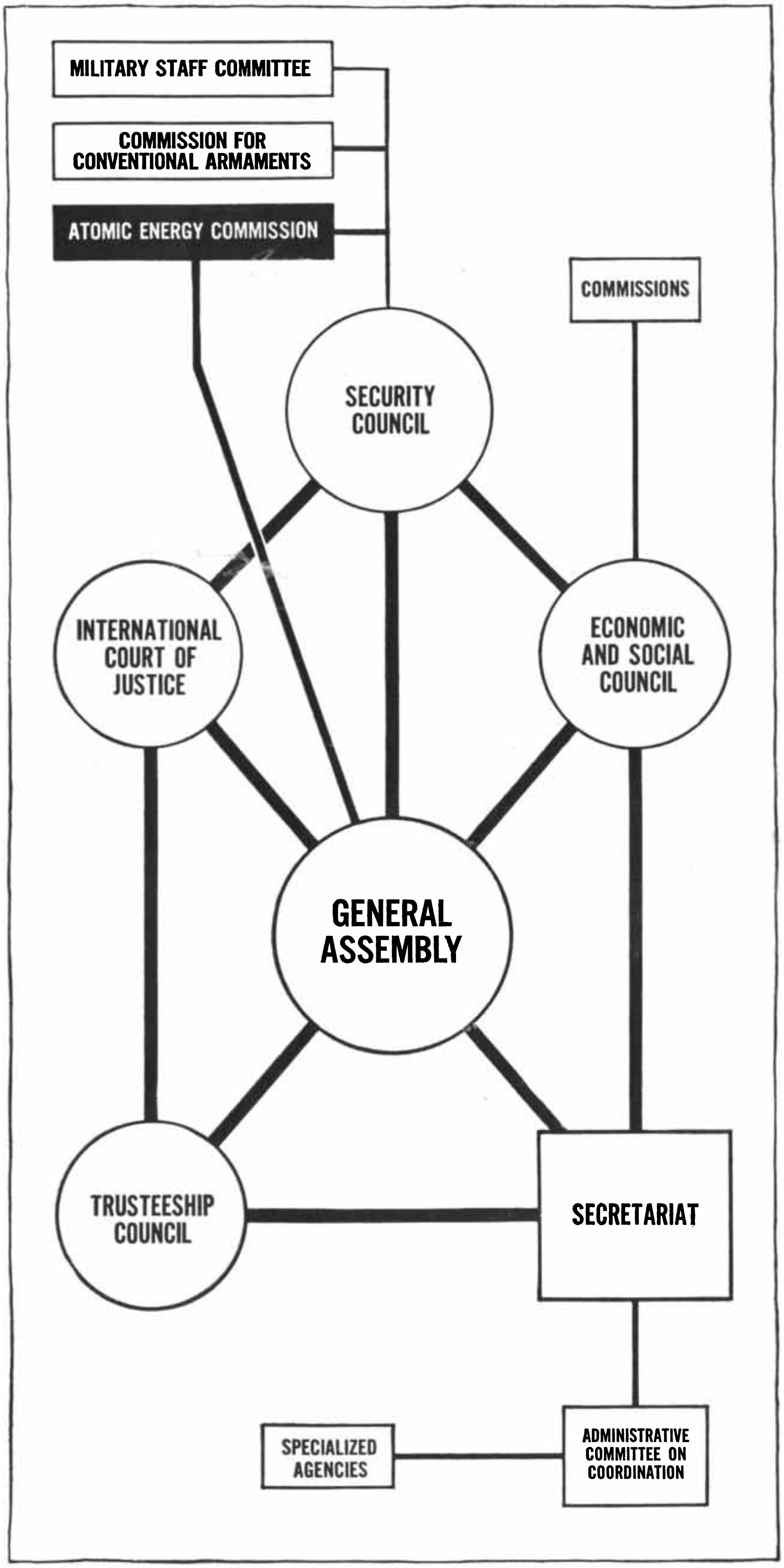
Thus we return to the heart of the matter, as stated by President Truman, Prime Minister Clement Attlee and Prime Minister MacKenzie King when they first proposed international control of atomic energy on November 15, 1945:

We are aware that the only complete protection for the civilized world from the destructive use of scientific knowledge lies in the prevention of war. No system of safeguards that can be devised will of itself provide an effective guarantee against production of atomic weapons by a nation bent on aggression. Nor can we ignore the possibility of the development of other weapons, or of new methods of warfare, which may constitute as great a threat to civilization as the military use of atomic energy.

Bernard M. Baruch repeated these words when he first presented the U. S. proposals for the control of atomic energy to the Atomic Energy Commission in June, 1946. The final safeguard is the prevention of war, and above all, world war, for once such a war broke out, even the most ironclad control system conceivable would be destroyed immediately. There would be no security any more, except the possible deterrent of fear of reprisal, against atomic destruction.

Every action of the UN that contributes to the lessening of tension between East and West, that increases confidence and develops the processes for the peaceful settlement of disputes among all nations, that extends the area of organized international cooperation, will help to prevent atomic destruction and to insure the use of atomic energy for peaceful progress. This is the road we must travel. Recent developments in atomic energy have once again brought home the lesson that real security from war can be attained only on a universal, world-wide basis through the UN. There is no possible substitute and there is no short cut. This means we must concentrate our efforts on making the UN work more effectively in the world that exists, not in the world as we might like to have it. It will be necessary to pay less attention to the many things that divide us and more attention to those that unite us. It is this realization that has given a hopeful new impetus to the negotiations. We must search unceasingly for the utmost in presently attainable political agreement, knowing that one step can lead to another and that realistic progress toward world peace in this way is better than either chasing mirages or sitting down and giving up.

Trygve Lie is Secretary General of the United Nations.



UN ORGANIZATION places the Atomic Energy Commission in a position that is primarily responsible to the General Assembly. The Commission is composed of all 11 nations belonging to the Security Council and Canada.

Heart Surgery

Until recently the vital muscular pump was considered outside the surgeon's domain. Now bold new operations correct several kinds of damage or congenital defect

by Frank G. Slaughter

IN all the history of surgery, there is no more dramatic chapter than the recent meteoric progress in surgery of the heart. Until about a decade ago operations on the heart were rare. The attitude of surgeons toward that critical organ was still much like that of the British physician Stephen Paget, who wrote in 1896: "Surgery of the heart has probably reached the limit set by nature to all surgery: No new method and no new discovery can overcome the natural difficulties that attend a wound of the heart." Yet within a decade the attitude has changed completely. Bold new methods, developed by military surgeons and by such pioneers as the Johns Hopkins University heart surgeon Alfred Blalock, have overcome many of the difficulties. Today operations on the heart are almost routine, and hundreds of persons are now alive who would be dead but for a surgeon's timely intervention with a scalpel.

For obvious reasons the heart does not lend itself easily to surgical procedures. Operating on the heart is in effect like trying to repair an engine while the engine is running. This engine, of course, must be kept running throughout the operation if the patient is to stay alive. In surgery of the heart there is the danger of stopping the engine, the danger of fatal bleeding, and above all the dangerous fact that any damage to the interior of the blood-vessel system is usually followed by the formation of clots, either stationary (thrombi) or floating (emboli), which may block the circulation.

Let us begin by picturing this organ upon which the surgeon is to operate (*see drawing on the opposite page*). Essentially the heart is a double-chambered, muscle-powered pump, which with each beat drives blood through the circulatory system. The cycle begins when blood returning from the body tissues comes by way of the great veins into the right auricle of the heart. It passes then through a set of valves into the right ventricle. From there the heartbeat pumps the blood through the pulmonary arteries into the lungs, where it takes up oxygen. The oxygenated blood, returning to the heart through the pulmonary veins, enters the left auricle, passes on to the left ventricle and then, by the powerful systolic contraction of the heart, is pumped under considerable pressure out to the tiniest arteries, carrying food and oxygen to all the body's cells. After giving up some of its oxygen and taking carbon dioxide and other waste products from the tissues, it returns to the heart through the veins. The heart itself, lying between the lungs, is surrounded by a tough-walled, fibrous sac called the pericardium. The lungs, on either side of the heart, are surrounded by membrane-lined spaces called the pleural cavities.

Injuries or disturbances of the heart fall into several distinct categories. The simplest category is a heart wound caused by some outside agent such as a knife. A stab wound in the heart is not always fatal; 10 per cent of the cases survive even without treatment. As for treatment, the surgical job of repair, *i.e.*, sewing up the wound, presents no great problem; but control of the hemorrhage, the usual cause of death, is another matter. If the weapon cuts into the heart from the side, penetrating both the pleural cavity and the pericardium, there is a "hidden" hemorrhage into the pleural cavity; in this case the bleeding may go undetected until it is too late for treatment. If the weapon comes in directly over the heart, penetrating only the pericardium and the heart itself, the resulting hemorrhage accumulates within the pericardial sac. Since the pericardium is inelastic, the accumulation of blood in the sac squeezes the heart, and the patient dies not from loss of blood but from a strangle hold that prevents the heart from beating. This type of constriction is known as "cardiac tamponade."

It was around 1933 that the cause and symptoms of cardiac tamponade first became generally recognized. The surgical remedy was obvious: withdraw blood from the pericardial sac, thus relieving the pressure on the heart and allowing the patient to survive long enough for the surgeon to suture the wound. This operation, known as "aspirating," that is, withdrawing blood by suction, was soon tried by many surgeons, and the results were startling: often the victims were literally brought back to life after their hearts had stopped beating. There are now on record many successful series of operations of this type, particularly in Southern cities; for example, Rettig A. Griswold and his surgical associates at the University of Louisville report only three deaths in 36 cases. Sometimes, when the heart is pierced by a small weapon such as an ice pick or a narrow-bladed knife, surgeons find it unnecessary to sew up the wound; they simply aspirate the pericardium sac and let the small wound seal and heal itself.

EVEN more spectacular progress in the surgery of heart wounds was achieved during the recent war by a group of surgeons led by Dwight E. Harken of Boston. Before the war surgeons seldom considered it safe to attempt to remove foreign bodies in or near the heart and the great vessels, even though such wounds often cause severe pain, rupture of the weakened heart and other serious consequences. During the invasion of Europe Harken's group daringly began to operate on the hearts of wounded men; in 13 cases they removed shell fragments and other foreign bodies from the heart chambers themselves. Altogether they performed 134 heart operations without a single fatality—one of the most remarkable feats in modern surgical history.

The second broad category of heart disorders is the group caused by infections. Some infections such as diphtheria weaken the heart muscles; others (syphilis, rheumatic fever, subacute bacterial endocarditis) cause scarring and distortion of the heart valves and of the lining of the heart chambers, with thrombosis and embolism as frequent complications; still others (pneumonia, tuberculosis) produce pericarditis, or inflammation of the pericardial sac. Many of these conditions can now be helped by surgery.

The surgical treatment for the acute, purulent type of pericarditis that sometimes follows pneumonia is to cut through the chest and open a small window in the pericardial sac for drainage and irrigation of the infection. This operation alone can cure 50 per cent of the cases of acute pericarditis; it now has an ally in the powerful antibiotic drugs, which in the majority of cases can stop the infection without surgery.

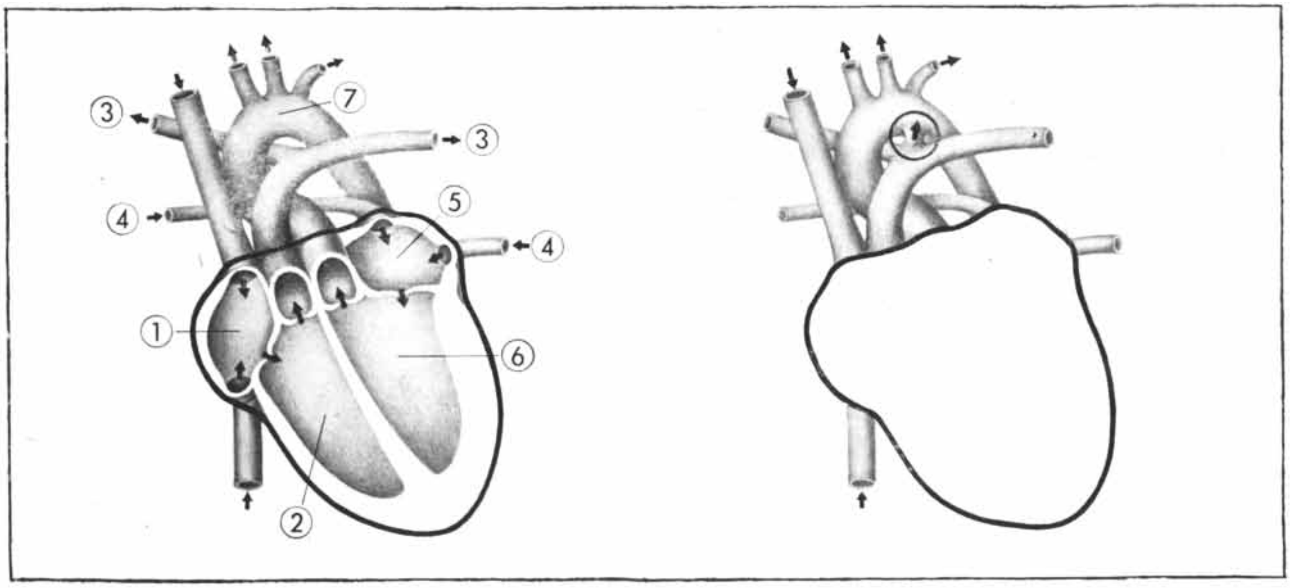
There is another type of pericarditis, often tuberculous in origin, which is chronic rather than acute and produces different results. The inflamed pericardial sac gradually shrinks, thickens, and finally squeezes the heart to death. This disease used to be virtually 100 per cent fatal. In 1928 the Boston chest surgeon Edward Delos Churchill performed the first in a series of modern operations on a doomed patient; he removed a portion of the thickened pericardium to give the heart room to work. The patient recovered. Since then surgeons have saved many lives with this type of operation; for example, in 1946 George Heuer, professor of surgery at the Cornell University Medical School, reported a series of 18 operations with cure or substantial improvement in 83 per cent of the cases and no deaths.

But the field in which the most striking advances in heart surgery have occurred is the large category of disorders arising from congenital defects in the development of the heart. Many children are born with one or more of the chambers or valves of the heart missing, or with abnormalities of the valves or arteries that block the free passage of blood, or with abnormally developed vessels that cause the flow of blood to by-pass the lungs so it cannot be oxygenated properly.

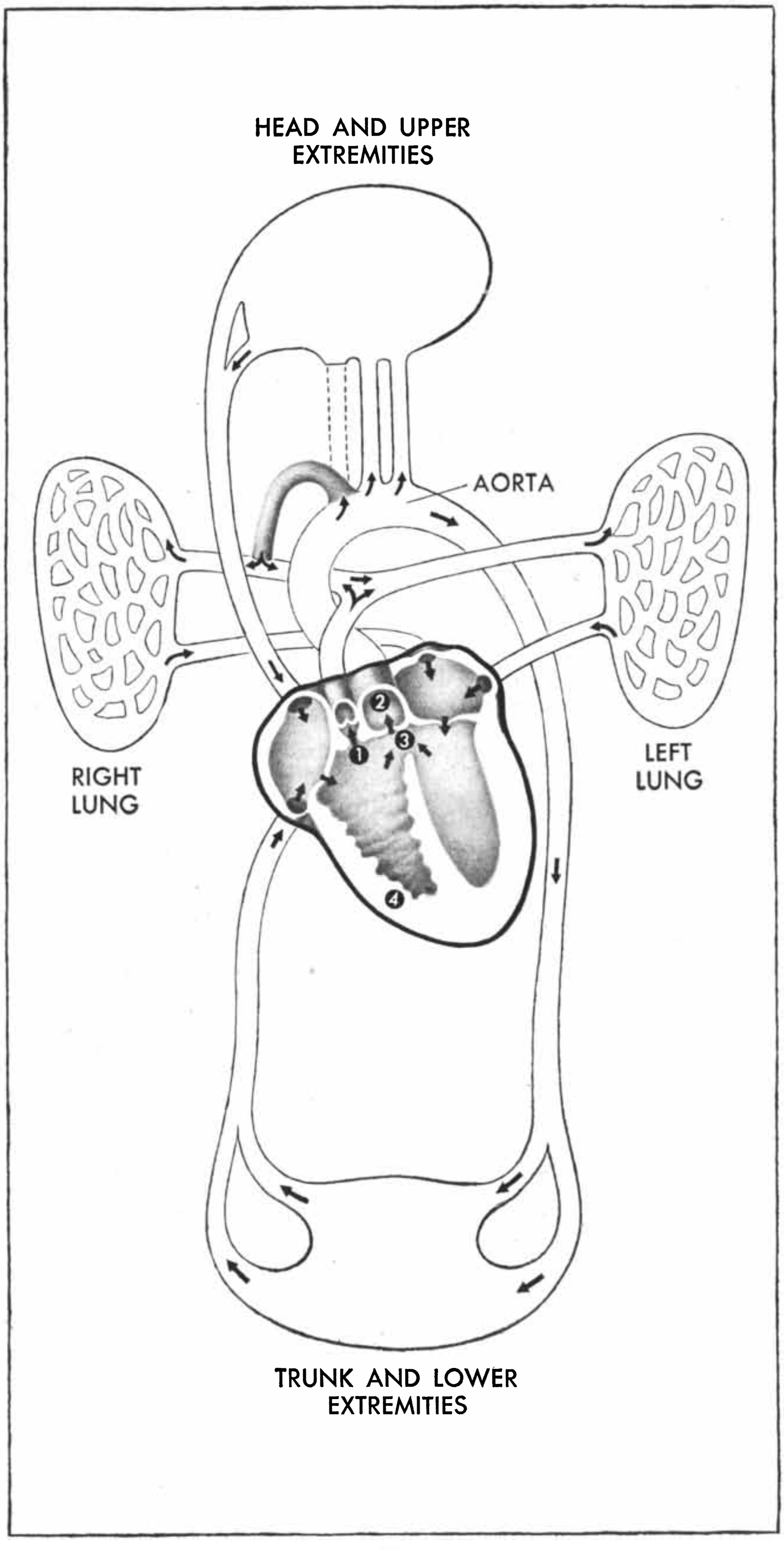
This last is a fairly common condition. It has its origin in the failure of the fetus to get rid of a convenient mechanism that becomes most inconvenient after the baby is born. Before birth the fetus of course does not need to circulate blood through its lungs; its blood is oxygenated in its mother's circulation. The fetus' blood by-passes its uninflated lungs through an ingenious short cut called the *ductus arteriosus*, a short, narrow vessel that carries the blood directly from the pulmonary artery to the aorta, the great artery through which blood is distributed to most of the body. When the baby is born and begins to breathe, normally the *ductus arteriosus* closes and the blood at once begins to circulate through the lungs. In some children, however, the *ductus arteriosus* fails to close, and much of the blood that should go to the lungs is short-circuited through the open vessel. If the opening is small, so that relatively little blood by-passes the lungs, the child may show few or no ill effects. But if it is large, the youngster soon shows certain typical symptoms: low resistance, quick exhaustion after any physical effort, susceptibility to respiratory infections such as bronchopneumonia, and most particularly, the development of the serious disease called subacute bacterial endocarditis, a grave inflammation of the inner lining of the heart and its valves. Most victims of "patent" (open) *ductus arteriosus* once were doomed to die, either of bacterial endocarditis or of progressive weakening of a heart overloaded by attempting to pump blood faster to obtain more oxygen.

Here again the solution of the problem required only boldness and skill. It was obvious that the condition could be corrected simply by ligating (tying up) the open passage. But the *ductus arteriosus* is so intimately connected with the vital aorta and pulmonary artery that surgeons long considered such an operation impossible. In 1938 the Boston surgeon Robert E. Gross finally performed it successfully. His operation was one of the great milestones of surgery. Soon afterward the New York surgeon Arthur S. W. Touroff showed that ligation of the patent *ductus* could cure even those victims who had already contracted subacute bacterial endocarditis—the first cure of what had previously been considered an inevitably fatal disease. (Later it was found that penicillin also could clear up subacute bacterial endocarditis, and deaths from this disease now are rare.) The operation for patent *ductus* today is so safe and successful in skilled hands (the average mortality is five per cent or less) that pediatricians do not hesitate to recommend it for all sufferers from this defect.

THE famous "blue baby" operation pioneered by Alfred Blalock and Helen A. Taussig of Johns Hopkins is the direct opposite of this operation—a "ductus-in-reverse." The basic result to be achieved—correction of an interference with proper oxygenation of the blood—is the same, but the method is different. In this case the operation in-



BLOOD CIRCULATES through the normal heart (*left*) by way of the right auricle (1), the right ventricle (2), the pulmonary arteries (3), the pulmonary veins (4), the left auricle (5) and the left ventricle (6). It is pumped out through the aorta (7). In fetal heart (*right*) blood by-passes lungs through *ductus arteriosus* (*circle*).



TETRALOGY OF FALLOT is four related heart defects: narrow entrance to the pulmonary arteries (1), displaced aorta (2), opening in the wall between the ventricles (3) and thickening of the right ventricle (4). In the "blue baby" operation the lack of oxygen due to these defects is corrected by connecting a branch of the aorta (*dotted lines*) to one pulmonary artery.

volves the creation of an artificial connection between the lung arteries and a branch of the aorta.

The abnormality that causes the trouble is not a single defect but a curious combination of deformities known as the "tetralogy of Fallot." This quartet of anomalies, which somehow are congenitally linked together, was first noticed by the British anatomist William Hunter at the end of the 18th century and later described more fully by the 19th-century French physician Étienne-Louis Arthur Fallot. The deformities are: 1) a narrowing of the opening from the heart to the pulmonary arteries; 2) a displacement of the aorta far to the right of its normal position, which constricts both the aorta and the pulmonary arteries; 3) a defect in the wall between the right and left ventricles which permits blood in one chamber to mix with that in the other; 4) a considerable thickening of the right ventricle. The net result of this combination of defects is that circulation to the lungs is impaired, and mixed venous and arterial blood from the ventricles is pumped into the general circulation, largely by-passing the lungs. It produces a set of markedly characteristic symptoms: cyanosis (blueness) of the skin, due to lack of sufficient oxygen in the blood; an increase in the number of red blood cells, manufactured by the body in an attempt to compensate for the lowered oxygen supply; clubbed fingers; shortness of breath even during mild exertion, and a rather striking tendency of the affected children to squat suddenly on their haunches after exertion in order to rest.

The conquest of this fatal disorder was achieved by the combination of the diagnostic insight of heart specialist Taussig and the surgical skill and daring of surgeon Blalock. It was Dr. Taussig who first proved that the baneful effects of the tetralogy of Fallot were due fundamentally to its interference with the flow of blood to the lungs. The two physicians at once saw that they might save these doomed children by a surgical operation on the arteries which would increase the blood flow to the pulmonary system. Dr. Blalock, who had long been interested in surgery of the great blood vessels, had worked out techniques for changing the connections of these vessels. In experiments on animals he had developed a method whereby he could cut the subclavian artery, which carries blood to the arm and shoulder, and by a procedure called anastomosis attach the stump of this artery to the side of the pulmonary artery. This maneuver shunted the mixed arterial and venous blood that came from the heart back into the lungs, thereby increasing the blood's oxygen supply. Fortunately the auxiliary circulation to the arm is sufficient to maintain an adequate blood supply to the arm even when the subclavian artery is cut, so the severing of this channel is not serious. Another difficulty about the operation also was overcome: it was feared that shutting off the blood supply to a lung for the period necessary to make an anastomosis would be dangerous for these already cyanotic patients, but with modern methods of anesthesia this fear has proved unfounded; the oxygen administered during anesthesia actually raises the oxygen level in the blood.

After trying his surgical procedures over and over again in experimental animals, Blalock performed the first operation on a human patient in 1945. The success of this operation is now a matter of surgical history. Hundreds of selected cases have been operated upon with a mortality of less than 10 per cent. The operation has steadily been improved. Blalock himself has varied his technique to fit particular conditions, and recently the Chicago heart surgeon Willis J. Potts worked out an important modification. He devised an ingenious clamp that closes off a small section of an artery, permitting the surgeon to operate on this section while blood continues to flow through the main channel. With the aid of this technique it is possible to anastomose the pulmonary artery directly to the aorta, obviating the need to sever the subclavian artery.

STILL another congenital heart condition in which surgery once seemed impossible has recently yielded to the scalpel. This is coarctation (a narrowing) of the aorta which sharply reduces the flow of blood to the body. In 1944 Clarence Crafoord, surgeon-in-chief of the Surgical Clinic in Stockholm, cut out the narrowed portion of the aorta in such a patient and successfully anastomosed the cut ends together again, thus restoring the free flow of blood. Shortly afterward the Boston surgeon Robert E. Gross, the originator of the patent *ductus* operation, independently performed an operation like Crafoord's, adding this accomplishment to his already impressive list. Dr. Gross has also originated operations to correct another troublesome condition—a congenital displacement of arteries in the chest that causes them to press upon the trachea or upper esophagus.

Thus surgery has made great strides in three of the four categories of heart disorders: wounds, infections and congenital abnormalities. The fourth category is the extremely dangerous group of disturbances involving interference with the blood circulation to the heart muscles, such as occurs in coronary thrombosis. Coronary heart disease may result in sudden death or grave weakening of the heart muscles. It remains one of the great challenges to medicine. Some progress in treating it has recently been made, however, not only by the use of anti-clotting ageis but even in surgery.

A coronary attack ma come without warning, but fortunatelyit is sometimes heralded by painful symtoms like those of angina pectoris, whic give notice of a failing heart circulatio before an actual block of the arteris takes place. With this warning, a fal break in the coronary blood supply mght be avoided by an operation that wold improve the blood flow to the damged heart. For many years Claude Bec, professor of surgery at the Western Ieserve Medical School, has been expdimenting with operations to accomplis this end. He began by grafting flaps of muscle from the chest wall to the hert, so that new blood vessels could gro into the heart muscle. His results we encouraging: about a third of his cass were considerably improved by th operation. In one remarkable case heactually put a patch on a weakened eart. More recently Beck has develoed a variation on the operation: he cts a window in the pericardium and itroduces some asbestos powder as a freign body to stimulate the growth o adhesions between the heart and ie chest wall. New arteries then growhrough the adhesions.

Another ingenious aproach has been devised by the Montre surgeon Mercier Fauteux, now at Irvard University's Laboratory for Sugical Research. His operations are desiged to increase the flow of blood throuh the coronary arteries and to slow tl flow through the veins coming fromthe heart. He achieves the former by svering the sympathetic nerves that corol constriction of the arteries, thus eminating such constrictions. He slows he flow in the veins by tying them f at the place where they come togeter to form the large vessel called thecoronary sinus. As a result of this slowig of circulation the blood stays in conta with the heart muscles longer and is ble to transmit more oxygen to them. Both Beck and Fauteux have also tried nastomosing an artery to the coronarysinus to bring more blood to the heart. While this work is still largely in the exprimental stages, it is quite likely to accoplish important results in the near futu.

Surgery has also bee effective in relieving circulatory disrders in other parts of the body, notab the extremities and the abdominal orns. As is well known, the constrictig sympathetic nerves play a large pt in controlling the flow of blood, paicularly in the small vessels. By cuttg the sympathetic nerves to vessels where the circulation is poor, surgeonhave been able to increase the blood flo materially and eliminate the pain tht attends poor circulation.

One of the greatest usolved problems in surgery of the hearis the repair of damage to the heart valves, such as occurs in rheumatic heart disease. Aside from all the other perils that attend operations within the heart—hemorrhage, clotting, fibrillation (disorganization of the rhythm) and stoppage of the heart—operations on the delicate valves tend to create scars that soon destroy the beneficial effects of the operation. The most promising work in this challenging field is that of the late Horace G. Smithy of Charleston, S. C., who, unhappily, himself died recently of rheumatic heart disease.

Only two years ago Smithy reported that in a number of experimental operations on the heart valves of dogs he had developed a method of restoring damaged valves to normal functioning. The valves of the heart are thin flaps of tissue which are opened and closed by the pressure of blood, depending on the direction of the flow. When scarred by the effects of rheumatic fever or other infections, the valves stick and fail to open or close properly. The surgical problem is to slit them apart in such a manner that they will not grow together again by adhesion. Several surgeons, among them the famous Elliott C. Cutler of Harvard, had tried to perform this operation but failed. Smithy, using a technique similar to Cutler's, inserted a hook-shaped knife, called the valvulotome, through the wall of the heart until the hook was curled around the scarred valve. Then he withdrew the instrument delicately, cutting a slit through the valve. After many trials on dogs, Smithy reported that he had performed the operation successfully in a human patient. It is still too early to tell whether the valves will eventually close again by new scar formation, *i.e.*, whether the good effects of the operation will be truly permanent. Fortunately Smithy left detailed instructions for the operation, and other surgeons may well be able to go on from his beginning.

THE operations on the heart described in this article are in a relatively new field which might be called physiologic surgery. In contrast to the classical reparative and extirpative types of surgery, such as the setting of bones and removal of cancers, physiologic surgery is directed to changing the functioning of organs to improve their action. It has made far greater progress in the past decade than in all previous surgical history. Its successful treatment of conditions hitherto deemed hopeless, exemplified so dramatically by Blalock's operations for the tetralogy of Fallot, seems to augur a bright future for this branch of surgery.

Frank G. Slaughter is a surgeon and an author of popular medical books.

TOPOLOGY

A fascinating and important branch of modern mathematics is concerned with such matters as turning an inner tube inside out and bands and bottles that have only one side

by Albert W. Tucker and Herbert S. Bailey, Jr.

He killed the noble Mudjokivis.
Of the skin he made him mittens,
Made them with the fur side inside
Made them with the skin side outside.
He, to get the warm side inside
Put the inside skin side outside;
He, to get the cold side outside
Put the warm side fur side inside.
That's why he put the fur side inside,
Why he put the skin side outside
Why he turned them inside outside.
—From *A Book of Humorous Verse,* compiled by Carolyn Wells.

LO, the poor Indian was faced with a problem in topology, and by putting the skin side outside and the fur side inside he solved it admirably, both from the physiological and topological points of view. Although the connection between this problem and mathematics may not be obvious, actually it is an exercise in topological reasoning that enables one to predict that turning a pair of mittens inside out will convert the right-hand mitten into a left and the left into a right. Insideness and outsideness are basic concepts in topology, one of the most active branches of modern mathematics.

Topology is the branch of mathematics that deals with properties of position that are unaffected by changes in size or shape. Its subjects are surfaces, knots, networks and many other figures. Perhaps the easiest way to define topological properties is to say that they are geometric properties which stay the same in spite of stretching or bending. Topology is full of apparent paradoxes and impossibilities, and is probably more fun than any other branch of mathematics.

The problems used as examples in this article may strike many readers as being mere curiosities. While the novel properties studied by topologists make the subject interesting and at times weird, this article will have failed in its purpose if it leaves the reader with the impression that topology is nothing more than a collection of Chinese puzzles. Topology is one of the most fundamental branches of mathematics. It may be described as the mathematics of the possible. Its function is to settle questions for other branches of mathematics, *i.e.*, whether certain solutions do or do not exist, or whether certain conditions are possible or impossible. It does not usually tell how to find solutions. Thus topology has not yet had much application to everyday problems in science or technology; it has an important indirect influence on practical affairs, however, because it is a basic part of the structure supporting those branches of mathematics that are directly applied.

Here is a typical topological problem, similar to that of the Indian's mittens but of a higher order of subtlety: Can the inner tube of a tire be turned inside out? This is not an easy problem for a non-topologist. The answer to the question is Yes, and what might be labeled "instructions for turning an inner tube inside out" are illustrated in the series of drawings on the opposite page. We assume that the rubber may be stretched as much as one pleases and that there is a hole in the tube at the place where the customary valve stem is attached. The reader is not advised to try the process with a real inner tube; it would require prodigious stretching. One begins by putting a finger in the hole and spreading the hole wider and wider until the tube is stretched out to a shape like two long strips of paper, attached to each other and interlocked. Give each ring a half-twist; this in effect turns the surface inside out. Next stretch the strips of rubber back into the shape of an inner tube. Note that the direction of the grain, if one assumes that rubber has a grain, has been changed; whereas originally it ran lengthwise along the tube, it now runs around the thickness of the tube. You have turned the tube inside out. And topologically the figure remains the same through all its contortions, since nothing has intervened except stretching. Topologically, if not practically, the inner tube is still an inner tube at every stage.

Problems such as this make topology amusing, and there have been a number of popular illustrations of various aspects of it. The most famous of them are the Moebius band, the seven bridges of Koenigsberg and the four-color map problem.

THE Moebius band is a favorite plaything of topologists. In 1858 the German mathematician A. F. Moebius discovered that if one takes a long strip of paper, gives it a half-twist and connects the ends to make a ring, one creates a seeming impossibility—an object that has only one side. Turn or trace it any way you wish; you will always find that it has a single continuous surface. A child of four can paint an ordinary paper ring blue on one side and red on the other, but not even Picasso could do that to a Moebius band. Consider further what happens if you cut the band along a line running around the middle of it. Cut it all the way around until you return to your starting point. Although you have cut the band "in two," it still is in one piece (*see top drawings on page 20*). This is known as a "loop cut," and some of its fascinating variations will be considered presently.

Another one-sided form is the Klein bottle, invented in 1882 by the great German mathematician Felix Klein. The easiest way to visualize this object is to imagine that an inner tube is cut through and straightened out like a cylinder, with one end stretched out to make a base and the other end narrowed like the neck of a bottle; then the narrow end is twisted over and thrust through the valve-stem hole in the side of the tube and finally is flared out and joined with the open end at the base (*see middle drawings on page 20*). This may be called a "punctured" Klein bottle, the hole in the tube being the puncture in the bottle. For topological purposes one usually supposes that no hole actually exists, so that the continuous one-sided surface passes through itself. This of course is physically impossible, but topologists make free use of such ghostly properties. A Klein bottle may be thought of as a pair of Moebius bands with the edges glued together; the bottom drawings on page 20 show how a Klein bottle can be split in half and opened out to make two Moebius bands.

These properties of Moebius bands and Klein bottles have been summarized in a pair of limericks:

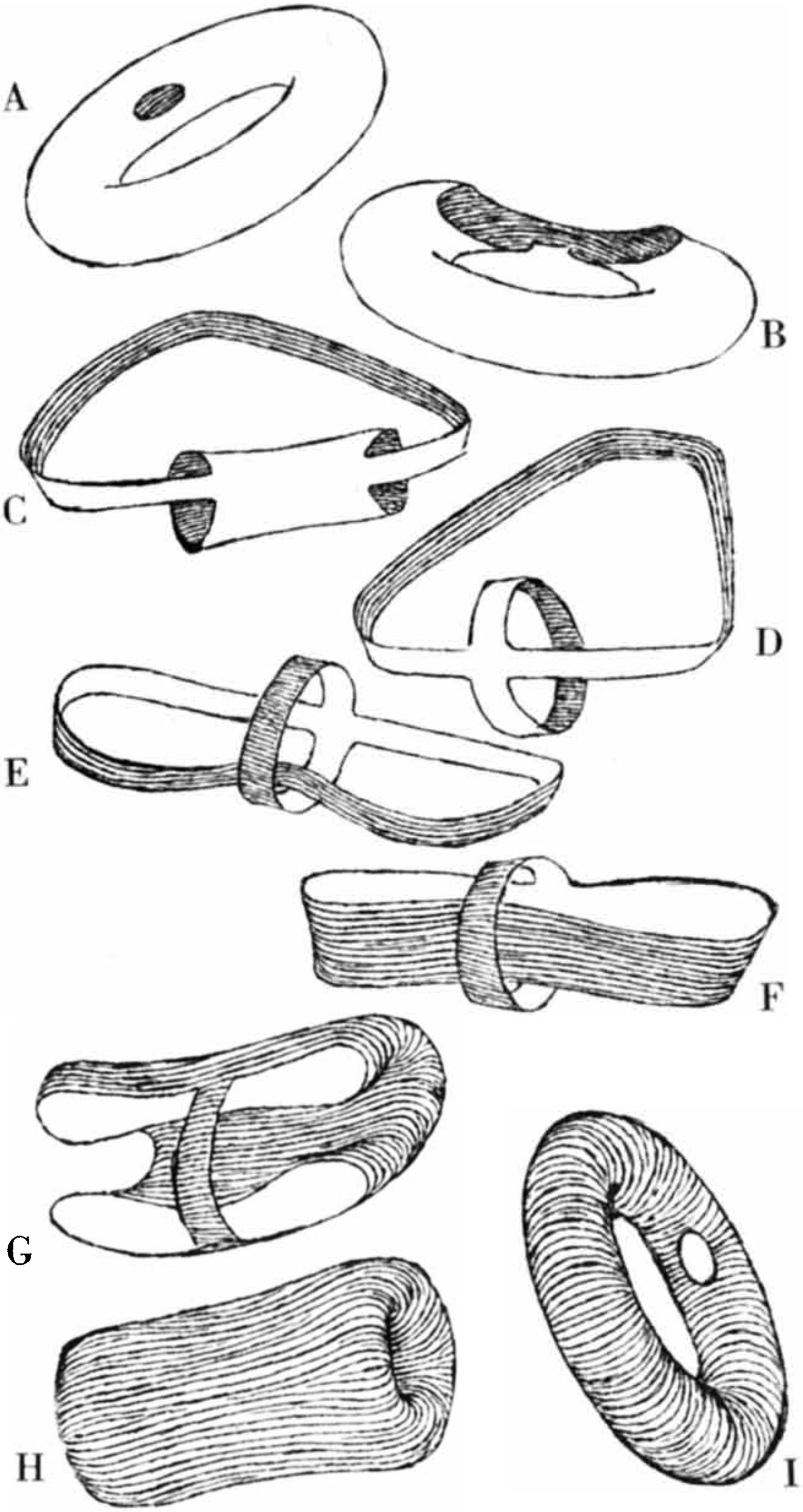
A mathematician confided
That a Moebius band is one-sided,
And you'll get quite a laugh
If you cut one in half,
For it stays in one piece when divided.

A mathematician named Klein
Thought the Moebius band was divine.
Said he, "If you glue
The edges of two,
You'll get a weird bottle like mine."

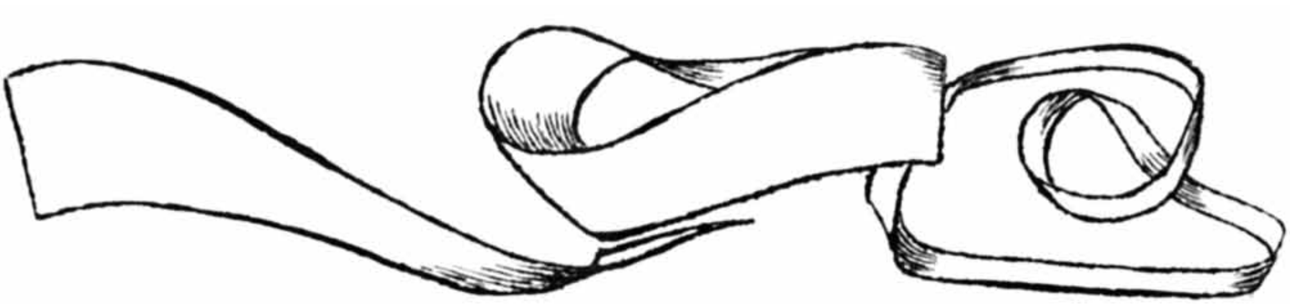
An ordinary flat surface such as a sheet of paper can be considered as a punctured sphere that has been stretched and flattened out into a sheet or disk. Topologists customarily proceed from such simple figures to more complicated surfaces, and they generalize their findings in two and three dimensions to include figures in four, five, and on to *n* dimensions, but here we shall confine our attention to the simple surfaces.

Since it may be difficult to recognize inner tubes or Klein bottles when they are badly stretched out of shape, it is desirable to characterize each topological type of surface by simple invariant properties. One of the distinguishing invariant properties of a surface is the number of edges, and here we are considering only surfaces with one edge. Another distinguishing invariant is the number of sides: one or two. A Moebius band or a punctured Klein bottle is an example of a one-sided surface; a disk or an inner tube has two sides. A third distinguishing invariant, unfamiliar to laymen but mathematically important and not difficult to grasp, is the Betti number. It is the maximum number of cross cuts that can be made on a surface without dividing it into more than one piece. A cross cut may be thought of as a simple cut with scissors; it begins and ends on the edge. Any cross cut on a disk will divide it into two pieces, so the Betti number of a disk is zero. The Betti number of a Moebius band is one; for a Klein bottle or inner tube it is two.

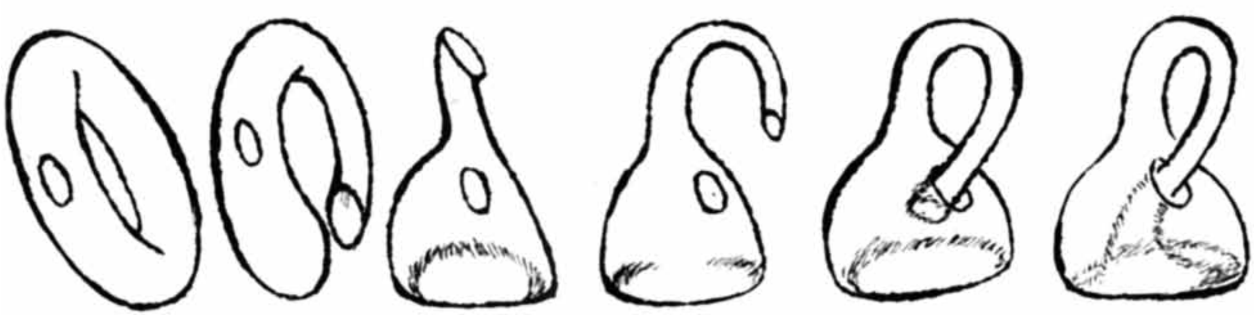
Loop cuts provide another way of finding the Betti number of a surface. These cuts begin and end at a point in



AN INNER TUBE may be turned inside out if one assumes that it is made of a remarkable kind of rubber that may be enormously stretched and shrunk. At the upper left is an inner tube (A) with the hole for the valve stem somewhat enlarged for clarity. The hole is first greatly stretched until rubber is in two strips (B, C and D). Each of the two interconnected rings is then given a half-twist and the whole process is reversed (E, F, G, H and I). Notice that the grain of the rubber, assuming it has a grain, now runs around the thickness of the tube instead of lengthwise along it.



A MOEBIUS BAND may be constructed by taking an ordinary strip of paper (*left*), giving it a half-twist and pasting its ends together. The resulting figure (*center*) has only one side instead of two. If the figure is then punctured with a pair of scissors and cut lengthwise down the middle, it will not, as one might expect, fall into two pieces. It will be changed into a band that has two sides and two full twists (*right*).



A KLEIN BOTTLE cannot be constructed as easily as a Moebius band, except in the imagination. There it can be made readily if one assumes that glass can be stretched and shrunk rather like the rubber of the inner tube on page 19. The resulting figure, like the Moebius band, has only one side. If it is assumed to have no hole, it has no edge. The punctured Klein bottle at the right, however, has a hole and one edge.

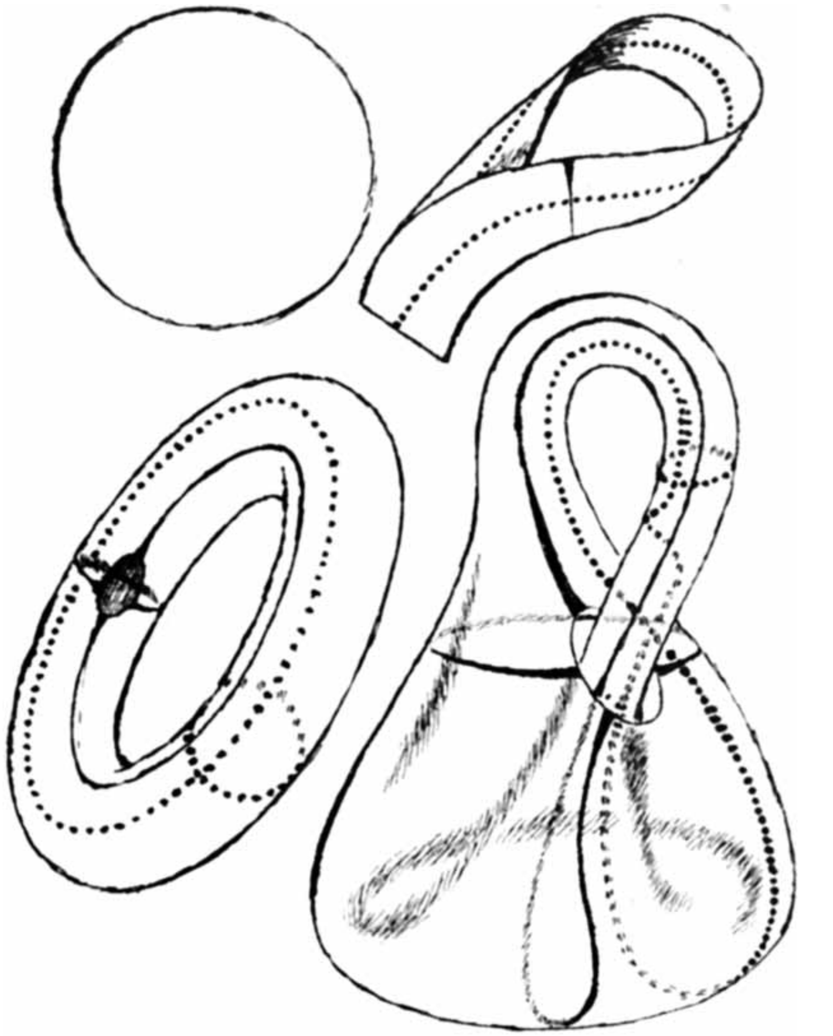
BAND AND BOTTLE have a close kinship that is revealed when the bottle is cut in half. The figure at the left is an intact Klein bottle. The figure in the center shows how one of its two halves would look if the bottle had been cut from top to bottom. If one again assumes glass that can be stretched and shrunk, half of a Klein bottle can be shaped into a Moebius band. The process has been nearly completed at the right.

the surface, avoiding the edge entirely. By counting the maximum number of loop cuts that can be made without dividing a one-edged surface into more than one piece (or a surface with m edges into more than m pieces) we again get the Betti number of the surface. Cross cuts and loop cuts were used by the German mathematician Bernhard Riemann in 1857 to define the connectivity of a surface. Riemann called a disk "simply connected," a band or halo "doubly connected," and so on, his connectivity number being always one greater than the Betti number.

By examining the drawings at the left on the opposite page, you will see that each loop cut intersects one and only one cross cut. This pairing illustrates a fundamental relation called duality. When generalized in n dimensions, it provides the content of a "duality theorem," formulated by S. Lefschetz of Princeton University in 1927, that is one of the major achievements of modern topological research.

So the intrinsic topological invariants of a two-dimensional surface are: 1) the number of edges, 2) the number of sides, 3) the Betti number. These will always be the same no matter how the surfaces are stretched or reshaped in three-dimensional space, provided there is no tearing or welding. Keeping these intrinsic invariants in mind, consider a Moebius band formed by making three half-twists in a paper band before connecting the ends. Such a band has only one edge and one side, and since only one cross cut is possible the Betti number is one. Intrinsically it is the same as the ordinary Moebius band with only one half-twist. But there is a difference in the way it is situated relative to three-dimensional space: the edge of the band traces out a knot, whereas the edge of an ordinary one half-twisted Moebius band is a simple unknotted curve (*see drawings at right on opposite page*).

Knots intrinsically are all the same; they are just loops or circles. The problem of classifying them by some reasonable system of invariants is as yet unsolved. But one-edged surfaces provide an excellent means of studying knots. For example, two distinct knots can be made by twisting a thrice half-twisted Moebius band to the right or to the left. One way produces a right-handed trefoil knot, the other a left-handed trefoil knot, and neither can be stretched or reshaped to make the other. Most of the known properties of any knot can be convenient-



CROSS CUTS (*solid lines*) **begin and end at the edge. Loop cuts** (*dotted lines*) **avoid edges. The Betti numbers are zero for a disk (two sides, one edge), one for a Moebius band (one side, one edge), two for an inner tube (two sides, one edge) and two for a punctured Klein bottle (one side, one edge).**

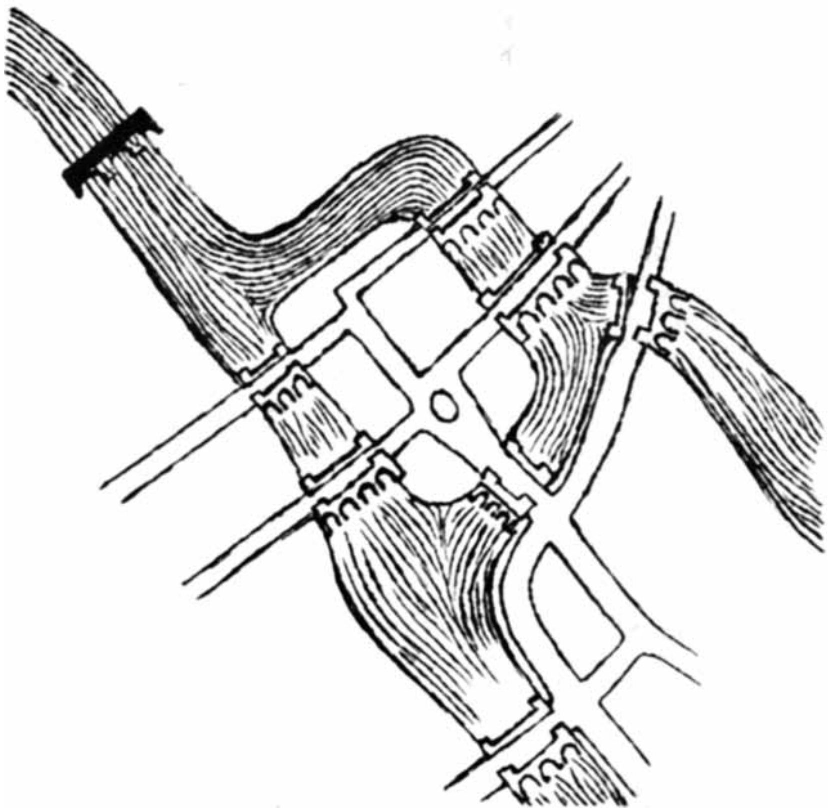
TREFOIL KNOT (*bottom*) **may be compared to a Moebius band that has three half-twists** (*top*) **by flattening a band and tracing path of its edge.**

ly derived by associating it with the one-edged, two-sided surface of lowest Betti number whose edge can be arranged to form the knot—a method introduced in 1934 by Herbert Seifert of Heidelberg. If the problem of the classification of knots could be solved by a general principle covering all cases, the road would be clear for many advances in related topological fields.

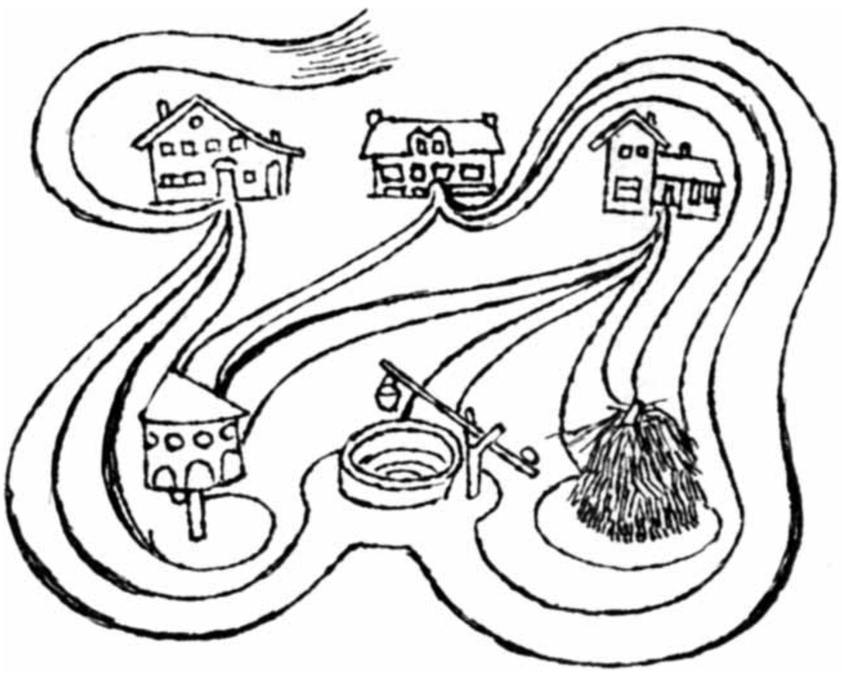
Since topology allows any amount of stretching or reshaping of the forms it considers, the ordinary knots that one can tie in a rope do not interest topologists. Every such knot can be reshaped into a straight line. In topology the only true knots are those that are untyable and un-untyable, so a topologist may legitimately raise the question, "Is this knot a knot or not?" Topologists have been known to discuss varying degrees of knottedness, knottiness and even beknottedness.

NETWORKS, unlike knots, do have intrinsic topological interest. The Koenigsberg bridge problem, one of the oldest of topology, has to do with an intrinsic property of a particular network formed from four points and seven lines. The German city of Koenigsberg, now part of the U.S.S.R., has its center on an island in the river Pregel. In the 17th century this island was joined to each bank of the Pregel by two bridges, and it was also linked by a bridge to a neighboring island, which in turn was joined to each bank by one bridge (*see top drawing on page 22*). The citizens of Koenigsberg liked to stroll on the bridges, and the question was proposed: "How could one stroll across all seven bridges without crossing any one of them twice?" The reader may convince himself after several tries that the feat is impossible.

In 1736 the great Swiss mathematician Leonhard Euler settled the question for all time by working out the general principle that underlies all such network problems. Suppose we replace the land areas by points and represent the bridges as lines between the points. The points are called vertices. A point with an odd number of paths leading from it is called an odd vertex; one with an even number is an even vertex. The general principle is: The number of journeys necessary to traverse a connected network is equal to half the number of odd vertices. (It is impossible to construct a network with an odd number of odd vertices, for each line is required to begin at a vertex and



BRIDGES OF KOENIGSBERG are a classical problem of topology. The problem is to try to walk across all the seven bridges that interconnect two islands and the mainland without crossing any bridge twice. The problem could be solved only after an eighth bridge had been built (*upper left*).



THREE COTTAGES make a problem rather similar to that of the Koenigsberg bridges. The problem here is to connect each cottage with a dovecote, a well and a haystack by paths that do not cross. As the unfinished path from the cottage at the upper left indicates, the problem cannot be solved.

end at one.) If the vertices are all even, or if there are not more than two odd vertices, it may be traversed in one journey. (In 1935 one of the authors—Tucker—actually walked the Koenigsberg bridges without crossing any bridge twice. An eighth bridge had been built.)

A connected network in which there are no cycles, or loops, is appropriately called a "tree." Such a network can always be built up from a single vertex by attaching lines and vertices alternately. Each time a new line is attached to any existing vertex a new vertex must be introduced as its terminus, else the line would terminate in an old vertex and create a cycle. So the number of vertices in a tree is one plus the number of lines. A connected network that is not a tree can always be reduced to a tree by removing a number of lines without removing any vertices. If the network has V vertices and L lines to start with, and B lines are removed to obtain the tree, then $V = 1 + (L - B)$ for the tree, and so $B = 1 + L - V$. This B is the Betti number of the network. It can be defined as the maximum number of lines that can be cut or removed from the network so as to leave all the vertices connected together in one piece by the remaining lines. For example, the Betti number of the Koenigsberg bridge network is four. The marked resemblance of the definition of the Betti number for a network to that for a surface is, of course, no accident.

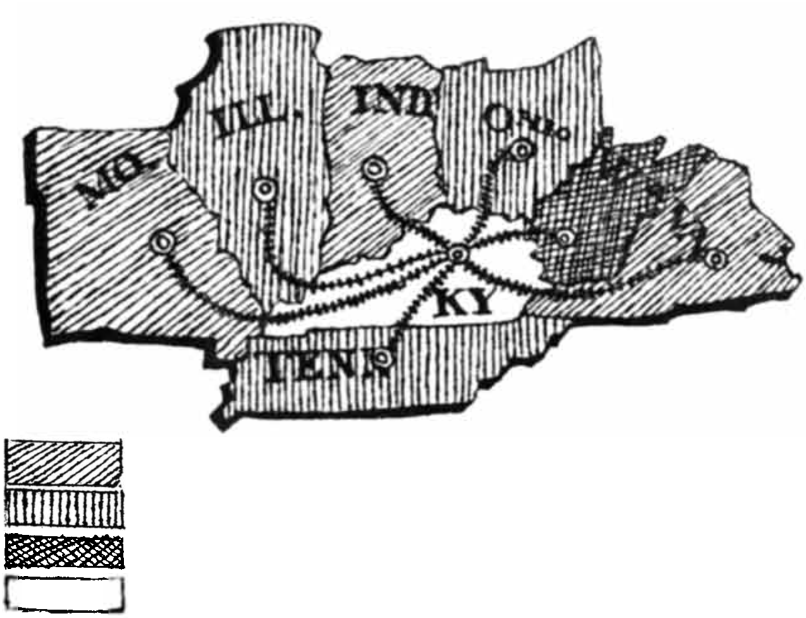
The Betti number has a long and interesting history, although it was not so named until 1895. The German physicist G. R. Kirchhoff, in his paper of 1847 that introduced two famous laws for electric networks, used the concept of Betti number to characterize the number of independent loop equations involved in determining the distribution of current in a network. The concept was picked up by the British physicist James Clerk Maxwell, who called it "cyclomatic number" in his famous text *Electricity and Magnetism* published in 1873. Thus two physicists had used the idea of the Betti number a generation before Henri Poincaré, the French mathematician, established it firmly in mathematics in 1895. Poincaré, who is regarded as the father of modern topology, named the Betti number after Enrico Betti, an Italian mathematical physicist who in 1871 had generalized the connectivity numbers of Riemann.

We now turn to networks drawn on some surface, it being required that the network lines meet only at the vertices. For a connected network drawn on the surface of a sphere there is a famous formula, $V - L + A = 2$, named after the same great Euler who settled the Koenigsberg bridge problem. Again V and L are the numbers of vertices and lines in the network; A is the number of areas into which the surface is divided by the network. Euler confined his attention to the vertices, lines and areas (or faces) of a polyhedron with a convex surface, but, of course, the properties are the same as on the surface of a sphere, since a polyhedral surface can be stretched and rounded out into spherical shape.

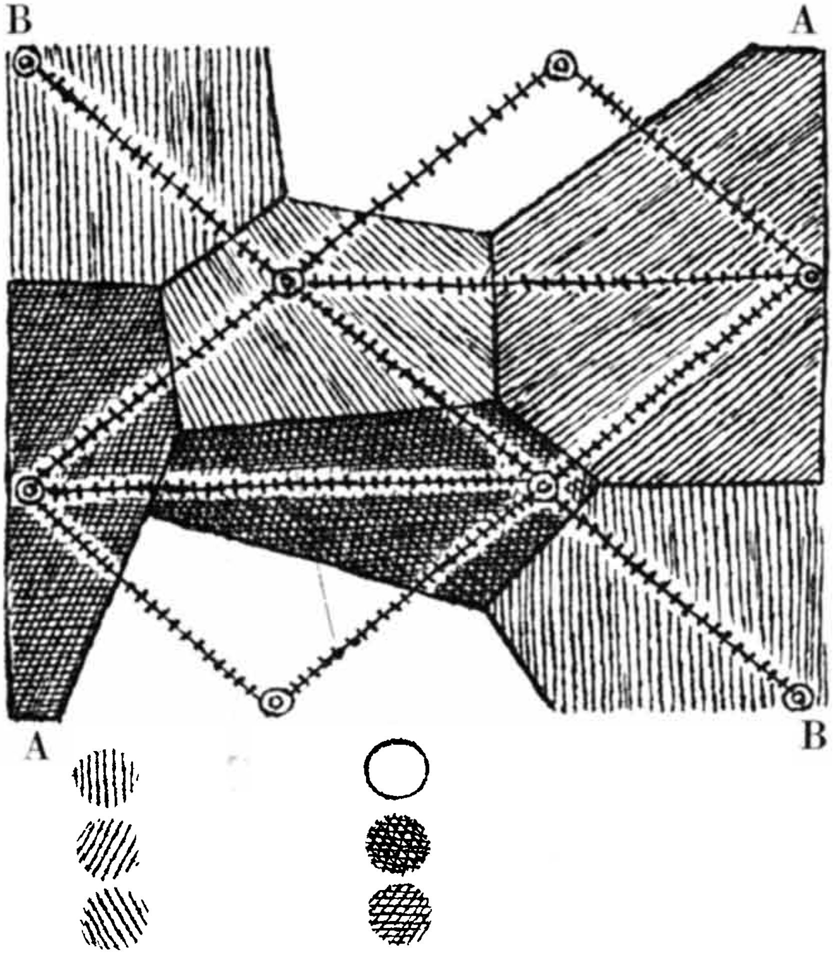
A spherical network can be turned into a network on a plane surface by puncturing the spherical surface in the middle of one of the areas and flattening the punctured sphere out into a disk. For the planar network, $V-L+A=1$, since one area is lost through the puncture. By rewriting this as $A=1+L-V$ the reader may observe that the number of areas enmeshed in a connected network on a plane surface is the Betti number of the network.

But some networks cannot be drawn in a plane without having their lines cross and create new unwanted vertices. Consider the following problem, which is as old as its wording suggests: Can you connect each of three cottages to a dovecote, a well and a haystack by paths that do not cross? A few tries will probably convince you that the problem is insoluble (*see bottom drawing on opposite page*). The Polish mathematician Casimir Kuratowski proved in 1930 that six points cannot be so connected, nor can five points be completely interconnected; but any network can be drawn in a plane without crossings except when one of the foregoing situations arises. On a Moebius band, however, even six points can be completely interconnected, and on an inner tube seven points can be so connected. In the full freedom of three-dimensional space, of course, any network can be drawn without unwanted crossings.

We cannot leave the subject of networks without referring to the famous four-color problem. Although it seems so simple that almost anyone feels he could solve it easily, no one has ever solved it, nor has anyone proved that it is insoluble. The rules are that a map must be colored so that every country is colored differently from every other country that it borders (point contact is not counted as a border), and that the minimum number of colors must be used. The problem is to prove that four colors are sufficient to color any map on a sphere or in a plane, or else to construct a map that requires five colors. The Belgian mathematician S. M. de Backer showed in 1946 that four colors are sufficient to color any map containing 35 countries or less, and C. N. Reynolds of the University of West Virginia has informed us that he has recently pushed this number up to 83, but no one has established a principle to cover all possible cases. Many maps require only three colors. The map of the U. S. requires four colors in the states bordering on Kentucky



FOUR-COLOR MAP sets forth the four-color problem. The four colors are symbolized by four tones. The basis of the problem is that each state be colored differently from all those adjacent to it. The problem is to prove that four colors are sufficient, or to invent a map that requires five.



SIX-COLOR MAP can be made on a Moebius band. Upper and lower edges are joined so that A meets A and B meets B. The colors are assumed to have soaked through the paper. Capital at upper left is the same as that at lower right. Capital at upper right center is the same as that at lower left center.

(*see top drawing on page 23*). The four-color problem applies only to plane surfaces or spheres; other surfaces create different problems.

THERE are listed below a group of related theorems concerning topological properties of spherical surfaces. Each theorem seems to be merely a bit of curiosa, an odd fact stated only for its oddity. But the theorems are illustrations of an important body of mathematical knowledge, and though the discussion given here is extremely brief, it is hoped that they will give the reader some insight into still another aspect of topology.

1. The wind cannot be blowing everywhere on the earth at once. At every instant there must be at least one windless point on the earth's surface. But it is possible for the wind to be blowing everywhere except at one place, *e.g.*, the South Pole.

2. If the wind is blowing everywhere in the Northern Hemisphere at any given instant, then on the Equator it must blow in every direction of the compass. That is, for any given direction—say, northeast—there must be some place on the Equator where the wind has this given direction.

3. Also, under the same conditions, there must be on the Equator at least one pair of diametrically opposite places at which the wind blows in exactly opposite directions of the compass.

4. At any given instant there is at least one pair of antipodal points on the earth's surface that have equal temperatures and equal readings of humidity.

5. If three empires covered the entire surface of the earth, land and water, then at least one empire could boast that the sun never set on its territory. For at least one of the three empires would have to contain a pair of antipodal points within or on its borders.

Of course these are mathematical theorems rather than physical actualities. The wind that is mentioned is an ideal wind without discontinuities and restricted to its surface component, and temperature and humidity are assumed to be continuous variables.

Theorems 1 and 2 are simple consequences of a general "fixed-point" theorem formulated for n dimensions by the Dutch mathematician L. E. J. Brouwer in 1912. Theorems 3 and 4 are simple consequences of a general "antipodal-point" theorem formulated for n dimensions by Karol Borsuk and S. M. Ulam of Poland in 1933. Theorem 5 follows from a general n-dimensional theorem stated by L. Lusternick and L. Schnirelmann of the U.S.S.R. in 1930. None of these five theorems would be true on a hypothetical ring-shaped planet.

The five theorems concern such diverse properties of spheres that it is difficult to see how they are related to one another. Yet all except the first can be proved by means of the general solution of the following apparently simple problem: Is it possible to arrange playing cards in a square so that no two cards of the same color are adjacent to each other—vertically, horizontally, or diagonally—unless they are of the same suit, and so that on the outside rows each pair of opposite cards is of the same color but of different suits? The answer is, No. (Topologists have won bets by challenging non-topologists to solve it.) Why should such a simple "card trick," one that cannot even be worked, be a revealing topological problem? Why should the generalized theorem which says that this cannot be solved be useful in solving so many other problems?

STONE LION beside a fireplace at Princeton University displays a Moebius strip on which a fly can crawl anywhere without crossing an edge.

In order to understand this paradox you must notice that basically this problem is quite different from most of the other problems discussed here. The other problems dealt with whole bodies, areas or surfaces; this theorem deals with a pattern that can be made to approximate the points of the square as closely as you please. This playing-card problem, then, shows a fundamental interplay between microscopic and macroscopic characteristics of a square (or disk, or other simple area). The theorem has been extended to n dimensions, where it may be used to show whether certain analogous relations can exist. Thus this playing-card problem has very deep topological significance.

MANY of the simpler topological concepts are used every day by people who have never heard of topology. The basic ideas of topology are so fundamental that we learn many of them as infants. The concepts of insideness and outsideness, of right-handedness and left-handedness, of linkedness and unlinkedness are forced on us at an early age.

During the last decade applied mathematicians and engineers have begun to realize the usefulness of topology in attacking certain types of problems, particularly those involving nonlinear differential equations. Most physical phenomena can be described mathematically by differential equations, *i.e.*, equations relating rates of change. In the past it was usually assumed that effects were linear, that is, directly proportional to causes; thus the vibrations of a spring were assumed to follow Hooke's law that stress is proportional to strain, and in calculating the gain of an amplifier the current in a vacuum tube was assumed to be proportional to the grid voltage. The assumption of linearity was made because calculation of nonlinear differential equations was extremely difficult if not impossible. But nature is rarely if ever "linear"; and for many modern applications, such as certain problems in electronics and supersonic aerodynamics, the assumption of linearity is downright misleading.

Topology is coming into use to show what types of solutions of certain nonlinear differential equations are possible. The answers are qualitative, not quantitative. Topology may tell an engineer what general type of circuit can satisfy his requirements, but it will not tell him the values of the circuit elements; these must be determined by other means. Nevertheless, the engineer might fail to hit on the desired general type of circuit without the aid of topology.

Topology is young as a branch of mathematics. Though the simpler ideas of topology are forced on every child by experience, its sophisticated development is only about a century old, and by far the most active development has been during the past 50 years, since Poincaré's contributions. Many of the theorems of topology are insufficiently related to other branches of mathematics. Many apparently simple problems still await solution. But topology is moving ahead rapidly, and most topologists are confident that progress in the next 50 years will be as significant as the developments of the first half of this century.

Albert W. Tucker is professor of mathematics at Princeton University. Herbert S. Bailey, Jr., is science editor of the Princeton University Press.

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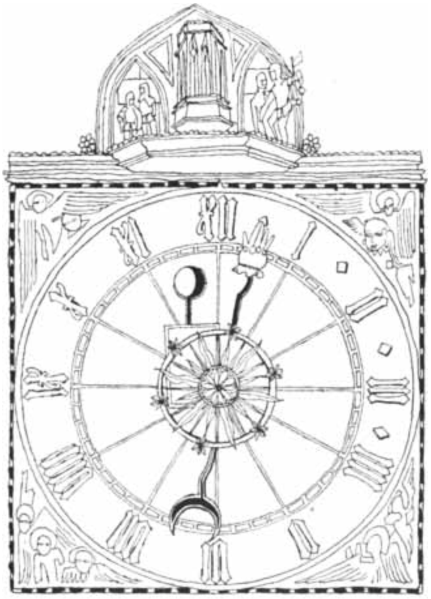


A New Einstein Theory?

THE 33 years since he announced his general theory of relativity in 1916 have in a sense been difficult and frustrating ones for Albert Einstein. As every physicist knows, during most of this period Einstein has been engaged in an effort to develop a "unified field theory." The challenging and ambitious task to which he has addressed himself is to relate the physical phenomena in the submicroscopic world of the atom to those in the macroscopic world of universal space-time, to find a common principle explaining both electromagnetic forces and gravitational force, or what relativists now call space-time curvature. In this inquiry Einstein has pursued a lonely course; most physicists have taken the apparently more promising road of quantum theory. Again and again in the past two decades Einstein and his few companions in the quest for a unified field theory have discovered what seemed to be hopeful avenues to a solution, only to be stopped by insurmountable flaws in their reasoning.

Now, at 70, though weakened by a recent operation, Einstein believes that he has finally achieved a solution, or at least the most successful solution so far. In a new edition of his famous work *The Meaning of Relativity*, to be published next month by the Princeton University Press, Einstein will set forth what some of his friends say is the long-sought unified field theory. The scientist himself has given no public hint of any such extraordinary development, but he is said to have told close associates at the Institute for Advanced Study that he regards the new theory as his greatest achievement. He is reported to have given enthusiastic blackboard explanations of his equations, switching from English to German and back again in his excitement, to spellbound groups of his colleagues at recent informal conferences at the Institute.

Einstein's paper explaining this new work will appear as a modest 16-page appendix to his republished book. If it is indeed a statement of a unified field theory, and if it can be confirmed by other workers, it will be the most important event in theoretical physics in many years.

The Specter of Defense

IF and when the world finds it necessary to prepare for atomic war in earnest, every nation will doubtless be compelled to attempt an all-out mobilization of its population that will make the civilian-defense measures of World War II look like a grammar-school fire drill. In the next few weeks proposals for atomic defense preparations in the U. S. will receive a full public airing. The Joint Congressional Committee on Atomic Energy plans to begin hearings on the question this month. Sometime "early in 1950" the National Security Resources Board, which has charge of coordinating the civil-defense plans of all U. S. agencies, will publish a comprehensive, long-range program for reducing the nation's vulnerability to atomic attack. And the Atomic Energy Commission soon will issue a report on the effects of atomic explosions and the medical treatment of victims which is described as the most important document on the atomic bomb since the Smyth report.

There is already in existence a plan for civilian atomic defense which will probably furnish the framework for the impending debate. This is the so-called Hopley report, prepared by the Office of Civil Defense Planning of the Department of Defense last year under the direction of the late telephone-company executive Russell J. Hopley of Omaha.

The Hopley report called for the creation of a National Office of Civil Defense with large powers for organizing defense activities. The report presented detailed plans for rescue and medical services on a block-by-block basis in every city. The program contemplated the mobilization of some 15 million civilians, with about 500,000 selected leaders, in this civil-defense army.

Though not widely publicized, the Hopley plan was sharply attacked by a few commentators as a dangerous militarization of the nation. President Truman disbanded the Hopley committee and transferred its planning function to the National Security Resources Board. The President explained: "Under present conditions the essential need of the Federal government in the area of civil defense is peacetime planning . . . rather than operation of a full-scale civil-defense program." The NSRB assigned medical planning to the U. S. Public Health Service, planning for disaster relief to the General Services Administration, and planning for the mobilization of civilian aides in military operations to the Department of Defense. Last September 12,000 volunteers joined the armed forces in a large-scale test of air-raid defenses along the Eastern seaboard. So far 11 states have passed laws authorizing local civil-defense activities.

The Russian atomic explosion, however, has revived discussion of the Hopley plan. Among those who have recently urged that the Government go beyond "peacetime planning" and initiate a program along the lines of the Hopley report are Bernard Baruch, members of Congress and military spokesmen. Britain, they point out, is already training volunteers in the use of Geiger counters and in rescue work in the ruins of specially built "atomic villages." Members of the Joint Committee on Atomic Energy have indicated that they are prepared to recommend legislation to establish a permanent Office of Civil Defense.

The Joint Committee will also consider proposals for dispersal of the population and of industries. Decentralization on a nation-wide basis is conceded to be out of the question, since it is estimated that to break up all cities into units of 50,000 or less—an idea of some atomic defense planners—would cost at least $500 billion. Some degree of future dispersal through city planning may, however, be seriously recommended. The AEC recently pointed out that three atomic bombs could immobilize all of Washington, and urged relocation of key government agencies and hospitals with "perhaps two miles between targets."

Those who advocate the dispersal of industry argue that a trend in that direction has been taking place anyway for many years; almost 30 per cent of all new plants are being built in towns with a population of 10,000 or less. The Air Force recently asked the Chase Aircraft Company to move from Trenton, N. J., to Marietta, Ga.; the Grumman plant on Long Island, the Boeing plant in Seattle and others are considering similar inland moves for military reasons. Already, however, important opposition to such relocations has developed. A group of Congressmen has organized a "National Defense Committee" under the leadership of Senator Warren G. Magnuson, Democrat of Washington, to prevent the removal of plants from the West and East Coasts and the Great Lakes region. The committee, which claims a membership of 62 Senators and 281 Representatives, is "deeply disturbed that these areas of the U. S. are not adequately defended. Even more alarming is recent evidence that the armed forces are . . . making efforts to move industries from these areas to inland locations."

The Insecurity of Security

IN the 16th century the question that perhaps most disturbed the collective security of mankind was whether the earth revolved around the sun or vice versa, and the ultimate mark of villainy was to be denounced for heresy on this question. Today possibly the chief disturber of public security in the U. S. is atomic "security," and the surest way to make the front pages is to accuse someone of giving atomic "secrets" to Russia. In recent months hardly a week has passed without a fresh proof of this axiom. The latest, as this issue went to press, was the case of Fulton Lewis, Jr., *v.* the late Harry L. Hopkins.

Lewis, a radio commentator who has often attacked atomic scientists, on December 2 introduced to his five million listeners an ex-Air Force major named George Racey Jordan. The latter deposed that in 1943 and 1944, while stationed at Great Falls, Mont., he discovered that 2,850 pounds of uranium compounds, 1,000 grams of heavy water and suitcases full of blueprints and documents from "Oak Ridge" were being flown from Great Falls to the U.S.S.R. under high-priority orders from Mr. Hopkins, then Lend-Lease expediter and assistant to President Roosevelt. Jordan said he had seen a note on White House stationery signed "H. H.," saying: "Had a hell of a time getting these away from Groves" (presumably Lieutenant General Leslie R. Groves, head of the Manhattan District). In a follow-up broadcast, Lewis charged that Henry A. Wallace, then Vice President, also overruled Groves to clear the shipments.

Wallace described these statements as the "sheerest fabrication." Hopkins was not present to answer for himself. But Jordan's story was pronounced incredible and circumstantially refuted by almost everyone concerned, including Jordan's former superior officer at Great Falls. (As for the old, often-rehearsed story of uranium shipments, the State Department acknowledged that early in 1943 export licenses were issued, with the approval of the Manhattan District, for the sale of 1,420 pounds of unrefined uranium compounds to the U.S.S.R. At the time these materials were in routine international trade, and the amount of uranium shipped was so small as to be insignificant for atomic bomb studies.) Groves, questioned by reporters, answered that he was waiting to hear "what the defenders of Harry Hopkins would say." Summoned before the House Committee on Un-American Activities, he finally acknowledged that neither Hopkins nor Wallace had ever attempted to apply pressure on him to release atomic research materials or documents to the U.S.S.R.; Wallace had divorced himself from the atomic bomb project, and with Harry Hopkins Groves had never had any communication whatever.

The New York *Herald Tribune* soberly observed: "Until there is some real evidence . . . one can only look upon the whole affair, with its overtones of character assassination, as an example of the nervous tension in these emotion-charged times."

The Jordan story had freshened the front pages just as a similar incident was fading from them. In this one the central figure was Senator Edwin C. Johnson, Colorado Democrat, a member of the Joint Committee on Atomic Energy and one of the most unflagging Congressional ferrets of suspected atomic treachery. Senator Johnson had appeared on a television program known as the Court of Current Issues to uphold the negative of the question, "Is There Too Much Secrecy in Our Atomic Program?" He convinced his jury—members of the Palisades Park, N. J., Lions Club—that there had not been enough secrecy. But in winning his point, the Senator unhappily pricked himself with it. During cross-examination he blurted: "The Russians have a bomb more or less similar to the bomb that we dropped at Nagasaki—a plutonium bomb." He also informed his audience that the latest U. S. atomic bomb is six times as powerful as the one used at Nagasaki, and that atomic scientists are working on plans for a super-bomb 1,000 times more powerful. As a member of the Joint Committee, he was presumed to be speaking from direct knowledge.

When the Washington *Post* published the story of Senator Johnson's performance, the Senator irately declared that his disclosures were "old stuff," and offered 25 citations of previously published statements, none of which, however, stated that the Russian bomb was made of plutonium or gave the Senator's figure for the power of the present U. S. bomb. President Truman, disturbed, summoned top officials to the White House and demanded a halt to leaks of classified information from members, of Congress. Said Senator Johnson: "I'm sure the President didn't refer to me. I'm glad he's cracking down on loose talk."

Lilienthal Resigns

AT a staff meeting of the Atomic Energy Commission early Wednesday afternoon, November 23, David E. Lilienthal, chairman, asked all persons but the other four members of the Commission to withdraw. Then he told his colleagues that at 4:00 p.m. the White House would release his letter of resignation and President Truman's reply. With this announcement Lilienthal ended nearly 20 years of government service, which included the chairmanship of the Tennessee Valley Authority as well as three harrowing years as head of the huge U. S. atomic energy enterprise.

Of the reasons behind his decision, Lilienthal in his letter to the President said only: "One of my chief reasons for wishing to return to private life is that I may be able to engage in public discussion and public affairs with a greater latitude than is either feasible or suitable for one who carries specific public responsibilities." Press correspondents' speculations about his other reasons ran a wide range: fatigue and ill health, weariness of the constant sniping by some Congressmen and parts of the press, a desire to take a more lucrative job in private industry (his AEC pay: $17,000), and so on. But those who knew him best thought that the major reason was that the atomic energy project had not turned out to be the great constructive, unhampered, trail-blazing enterprise that he had hoped it would be. Under cold-war pressures and the strait jackets imposed by suspicious Congressmen, the AEC has been restricted largely to atomic bomb manufacture; and to Lilienthal a continuing career as a peacetime munitions maker looked unattractive.

Reactor for Power

SIMULTANEOUSLY with his resignation, Lilienthal was able to announce that the Atomic Energy Commission had at last taken the first important step toward developing an atomic power plant. Designs were completed and a contract was awarded for the construction of an experimental power reactor at the Commission's testing station near Arco, Idaho. The external structure, to cost $2.5 million, will be built by the Bechtel Corporation of San Francisco; the chain-reacting uranium core, costing an estimated $1 million, will be assembled by physicists and technicians of the Argonne National Laboratory.

The reactor will be a "fast breeder," meaning that it will use fast neutrons and attempt to breed new fuel as it uses up the old. The theory is that in the pile of natural uranium, containing 139 atoms of U-238 to each atom of U-235, the fission of a U-235 atom will provide one neutron to continue the chain reaction among the U-235 atoms and another to convert a U-238 atom into fissionable plutonium; thus the reaction, besides releasing energy in the form of heat, will continuously create as much fuel as it consumes (SCIENTIFIC AMERICAN, July, 1949). The Commission does not know whether the design it now has will work; its purpose is simply to test the theory. If it does work, however, the launching of this reactor sometime in 1951 may be as historic an occasion as the beginning of the first uranium chain reaction in Chicago in December, 1942.

The Commission announced that the design of the other three power reactors in its experimental program also is well under way; construction of a materials-testing reactor at Arco will begin next spring, that of a ship-propulsion reactor at Arco in 1952, and that of an intermediate breeder reactor at Knolls Atomic Power Laboratory sometime this year. On the other hand, unexpected difficulties have arisen in the construction of the 30,000-kilowatt research reactor at Brookhaven National Laboratory. It was scheduled to go into operation last fall, but the air-cooling system proved inadequate and is being rebuilt.

The Commission and the Department of Defense disclosed that new tests of atomic bombs will be made soon, presumably sometime this year, at the Eniwetok Proving Grounds. The bombs are assumed to be new models developed since the Eniwetok tests of 1948.

Portable Pile

SHORTLY after the war the British ASP Chemical Company embarked on a top-secret research project in the basement of a massive old country house in the town of Gerrard's Cross, Buckinghamshire. Recently Robert Barker, the physicist who conducted the project, exhibited the result—a nuclear reactor called the "Aspatron," the first attempt at a portable atomic furnace. The pile, housed in a metal cylinder about the size of a beer barrel, has a 25-pound charge of uranium oxide that yields a low-energy chain reaction. It is designed to produce short-lived radioactive isotopes in any laboratory so they can be used immediately.

The pile consists of two copper drums, one inside the other, with water between them. The water serves as a shield to absorb part of the neutron radiation, and the copper drums are reflectors that also help contain neutrons in the reactor. The reactor mechanism itself is a series of circular trays laid atop one another in the inner drum, alternately containing uranium oxide and paraffin as the moderator to slow the neutrons from the fissioning uranium atoms. Down the center of this cylinder is a two-inch hollow core in which samples of material are inserted for irradiation with neutrons to make isotopes. To shut down the reactor, a boron-steel control rod that stops the chain reaction is inserted in this core.

Whether the reactor will provide enough available neutrons to produce isotopes in appreciable quantities will depend on the effectiveness of the copper reflector in retaining neutrons within the pile. If current tests are successful, the Aspatron will be available f.o.b. Gerrard's Cross for about $4,200.

California Depression

AN area of 12 square miles in the Los Angeles-Long Beach harbor district of California is sinking at the rate of about two inches a month. The waterfront piers of the Long Beach Naval Shipyard have already sunk so much that at high tide the water is less than two feet from the tops of the piers, and earth dikes and concrete walls have been built to forestall flooding of the shipyard and nearby factories. Several factories have shifted two or three feet horizontally; the main power plant of the Southern California Edison Company has rotated through an arc of more than one degree from its original position.

A slight sinking was first noticed by the U. S. Geological Survey just before the war, but no one realized that it was anything unusual until 1945, when level-measuring instruments showed a drop at the basin's center of about 4.5 feet. Engineers have now discovered the cause. The area lies directly above the richest deposits in the largest producing oil field of California. The extraction of oil from the underlying sands, it appears, has undermined the area and caused it to settle. About 45 million barrels of petroleum and 25 billion cubic feet of natural gas are being withdrawn from the deposit annually. Since 1937 the land has sunk nearly 10 feet.

When geologists discovered the field in 1932, they assumed that underground water would seep into the sand to replace the oil and gas, thus providing continuing support for the overlying earth. But they have now learned that the sand layers are effectively sealed off at both ends by rock barriers and unusually large masses of thick tar, so only a trickle of water seeps in.

Engineers estimate that stopgap construction of dikes and the filling of depressions to prevent the flooding of the $500 million worth of property in the area might cost as much as $30 million. But this would be no solution as the land continued to sink. Reluctant to take the step of curtailing oil production, petroleum engineers have suggested pumping water at high pressures into the oil sands to shore up the sinking crust.

Conservation Is Legal

FOURTEEN states have forest-conservation laws limiting the cutting of timberlands and requiring new planting to replace trees cut down. One of the strictest laws is that of the State of Washington, which imposes stiff fines and authorizes injunctive orders against timberland owners who fail to take conservation measures. About a year ago Avery Dexter, who owns 320 acres in Pend Oreille County, challenged the law as an unconstitutional "exercise of police power." The case went to the Washington State Supreme Court and finally the U. S. Supreme Court. The supreme tribunal has now rendered a final decision: the law is constitutional. It upheld this statement by the Washington court: "It must be realized that private enterprise must utilize its private property in ways that are not inconsistent with the public welfare. We do not think that the State is required under the constitution of the U. S. to stand idly by while its natural resources are depleted. . . . The challenged legislation is . . . a proper exercise of the police power."

Conservationists believe the decision sets a precedent of far-reaching importance. Efforts are under way to apply its principles to the conservation of water, soil and other natural resources.

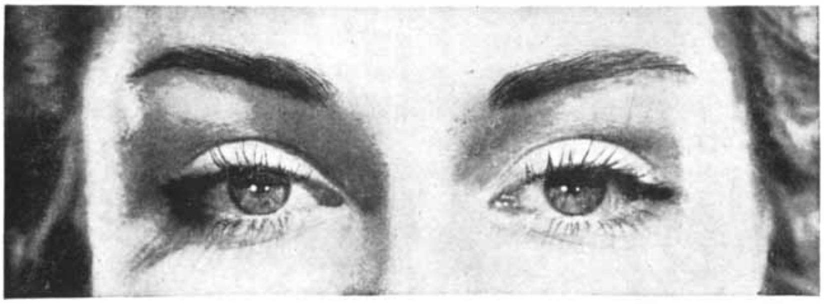
Science in India

INDIA'S special interest in the development of science is indicated by the fact that its Department of Scientific Research has Cabinet ranking and Prime Minister Pandit Nehru himself occupies this portfolio as titular head of the Department. During his recent visit to the U. S. Nehru discussed India's scientific progress to date and plans for the future. Nehru's scientific executive officer, S. S. Bhatnagar, also visited the U. S. recently.

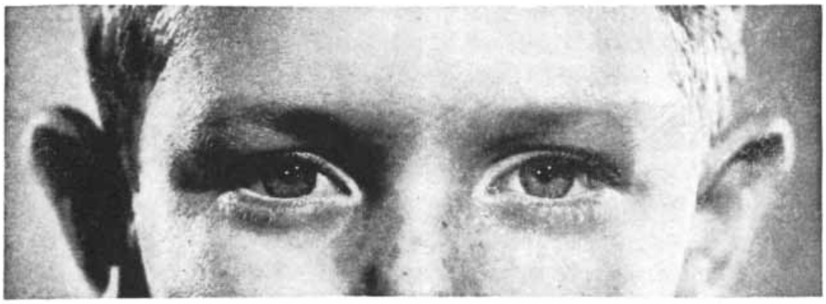
India has established 11 national laboratories, including centers for research in physics, chemistry, fuels, metallurgy and glass and ceramics. The work is supported from a $6 million fund, half of which is contributed by industry and half by government. The newest laboratory, the Central Drug Research Institute, is located in a former maharajah's palace at Lucknow. After the Sepoy Mutiny of 1857, the British turned it into a swank club. Some six months ago workers started remodeling the 200-room palace into a scientific laboratory. About 300 investigators are already doing research in air-conditioned rooms that were once banquet halls and luxuriously furnished chambers. Another palace at Mysore is being used for the new Central Food Technological Research Institute, and other palaces are scheduled for similar reconversion.

Bhatnagar also discussed progress in education. Ten years ago India had only 10,000 scientists and technicians, including about 2,000 Ph.D.'s. Today there are more than 25,000 scientific workers and the number of Ph.D.'s has doubled. Indian universities are training 20,000 students, as compared with less than 10,000 in 1939. To interest larger numbers of high-school children in science, the educational department several months ago organized in Calcutta the first science club.

How will they look to YOU a few years from now?



Your wife's eyes: What will you read in hers when she asks whether you can afford that modest cottage that's for sale?



Your boy's eyes: What will you see in his eyes the day he asks whether you can afford to send him to college?

Your own eyes: What will the mirror tell you about them when it's time to retire, and take things easier?

There's no better time than right now to sit back and think what *you* will see in your family's eyes a few years from now.

Whether they glow with happiness or turn aside with disappointment depends, to a very large extent, upon what you do *now*.

So plan *now* for that home you plan to buy eventually . . . set aside money *now* for his college education . . . plan *now* for the day you can retire.

Decide now to put part of your salary week after week, year after year in U. S. Savings Bonds, so that you will have the money for the *important* things you and your family want.

Insure your future by signing up on the Payroll Savings Plan where you work, or the Bond-A-Month Plan where you have a checking account. Chances are you won't miss the money now, but you certainly will a few short years from now if you haven't got it!!

P. S. Remember, too, that every \$3 you invest now in U. S. Savings Bonds returns \$4 to you in just ten short years.

Automatic saving is sure saving—U.S. SAVINGS BONDS

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THE GENETIC BASIS OF EVOLUTION

The rich variety of living and dead species of plants and animals is the result of subtle interplay between the hereditary mechanism and a diversified environment

by Theodosius Dobzhansky

THE living beings on our planet come in an incredibly rich diversity of forms. Biologists have identified about a million species of animals and some 267,000 species of plants, and the number of species actually in existence may be more than twice as large as the number known. In addition the earth has been inhabited in the past by huge numbers of other species that are now extinct, though some are preserved as fossils. The organisms of the earth range in size from viruses so minute that they are barely visible in electron microscopes to giants like elephants and sequoia trees. In appearance, body structure and ways of life they exhibit an endlessly fascinating variety.

What is the meaning of this bewildering diversity? Superficially considered, it may seem to reflect nothing more than the whims of some playful deity, but one soon finds that it is not fortuitous. The more one studies living beings the more one is impressed by the wonderfully effective adjustment of their multifarious body structures and functions to their varying ways of life. From the simplest to the most complex, all organisms are constructed to function efficiently in the environments in which they live. The body of a green plant can build itself from food consisting merely of water, certain gases in the air and some mineral salts taken from the soil. A fish is a highly efficient machine for exploiting the organic food resources of water, and a bird is built to get the most from its air environment. The human body is a complex, finely coordinated machine of marvelously precise engineering, and through the inventive abilities of his brain man is able to control his environment. Every species, even the most humble, occupies a certain place in the economy of nature, a certain adaptive niche which it exploits to stay alive.

The diversity and adaptedness of living beings were so difficult to explain that during most of his history man took the easy way out of assuming that every species was created by God, who contrived the body structures and functions of each kind of organism to fit it to a predestined place in nature. This idea has now been generally replaced by the less easy but intellectually more satisfying explanation that the living things we see around us were not always what they are now, but evolved gradually from very different-looking ancestors; that these ancestors were in general less complex, less perfect and less diversified than the organisms now living; that the evolutionary process is still under way, and that its causes can therefore be studied by observation and experiment in the field and in the laboratory.

The origins and development of this theory, and the facts that finally convinced most people of its truth beyond reasonable doubt, are too long a story to be presented here. After Charles Darwin published his convincing exposition and proof of the theory of evolution in 1859, two main currents developed in evolutionary thought. Like any historical process, organic evolution may be studied in two ways. One may attempt to infer the general features and the direction of the process from comparative studies of the sequence of events in the past; this is the method of paleontologists, comparative anatomists and others. Or one may attempt to reconstruct the causes of evolution, primarily through a study of the causes and mechanisms that operate in the world at present; this approach, which uses experimental rather than observational methods, is that of the geneticist and the ecologist. This article will consider what has been learned about the causes of organic evolution through the second approach.

Darwin attempted to describe the causes of evolution in his theory of natural selection. The work of later biologists has borne out most of his basic contentions. Nevertheless, the modern theory of evolution, developed by a century of new discoveries in biology, differs greatly from Darwin's. His theory has not been overthrown; it has evolved. The authorship of the modern theory can be credited to no single person. Next to Darwin, Gregor Mendel of Austria, who first stated the laws of heredity, made the greatest contribution. Within the past two decades the study of evolutionary genetics has developed very rapidly on the basis of the work of Thomas Hunt Morgan and Hermann J. Muller of the U. S. In these developments the principal contributors have been C. D.

Darlington, R. A. Fisher, J. B. S. Haldane, J. S. Huxley and R. Mather in England; B. Rensch and N. W. Timofeeff-Ressovsky in Germany; S. S. Chetverikov, N. P. Dubinin and I. I. Schmalhausen in the U.S.S.R.; E. Mayr, J. T. Patterson, C. G. Simpson, G. L. Stebbins and Sewall Wright in the U. S., and some others.

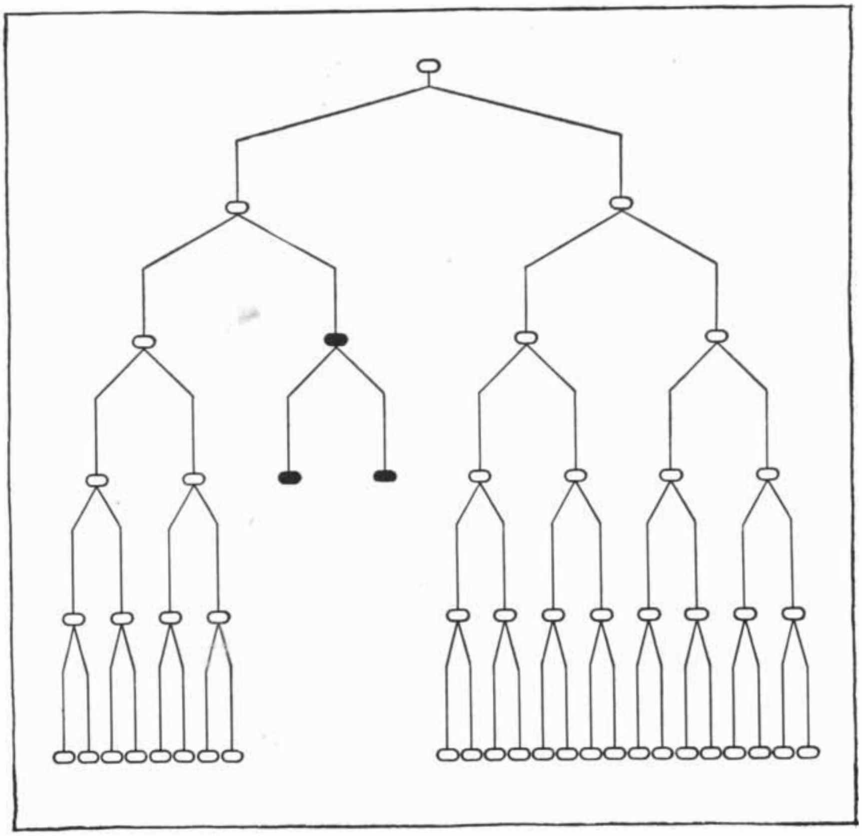
Evolution in the Laboratory

Evolution is generally so slow a process that during the few centuries of recorded observations man has been able to detect very few evolutionary changes among animals and plants in their natural habitats. Darwin had to deduce the theory of evolution mostly from indirect evidence, for he had no means of observing the process in action. Today, however, we can study and even produce evolutionary changes at will in the laboratory. The experimental subjects of these studies are bacteria and other low forms of life which come to birth, mature and yield a new generation within a matter of minutes or hours, instead of months or years as in most higher beings. Like a greatly speeded-up motion picture, these observations compress into a few days evolutionary events that would take thousands of years in the higher animals.

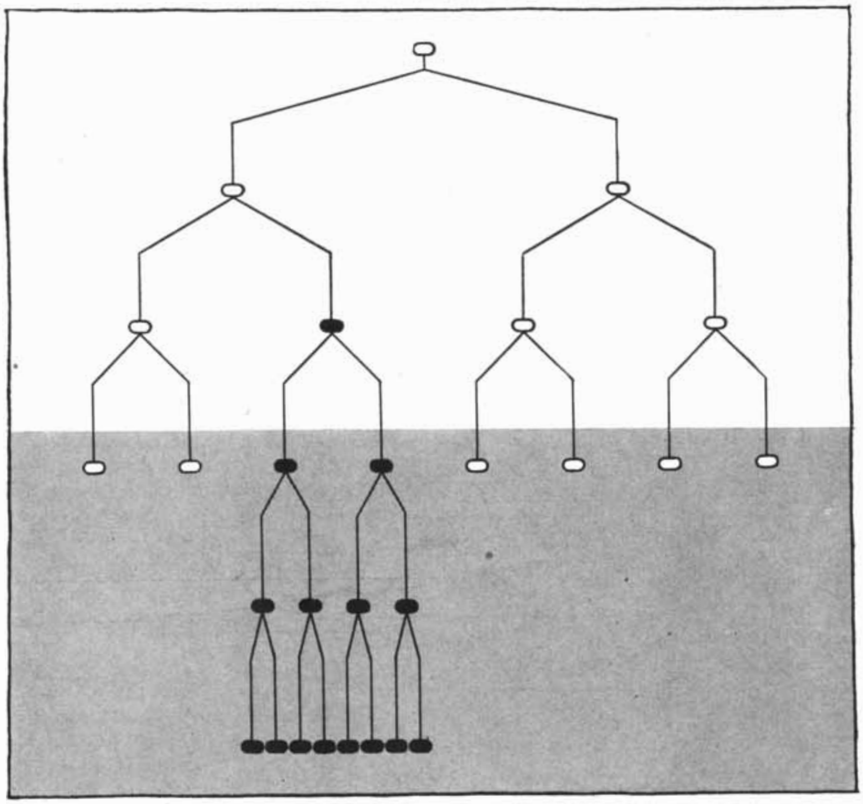
One of the most useful bacteria for this study is an organism that grows, usually harmlessly, in the intestines of practically every human being: *Escherichia coli,* or colon bacteria. These organisms can easily be cultured on a nutritive broth or nutritive agar. At about 98 degrees Fahrenheit, bacterial cells placed in a fresh culture medium divide about every 20 minutes. Their numbers increase rapidly until the nutrients in the culture medium are exhausted; a single cell may yield billions of progeny in a day. If a few cells are placed on a plate covered with nutritive agar, each cell by the end of the day produces a whitish speck representing a colony of its offspring.

Now most colon bacteria are easily killed by the antibiotic drug streptomycin. It takes only a tiny amount of streptomycin, 25 milligrams in a liter of a nutrient medium, to stop the growth of the bacteria. Recently, however, the geneticist Milislav Demerec and his collaborators at the Carnegie Institution in Cold Spring Harbor, N. Y., have shown that if several billion colon bacteria are placed on the streptomycin-containing medium, a few cells will survive and form colonies on the plate. The offspring of these hardy survivors are able to multiply freely on a medium containing streptomycin. A mutation has evidently taken place in the bacteria; they have now become resistant to the streptomycin that was poisonous to their sensitive ancestors.

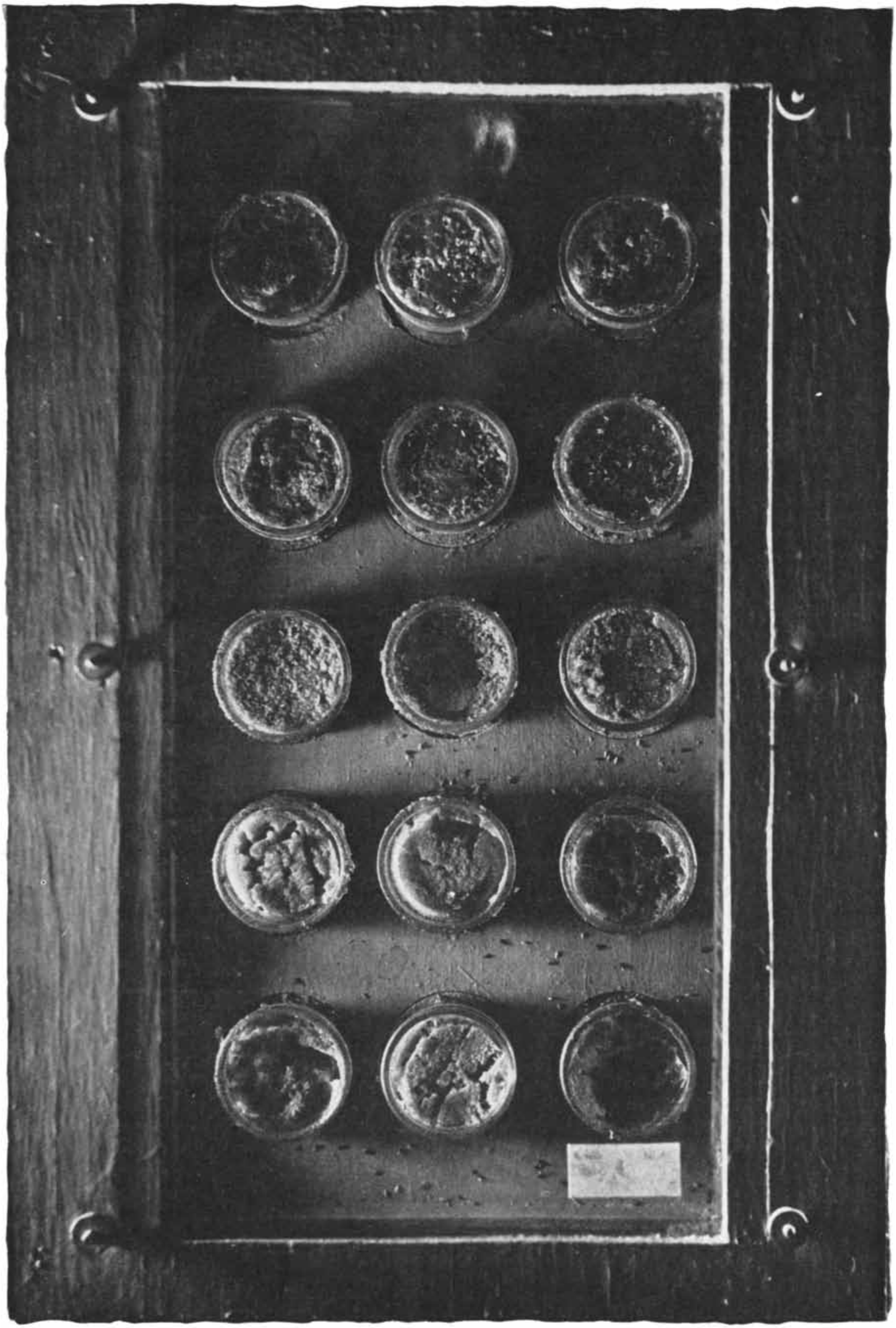
How do the bacteria acquire their



IN NORMAL ENVIRONMENT the common strain of the bacterium *Escherichia coli* (*white bacteria*) multiplies. A mutant strain resistant to streptomycin (*black bacteria*) remains rare because the mutation is not useful.



IN CHANGED ENVIRONMENT produced by the addition of streptomycin (*gray area*) the streptomycin-resistant strain is better adapted than the common strain. The mutant strain then multiplies and the common one dies.



CONTROLLED ENVIRONMENT for the study of fruit-fly populations is a glass-covered box. In bottom of the box are cups of food that are filled in rotation to keep food a constant factor in environment.

resistance? Is the mutation caused by their exposure to streptomycin? Demerec has shown by experimental tests that this is not so; in any large culture a few resistant mutants appear even when the culture has not been exposed to streptomycin. Some cells in the culture undergo mutations from sensitivity to resistance regardless of the presence or absence of streptomycin in the medium. Demerec found that the frequency of mutation was about one per billion; *i.e.*, one cell in a billion becomes resistant in every generation. Streptomycin does not induce the mutations; its role in the production of resistant strains is merely that of a selecting agent. When streptomycin is added to the culture, all the normal sensitive cells are killed, and only the few resistant mutants that happened to be present before the streptomycin was added survive and reproduce. Evolutionary changes are controlled by the environment, but the control is indirect, through the agency of natural or artificial selection.

What governs the selection? If resistant bacteria arise in the absence of streptomycin, why do sensitive forms predominate in all normal cultures; why has not the whole species of colon bacteria become resistant? The answer is that the mutants resistant to streptomycin are at a disadvantage on media free from this drug. Indeed, Demerec has discovered the remarkable fact that about 60 per cent of the bacterial strains derived from streptomycin-resistant mutants become dependent on streptomycin; they are unable to grow on media free from it!

On the other hand one can reverse the process and obtain strains of bacteria that can live without streptomycin from cultures predominantly dependent on the drug. If some billions of dependent bacteria are plated on nutrient media free of the drug, all dependent cells cease to multiply and only the few mutants independent of the drug reproduce and form colonies. Demerec estimates the frequency of this "reverse" mutation at about 37 per billion cells in each generation.

Evolutionary changes of the type described in colon bacteria have been found in recent years in many other bacterial species. The increasing use of antibiotic drugs in medical practice has made such changes a matter of considerable concern in public health. As penicillin, for example, is used on a large scale against bacterial infections, the strains of bacteria that are resistant to penicillin survive and multiply, and the probability that they will infect new victims is increased. The mass application of antibiotic drugs may lead in the long run to increased incidence of cases refractory to treatment. Indications exist that this has already happened in some instances: in certain cities penicillin-resistant gonorrhea has become more frequent than it was.

The same type of evolutionary change has also been noted in some larger organisms. A good example is the case of DDT and the common housefly, *Musca domestica.* DDT was a remarkably effective poison for houseflies when first introduced less than 10 years ago. But already reports have come from places as widely separated as New Hampshire, New York, Florida, Texas, Italy and Sweden that DDT sprays in certain localities have lost their effectiveness. What has happened, of course, is that strains of houseflies relatively resistant to DDT have become established in these localities. Man has unwittingly become an agent of a selection process which has led to evolutionary changes in housefly populations. Similar changes are known to have occurred in other insects; *e.g.*, in some orchards of California where hydrocyanic gas has long been used as a fumigant to control scale insects that prey on citrus fruits, strains of these insects that are resistant to hydrocyanic gas have developed.

Obviously evolutionary selection can take place only if nature provides a supply of mutants to choose from. Thus no bacteria will survive to start a new strain resistant to streptomycin in a culture in which no resistant mutant cells were present in the first place, and housefly races resistant to DDT have not appeared everywhere that DDT is used. Adaptive changes are not mechanically forced upon the organism by the environment. Many species of past geological epochs died out because they did not have a supply of mutants which fitted changing environments. The process of mutation furnishes the raw materials from which evolutionary changes are built.

Mutations

Mutations arise from time to time in all organisms, from viruses to man. Perhaps the best organism for the study of mutations is the now-famous fruit fly, Drosophila. It can be bred easily and rapidly in laboratories, and it has a large number of bodily traits and functions that are easy to observe. Mutations affect the color of its eyes and body, the size and shape of the body and of its parts, its internal anatomical structures, its fecundity, its rate of growth, its behavior, and so on. Some mutations produce differences so minute that they can be detected only by careful measurements; others are easily seen even by beginners; still others produce changes so drastic that death occurs before the development is completed. The latter are called lethal mutations.

The frequency of any specific mutation is usually low. We have seen that in colon bacteria a mutation to resistance to streptomycin occurs in only about one cell per billion in every generation, and the reverse mutation to independence of streptomycin is about 37 times more frequent. In Drosophila and in the corn plant mutations have been found to range in frequency from one in 100,000 to one in a million per generation. In man, according to estimates by Haldane in England and James Neel in the U. S., mutations that produce certain hereditary diseases, such as hemophilia and Cooley's anemia, arise in one in 2,500 to one in 100,000 sex cells in each generation. From this it may appear that man is more mutable than flies and bacteria, but it should be remembered that a generation in man takes some 25 years, in flies two weeks, and in bacteria 25 minutes. The frequency of mutations per unit of time is actually greater in bacteria than in man.

A single organism may of course produce several mutations, affecting different features of the body. How frequent are all mutations combined? For technical reasons, this is difficult to determine; for example, most mutants produce small changes that are not detected unless especially looked for. In Drosophila it is estimated that new mutants affecting one part of the body or another are present in between one and 10 per cent of the sex cells in every generation.

In all organisms the majority of mutations are more or less harmful. This may seem a very serious objection against the theory which regards them as the mainspring of evolution. If mutations produce incapacitating changes, how can adaptive evolution be compounded of them? The answer is: a mutation that is harmful in the environment in which the species or race lives may become useful, even essential, if the environment changes. Actually it would be strange if we found mutations that improve the adaptation of the organism in the environment in which it normally lives. Every kind of mutation that we observe has occurred numerous times under natural conditions, and the useful ones have become incorporated into what we call the "normal" constitution of the species. But when the environment changes, some of the previously rejected mutations become advantageous and produce an evolutionary change in the species. The writer and B. A. Spassky have carried out certain experiments in which we intentionally disturbed the harmony between an artificial environment and the fruit flies living in it. At first the change in environment killed most of the flies, but during 50 consecutive generations most strains showed a gradual improvement of viability, evidently owing to the environment's selection of the better-adapted variants.

This is not to say that every mutation will be found useful in some environment somewhere. It would be difficult to imagine environments in which such human mutants as hemophilia or the absence of hands and feet might be useful. Most mutants that arise in any species are, in effect, degenerative changes; but some, perhaps a small minority, may be beneficial in some environments. If the environment were forever constant, a species might conceivably reach a summit of adaptedness and ultimately suppress the mutation process. But the environment is never constant; it varies not only from place to place but from time to time. If no mutations occur in a species, it can no longer become adapted to changes and is headed for eventual extinction. Mutation is the price that organisms pay for survival. They do not possess a miraculous ability to produce only useful mutations where and when needed. Mutations arise at random, regardless of whether they will be useful at the moment, or ever; nevertheless, they make the species rich in adaptive possibilities.

The Genes

To understand the nature of the mutation process we must inquire into the nature of heredity. A man begins his individual existence when an egg cell is fertilized by a spermatozoon. From an egg cell weighing only about a 20-millionth of an ounce, he grows to an average weight at maturity of some 150 pounds—a 48-billionfold increase. The material for this stupendous increase in mass evidently comes from the food consumed, first by the mother and then by the individual himself. But the food becomes a constituent part of the body only after it is digested and assimilated, *i.e.*, transformed into a likeness of the assimilating body. This body, in turn, is a likeness of the bodies of the individual's ancestors. Heredity is, then, a process whereby the organism reproduces itself in its progeny from food materials taken in from the environment. In short, heredity is self-reproduction.

The units of self-reproduction are called genes. The genes are borne chiefly in chromosomes of the cell nucleus, but certain types of genes called plasmagenes are present in the cytoplasm, the part of the cell outside the nucleus. The chemical details of the process of self-reproduction are unknown. Apparently a gene enters into some set of chemical reactions with materials in its surroundings; the outcome of these reactions is the appearance of two genes in the place of one. In other words, a gene synthesizes a copy of itself from nongenic materials. The genes are considered to be stable because the copy is a true likeness of the original in the overwhelming majority of cases; but occasionally the copying process is faulty, and the new gene that emerges differs from its model. This is a mutation. We can increase the frequency of mutations in experimental animals by treating the genes with X-rays, ultraviolet rays, high temperature or certain chemical substances.

Can a gene be changed by the environment? Assuredly it can. But the important point is the kind of change produced. The change that is easiest to make is to treat the gene with poisons or heat in such a way that it no longer reproduces itself. But a gene that cannot produce a copy of itself from other materials is no longer a gene; it is dead. A mutation is a change of a very special kind: the altered gene can reproduce itself, and the copy produced is like the changed structure, not like the original. Changes of this kind are relatively rare. Their rarity is not due to any imperviousness of the genes to influences of the environment, for genic materials are probably the most active chemical constituents of the body; it is due to the fact that genes are by nature self-reproducing, and only the rare changes that preserve the genes' ability to reproduce can effect a lasting alteration of the organism.

Changes in heredity should not be confused, as they often are, with changes in the manifestations of heredity. Such expressions as "gene for eye color" or "inheritance of musical ability" are figures of speech. The sex cells that transmit heredity have no eyes and no musical ability. What genes determine are patterns of development which result in the emergence of eyes of a certain color and of individuals with some musical abilities. When genes reproduce themselves from different food materials and in different environments, they engender the development of different "characters" or "traits" in the body. The outcome of the development is influenced both by heredity and by environment.

In the popular imagination, heredity is transmitted from parents to offspring through "blood." The heredity of a child is supposed to be a kind of alloy or solution, resulting from the mixture of the paternal and maternal "bloods." This blood theory became scientifically untenable as long ago as Mendel's discovery of the laws of heredity in 1865. Heredity is transmitted not through miscible bloods but through genes. When different variants of a gene are brought together in a single organism, a hybrid, they do not fuse or contaminate one another; the genes keep their integrity and separate when the hybrid forms sex cells.

Genetics and Mathematics

Although the number of genes in a single organism is not known with precision, it is certainly in the thousands, at least in the higher organisms. For Drosophila, 5,000 to 12,000 seems a reasonable estimate, and for man the figure is, if anything, higher. Since most or all genes suffer mutational changes from time to time, populations of virtually every species must contain mutant variants of many genes. For example, in the human species there are variations in the skin, hair and eye colors, in the shape and distribution of hair, in the form of the head, nose and lips, in stature, in body proportions, in the chemical composition of the blood, in psychological traits, and so on. Each of these traits is influenced by several or by many genes. To be conservative, let us assume that the human species has only 1,000 genes and that each gene has only two variants. Even on this conservative basis, Mendelian segregation and recombination would be capable of producing 2^{1000} different gene combinations in human beings.

The number 2^{1000} is easy to write but is utterly beyond comprehension. Compared with it, the total number of electrons and protons estimated by physicists to exist in the universe is negligibly small! It means that except in the case of identical twins no two persons now living, dead, or to live in the future are at all likely to carry the same complement of genes. Dogs, mice and flies are as individual and unrepeatable as men are. The mechanism of sexual reproduction, of which the recombination of genes is a part, creates ever new genetic constitutions on a prodigious scale.

One might object that the number of possible combinations does not greatly matter; after all, they will still be combinations of the same thousand gene variants, and the way they are combined is not significant. Actually it is: the same gene may have different effects in combinations with different genes. Thus Timofeeff-Ressovsky showed that two mutants in Drosophila, each of which reduced the viability of the fly when it was present alone, were harmless when combined in the same individual by hybridization. Natural selection tests the fitness in certain environments not of single genes but of constellations of genes present in living individuals.

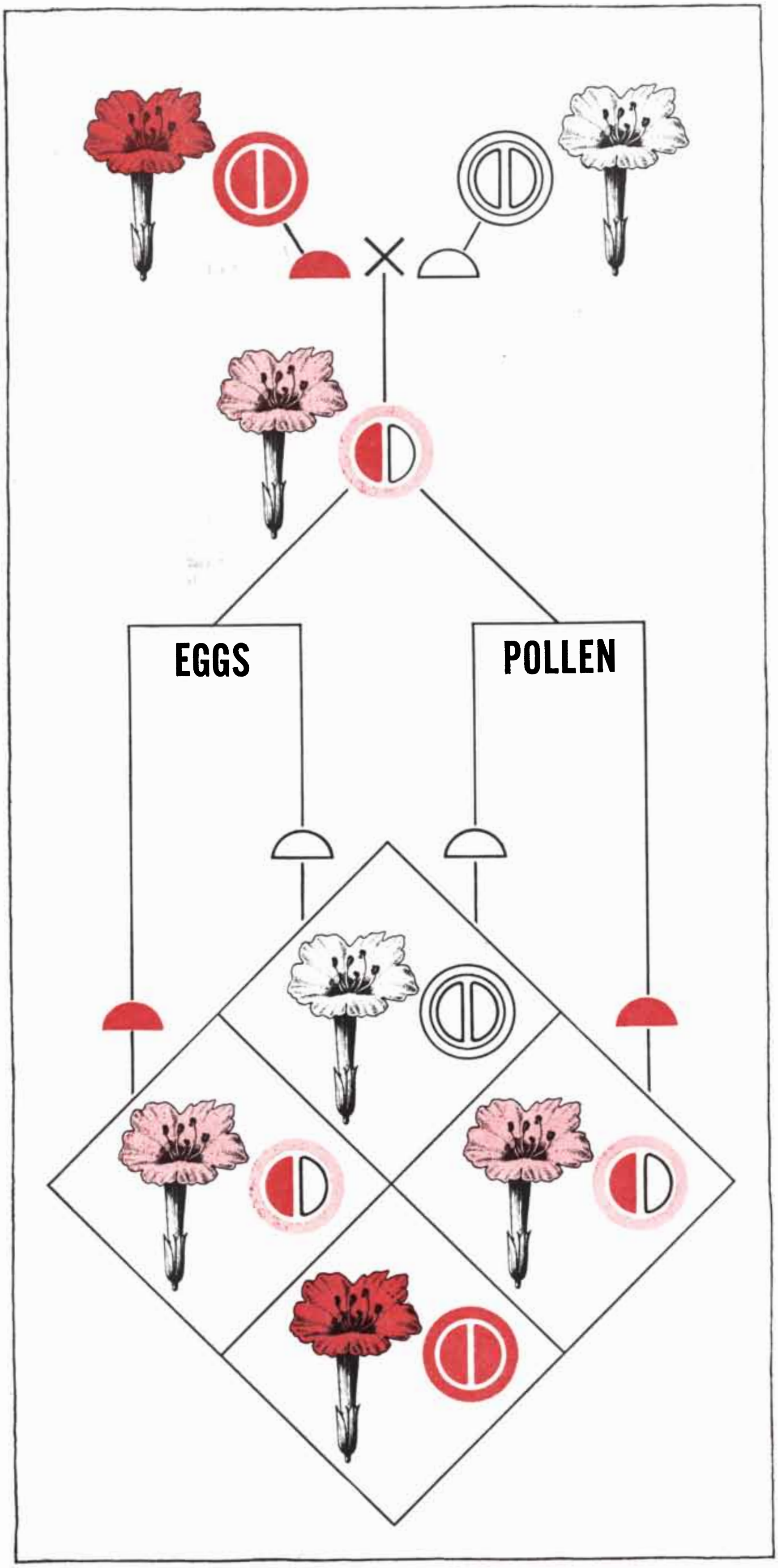
Sexual reproduction generates, therefore, an immense diversity of genetic constitutions, some of which, perhaps a small minority, may prove well attuned to the demands of certain environments. The biological function of sexual reproduction consists in providing a highly efficient trial-and-error mechanism for the operation of natural selection. It is a reasonable conjecture that sex became established as the prevalent method of reproduction because it gave organisms the greatest potentialities for adaptive and progressive evolution.

Let us try to imagine a world providing a completely uniform environment. Suppose that the surface of our planet were absolutely flat, covered everywhere with the same soil; that instead of summer and winter seasons we had eternally constant temperature and humidity; that instead of the existing diversity of foods there was only one kind of energy-yielding substance to serve as nourishment. The Russian biologist Gause has pointed out that only a single kind of organism could inhabit such a tedious world. If two or more kinds appeared in it, the most efficient form would gradually crowd out and finally eliminate the less efficient ones, remaining the sole inhabitant. In the world of reality, however, the environment changes at every step. Oceans, plains, hills, mountain ranges, regions where summer heat alternates with winter cold, lands that are permanently warm, dry deserts, humid jungles —these diverse environments have engendered a multitude of responses by protoplasm and a vast proliferation of distinct species of life through the evolutionary process.

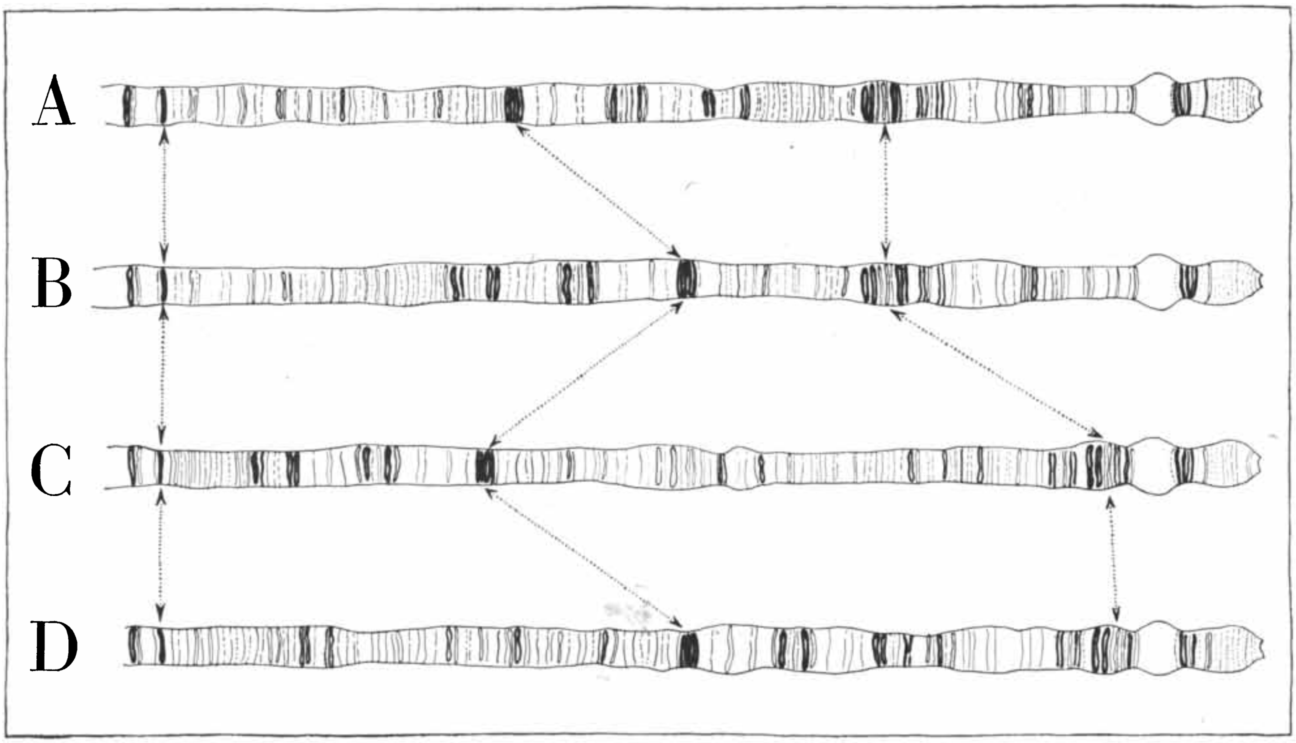
Some Adaptations

Many animal and plant species are polymorphic, *i.e.*, represented in nature by two or more clearly distinguishable kinds of individuals. For example, some individuals of the ladybird beetle *Adalia bipunctata* are red with black spots while others are black with red spots. The color difference is hereditary, the black color behaving as a Mendelian dominant and red as a recessive. The red and black forms live side by side and interbreed freely. Timofeeff-Ressovsky observed that near Berlin, Germany, the black form predominates from spring to autumn, and the red form is more numerous during the winter. What is the origin of these changes? It is quite improbable that the genes for color are transformed by the seasonal variations in temperature; that would mean epidemics of directed mutations on a scale never observed. A much more plausible view is that the changes are produced by natural selection. The black form is, for some reason, more successful than the red in survival and reproduction during summer, but the red is superior to the black under winter conditions. Since the beetles produce several generations during a single season, the species undergoes cyclic changes in its genetic composition in response to the seasonal alterations in the environment. This hypothesis was confirmed by the discovery that black individuals are more frequent among the beetles that die during the rigors of winter than among those that survive.

The writer has observed seasonal changes in some localities in California in the fly *Drosophila pseudoobscura*. Flies of this species in nature are rather uniform in coloration and other external traits, but they are very variable in the structure of their chromosomes, which can be seen in microscopic preparations. In the locality called Piñon Flats, on Mount San Jacinto in southern Califor-



MENDELIAN SEGREGATION is illustrated by the four o'clock (*Mirabilis jalapa*). The genes of red and white flowers combine in a pink hybrid. Genes are segregated in the cross-fertilized descendants of pink flowers.



FOUR VARIETIES of the species *Drosophila pseudoobscura* are revealed by differences in the structure of their chromosomes. Under the microscope similar markings may be observed at different locations (*arrows*).

nia, the fruit-fly population has four common types of chromosome structure, which we may, for simplicity, designate as types A, B, C and D. From 1939 to 1946, samples of flies were taken from this population in various months of the year, and the chromosomes of these flies were examined. The relative frequencies of the chromosomal types, expressed in percentages of the total, varied with the seasons as follows:

Month	A	B	C	D
March	52	18	23	7
April	40	28	28	4
May	34	29	31	6
June	28	28	39	5
July	42	22	31	5
Aug.	42	28	26	4
Sept.	48	23	26	3
Oct.-Dec.	50	26	20	4

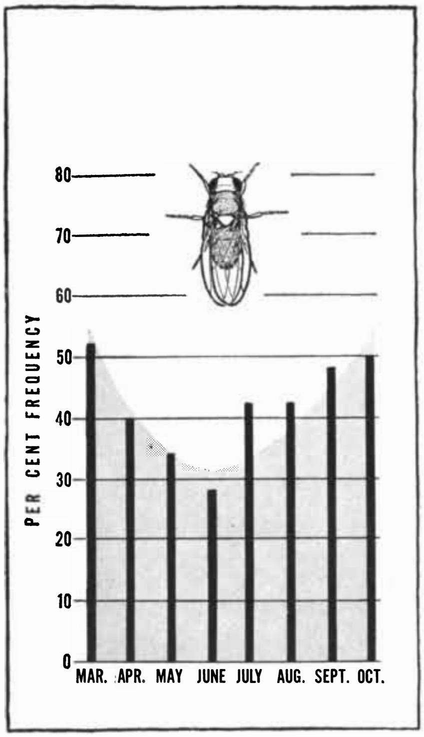
Thus type A was common in winter but declined in the spring, while type C waxed in the spring and waned in summer. Evidently flies carrying chromosomes of type C are somehow better adapted than type A to the spring climate; hence from March to June, type A decreases and type C increases in frequency. Contrariwise, in the summer type A is superior to type C. Types B and D show little consistent seasonal variation.

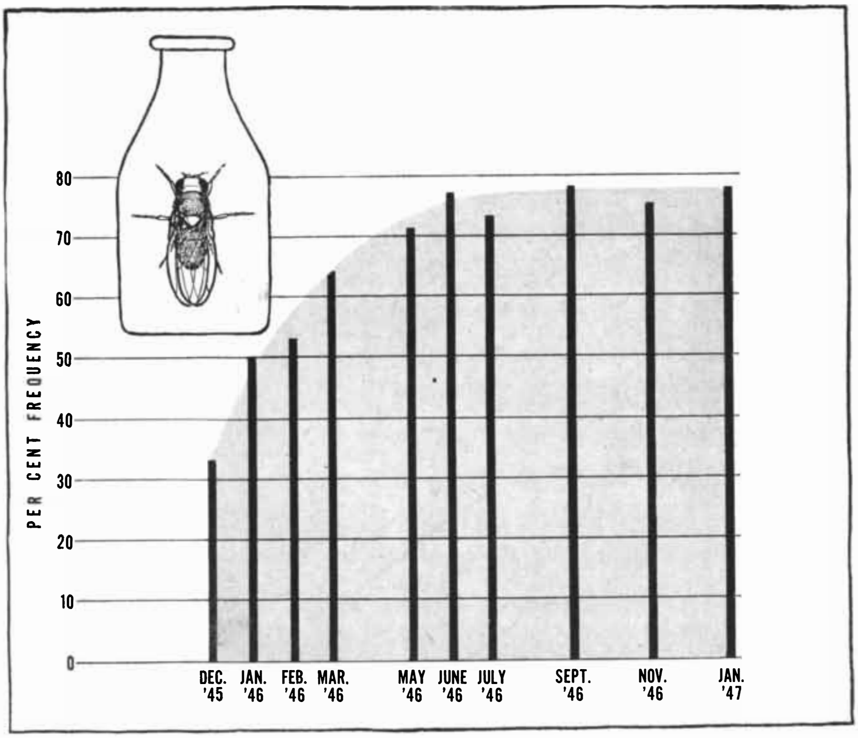
Similar changes can be observed under controlled laboratory conditions. Populations of Drosophila flies were kept in a very simple apparatus consisting of a wood and glass box, with openings in the bottom for replenishing the nutrient medium on which the flies lived—a kind of pudding made of Cream of Wheat, molasses and yeast. A mixture of flies of which 33 per cent were type A and 67 per cent type C was introduced into the apparatus and left to multiply freely, up to the limit imposed by the quantity of food given. If one of the types was better adapted to the environment than the other, it was to be expected that the better-adapted type would increase and the other decrease in relative numbers. This is exactly what happened. During the first six months the type A flies rose from 33 to 77 per cent of the population, and type C fell from 67 to 23 per cent. But then came an unexpected leveling off: during the next seven months there was no further change in the relative proportions of the flies, the frequencies of types A and C oscillating around 75 and 25 per cent respectively.

If type A was better than type C under the conditions of the experiment, why were not the flies with C chromosomes crowded out completely by the carriers of A? Sewall Wright of the University of Chicago solved the puzzle by mathematical analysis. The flies of these types interbreed freely, in natural as well as in experimental populations. The populations therefore consist of three kinds of individuals: 1) those that obtained chromosome A from father as well as from mother, and thus carry two A chromosomes (AA); 2) those with two C chromosomes (CC); 3) those that received chromosomes of different types from their parents (AC). The mixed type, AC, possesses the highest adaptive value; it has what is called "hybrid vigor." As for the pure types, under the conditions that obtain in nature AA is superior to CC in the summer. Natural selection then increases the frequency of A chromosomes in the population and diminishes the C chromosomes. In the spring, when CC is better than AA, the reverse is true. But note now that in a population of mixed types neither the A nor the C chromosomes can ever be entirely eliminated from the population, even if the flies are kept in a constant environment where type AA is definitely superior to type CC. This, of course, is highly favorable to the flies as a species, for the loss of one of the chromosome types, though it might be temporarily advantageous, would be prejudicial in the long run, when conditions favoring the lost type would return. Thus a polymorphic population is better able than a uniform one to adjust itself to environmental changes and to exploit a variety of habitats.

Races

Populations of the same species which inhabit different environments become genetically different. This is what a geneticist means when he speaks of races. Races are populations within a species that differ in the frequencies of some genes. According to the old concept of race, which is based on the notion that





NUMBER OF FLIES of one chromosomal type varies in nature (*left*) and in the laboratory. In seasonal environment of nature the type increases and decreases regularly; in constant environment of laboratory it levels off.

heredity is transmitted through "blood" and which still prevails among those ignorant of modern biology, the hereditary endowment of an isolated population would become more and more uniform with each generation, provided there was no interbreeding with other tribes or populations. The tribe would eventually become a "pure" race, all members of which would be genetically uniform. Scientists misled by this notion used to think that at some time in the past the human species consisted of an unspecified number of "pure" races, and that intermarriage between them gave rise to the present "mixed" populations.

In reality, "pure" races never existed, nor can they possibly exist in any species, such as man, that reproduces by sexual combination. We have seen that all human beings except identical twins differ in heredity. In widely differing climatic environments the genetic differences may be substantial. Thus populations native in central Africa have much higher frequencies of genes that produce dark skin than do European populations. The frequency of the gene for blue eye color progressively diminishes southward from Scandinavia through central Europe to the Mediterranean and Africa. Nonetheless some blue-eyed individuals occur in the Mediterranean region and even in Africa, and some brown-eyed ones in Norway and Sweden.

It is important to keep in mind that races are populations, not individuals. Race differences are relative and not absolute, since only in very remote races do all members of one population possess a set of genes that is lacking in all members of another population. It is often difficult to tell how many races exist in a species. For example, some anthropologists recognize only two human races while others list more than 100. The difficulty is to know where to draw the line. If, for example, the Norwegians are a "Nordic race" and the southern Italians a "Mediterranean race," to what race do the inhabitants of Denmark, northern Germany, southern Germany, Switzerland and northern Italy belong? The frequencies of most differentiating traits change rather gradually from Norway to southern Italy. Calling the intermediate populations separate races may be technically correct, but this confuses the race classification even more, because nowhere can sharp lines of demarcation between these "races" be drawn. It is quite arbitrary whether we recognize 2, 4, 10, or more than 100 races—or finally refuse to make any rigid racial labels at all.

The differences between human races are, after all, rather small, since the geographic separation between them is nowhere very marked. When a species is distributed over diversified territories, the process of adaptation to the different environments leads to the gradual accumulation of more numerous and biologically more and more important differences between races. The races gradually diverge. There is, of course, nothing fatal about this divergence, and under some circumstances the divergence may stop or even be turned into convergence. This is particularly true of the human species. The human races were somewhat more sharply separated in the past than they are today. Although the species inhabits almost every variety of environment on earth, the development of communications and the increase of mobility, especially in modern times, has led to much intermarriage and to some genetic convergence of the human races.

The diverging races become more and more distinct with time, and the process of divergence may finally culminate in transformation of races into species. Although the splitting of species is a gradual process, and it is often impossible to tell exactly when races cease to be races and become species, there exist some important differences between race and species which make the process of species formation one of the most important biological processes. Indeed, Darwin called his chief work *The Origin of Species*.

Races of sexually reproducing organisms are fully capable of intercrossing; they maintain their distinction as races only by geographical isolation. As a rule in most organisms no more than a single race of any one species inhabits the same territory. If representatives of two or more races come to live in the same territory, they interbreed, exchange genes, and eventually become fused into a single population. The human species, however, is an exception. Marriages are influenced by linguistic, religious, social, economic and other cultural factors.

Hence cultural isolation may keep populations apart for a time and slow down the exchange of genes even though the populations live in the same country. Nevertheless, the biological relationship proves stronger than cultural isolation, and interbreeding is everywhere in the process of breaking down such barriers. Unrestricted interbreeding would not mean, as often supposed, that all people would become alike. Mankind would continue to include at least as great a diversity of hereditary endowments as it contains today. However, the same types could be found anywhere in the world, and races as more or less discrete populations would cease to exist.

The Isolationism of Species

Species, on the contrary, can live in the same territory without losing their identity. F. Lutz of the American Museum of Natural History found 1,402 species of insects in the 75-by-200-foot yard of his home in a New Jersey suburb. This does not mean that representatives of distinct species never cross. Closely related species occasionally do interbreed in nature, especially among plants, but these cases are so rare that the discovery of one usually merits a note in a scientific journal.

The reason distinct species do not interbreed is that they are more or less completely kept apart by isolating mechanisms connected with reproduction, which exist in great variety. For example, the botanist Carl C. Epling of the University of California found that two species of sage which are common in southern California are generally separated by ecological factors, one preferring a dry site, the other a more humid one. When the two sages do grow side by side, they occasionally produce hybrids. The hybrids are quite vigorous, but their seed set amounts to less than two per cent of normal; *i.e.*, they are partially sterile. Hybrid sterility is a very common and effective isolating mechanism. A classic example is the mule, hybrid of the horse and donkey. Male mules are always sterile, females usually so. There are, however, some species, notably certain ducks, that produce quite fertile hybrids, not in nature but in captivity.

Two species of Drosophila, *pseudoobscura* and *persimilis*, are so close together biologically that they cannot be distinguished by inspection of their external characteristics. They differ, however, in the structure of their chromosomes and in many physiological traits. If a mixed group of females of the two species is exposed to a group of males of one species, copulations occur much more frequently between members of the same species than between those of different species, though some of the latter do take place. Among plants, the flowers of related species may differ so much in structure that they cannot be pollinated by the same insects, or they may have such differences in smell, color and shape that they attract different insects. Finally, even when cross-copulation or cross-pollination can occur, the union may fail to result in fertilization or may produce offspring that cannot live. Often several isolating mechanisms, no one of which is effective separately, combine to prevent interbreeding. In the case of the two fruit-fly species, at least three such mechanisms are at work: 1) the above-mentioned disposition to mate only with their own kind, even when they are together; 2) different preferences in climate, one preferring warmer and drier places than the other; 3) the fact that when they do interbreed the hybrid males that result are completely sterile and the hybrid females, though fertile, produce offspring that are poorly viable. There is good evidence that no gene exchange occurs between these species in nature.

The fact that distinct species can coexist in the same territory, while races generally cannot, is highly significant. It permits the formation of communities of diversified living beings which exploit the variety of habitats present in a territory more fully than any single species, no matter how polymorphic, could. It is responsible for the richness and colorfulness of life that is so impressive to biologists and non-biologists alike.

Evolution *v.* Predestination

Our discussion of the essentials of the modern theory of evolution may be concluded with a consideration of the objections raised against it. The most serious objection is that since mutations occur by "chance" and are undirected, and since selection is a "blind" force, it is difficult to see how mutation and selection can add up to the formation of such complex and beautifully balanced organs as, for example, the human eye. This, say critics of the theory, is like believing that a monkey pounding a typewriter might accidentally type out Dante's *Divine Comedy*. Some biologists have preferred to suppose that evolution is directed by an "inner urge toward perfection," or by a "combining power which amounts to intentionality," or by "telefinalism" or the like. The fatal weakness of these alternative "explanations" of evolution is that they do not explain anything. To say that evolution is directed by an urge, a combining power, or a telefinalism is like saying that a railroad engine is moved by a "locomotive power."

The objection that the modern theory of evolution makes undue demands on chance is based on a failure to appreciate the historical character of the evolutionary process. It would indeed strain credulity to suppose that a lucky sudden combination of chance mutations produced the eye in all its perfection. But the eye did not appear suddenly in the offspring of an eyeless creature; it is the result of an evolutionary development that took many millions of years. Along the way the evolving rudiments of the eye passed through innumerable stages, all of which were useful to their possessors, and therefore all adjusted to the demands of the environment by natural selection. Amphioxus, the primitive fish-like darling of comparative anatomists, has no eyes, but it has certain pigment cells in its brain by means of which it perceives light. Such pigment cells may have been the starting point of the development of eyes in our ancestors.

We have seen that the "combining power" of the sexual process is staggering, that on the most conservative estimate the number of possible gene combinations in the human species alone is far greater than that of the electrons and protons in the universe. When life developed sex, it acquired a trial-and-error mechanism of prodigious efficiency. This mechanism is not called upon to produce a completely new creature in one spectacular burst of creation; it is sufficient that it produces slight changes that improve the organism's chances of survival or reproduction in some habitat. In terms of the monkey-and-typewriter analogy, the theory does not require that the monkey sit down and compose the *Divine Comedy* from beginning to end by a lucky series of hits. All we need is that the monkey occasionally form a single word, or a single line; over the course of eons of time the environment shapes this growing text into the eventual masterpiece. Mutations occur by "chance" only in the sense that they appear regardless of their usefulness at the time and place of their origin. It should be kept in mind that the structure of a gene, like that of the whole organism, is the outcome of a long evolutionary development; the ways in which the genes can mutate are, consequently, by no means indeterminate.

Theories that ascribe evolution to "urges" and "telefinalisms" imply that there is some kind of predestination about the whole business, that evolution has produced nothing more than was potentially present at the beginning of life. The modern evolutionists believe that, on the contrary, evolution is a creative response of the living matter to the challenges of the environment. The role of the environment is to provide opportunities for biological inventions. Evolution is due neither to chance nor to design; it is due to a natural creative process.

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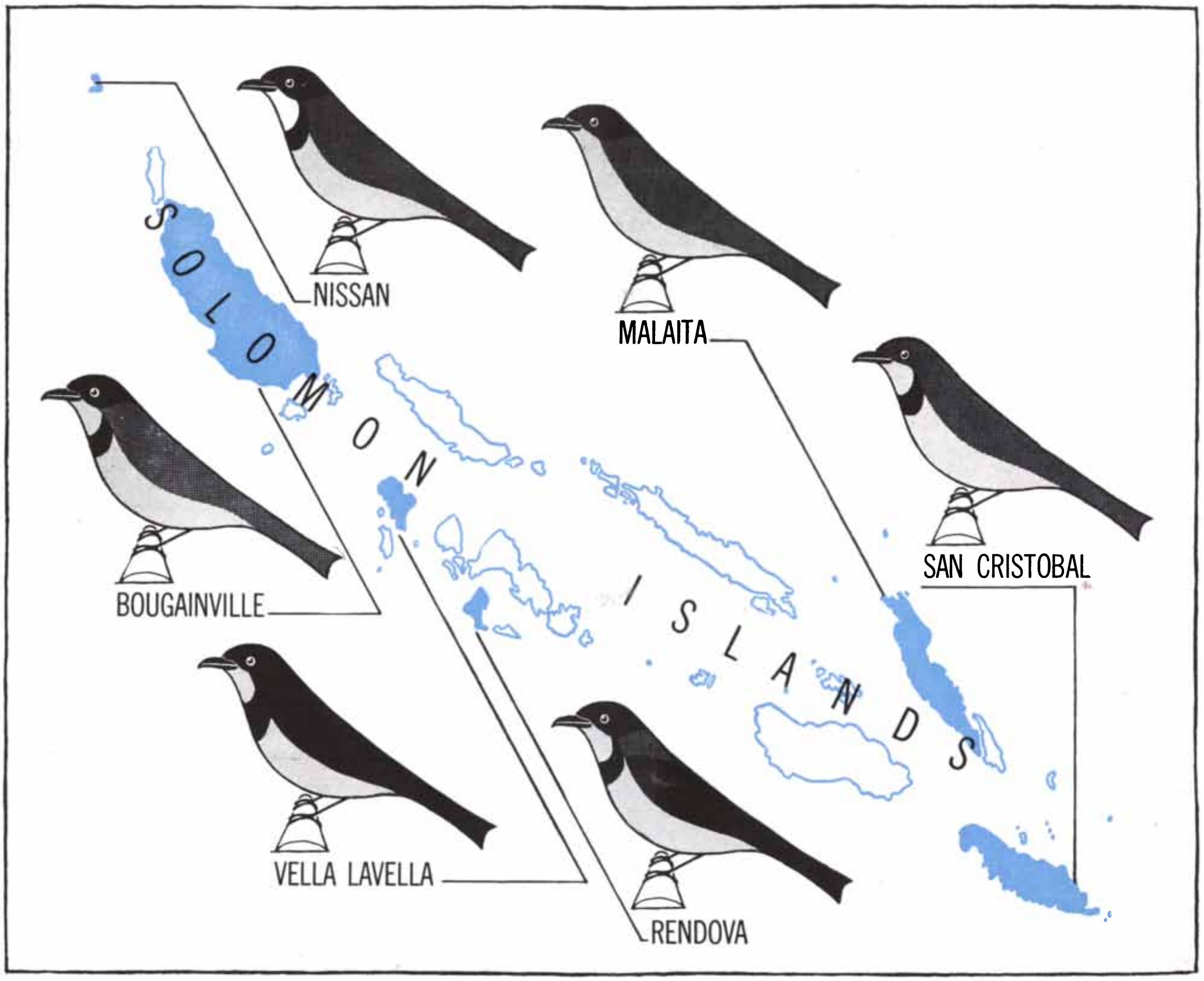
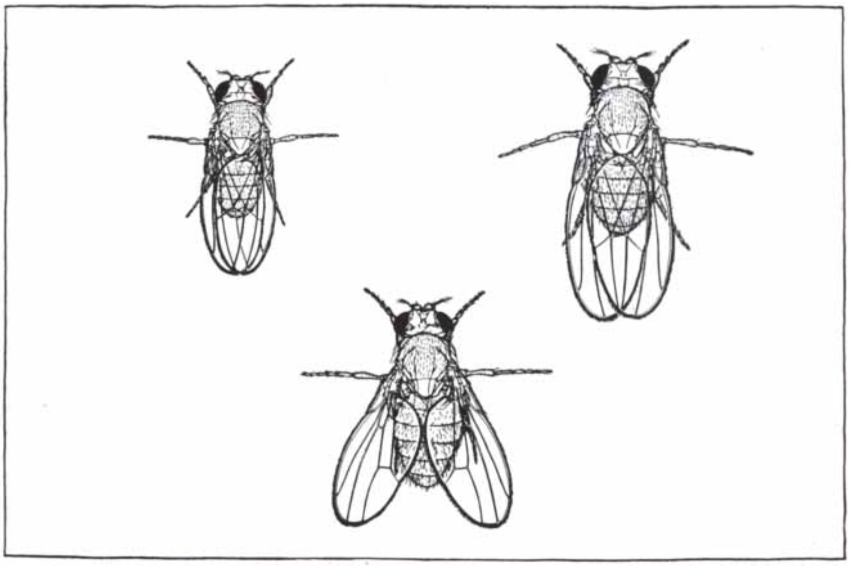
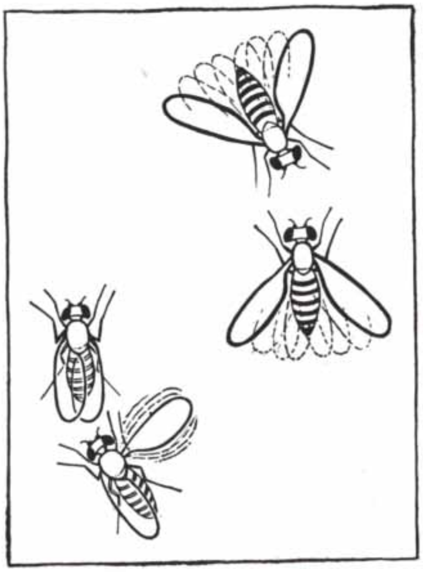


CONCEPT OF RACE is illustrated by the varieties of the golden whistler (*Pachycephala pectoralis*) of the Solomon Islands. The races are kept distinct principally by geographical isolation. They differ in their black and white and colored markings. Dark gray areas are symbol for green markings; light gray for yellow.



SPECIES OF DROSOPHILA and some other organisms tend to remain separate because their hybrid offspring are often weak and sterile. At left is *D. pseudoobscura;* at right *D. miranda.* Their hybrid descendant is at bottom.

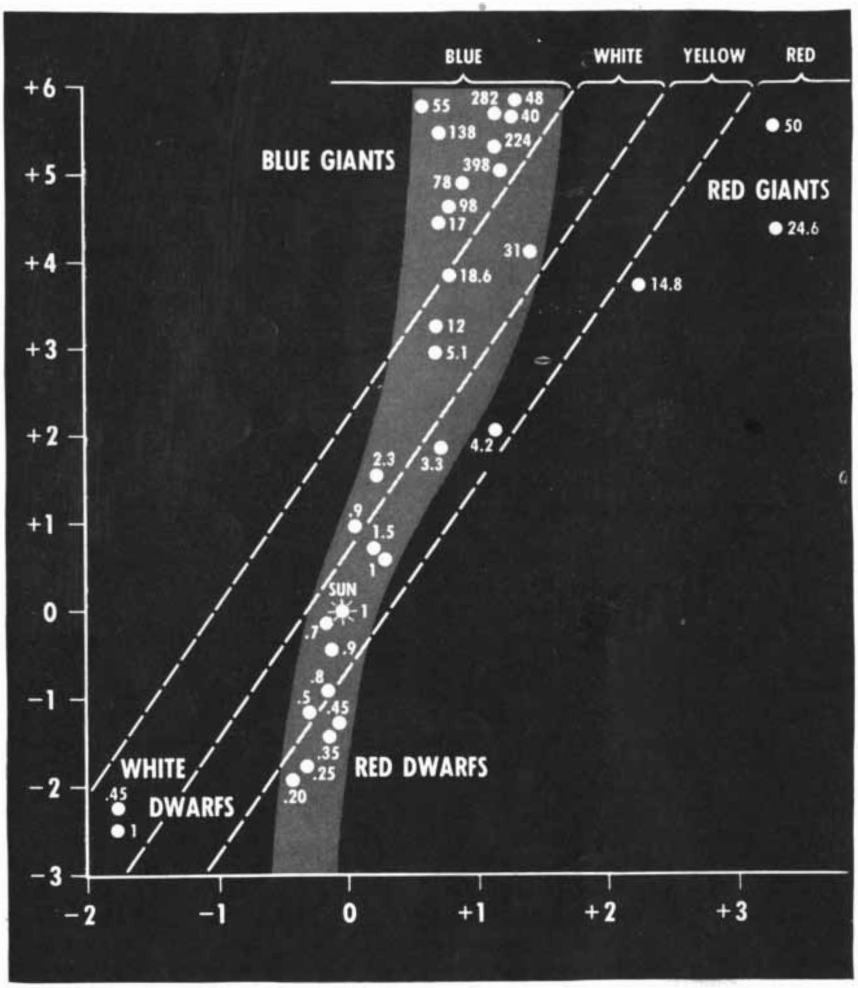


RITUALS OF MATING in *D. nebulosa* (*top*) and *D. willistoni* are example of factor that separates species.

THE ENERGY OF STARS

The radiation which ceaselessly floods interstellar space originates from the nuclear reactions of stellar interiors

by Robert E. Marshak



RADIUS AND LUMINOSITY of an average group of stars are plotted against each other. The logarithm of the radius in units of the sun's radius is given in the horizontal numbers at bottom; the logarithm of the luminosity in units of the sun's luminosity in the vertical numbers at left. Mass in units of the sun's mass is given in the number beside each star. Color of the stars is indicated by the dotted lines running from the brackets at top. Most of the stars fall in a "main sequence" indicated by the gray strip. White dwarfs and red giants are outside the main sequence.

THE stars of the universe hurl energy into space on a scale so gigantic that the numbers in which it is measured are almost meaningless to human understanding. The sun, for example, which is by no means a giant among the stars, radiates energy at the rate of half a million billion billion horsepower—of which only a small fraction is intercepted by the earth. Ever since man began to acquire some conception of the magnitude of the stars' radiations, he has been fascinated by the problem of how the stars have been able to maintain these tremendous outpourings of energy for so many millions of years. Thus in *Gulliver's Travels* the inhabitants of Laputa were worried lest "the sun daily spending its rays without any nutriment to supply them, will at last be wholly consumed and annihilated —which must be attended with the destruction of this earth and of all the planets that receive their light from it."

When astronomers began to make a scientific attempt to explain the source of stellar energy more than a hundred years ago, their first idea was that a star's energy derives from gravitational contraction. The mass of an average star is so huge that a large amount of energy could be released by the gradual shrinking of the star. Investigators eventually found, however, that this process could not account for the rate at which a star generates energy; in the case of the sun the gravitational source of energy would have been exhausted in a time much shorter than the age of the earth. Then, after the discovery of radioactivity at the turn of the present century, speculation turned to that process as a possible source of stellar energy. But it soon became clear that there was a conclusive objection to this theory: the rate of radioactive disintegration of atoms is not influenced by temperature, whereas it was shown by various kinds of evidence that the rate of generation of energy by a star depends directly on its internal temperature.

It was the study of the probable physical conditions in the interiors of stars that finally provided the clue to the origin of stellar energy. By 1930 the researches of the great British astrophysicist Sir Arthur Eddington and others had shown that the stars are very hot masses of gas with interior temperatures of 15 to 30 million degrees Centigrade. At such high temperatures all molecules are decomposed into atoms, the atoms themselves are stripped of their electrons, and only the atomic nuclei can remain intact. Moreover, the nuclei travel at such high speeds that they overcome the nuclear forces of repulsion and occasionally crash into one another.

The next question was: How much energy could such collisions release? By 1938 it became known that the forces holding together the protons and neutrons inside an atomic nucleus were about a million times as strong as the electrical force holding the electrons in an atom. This means that if the atomic nuclei in the stars interact with one another in such a way as to tap their inner sources of energy, the reaction will release a million times as much energy as when the electrons of atoms interact in energy-producing chemical reactions.

What might these nuclear reactions be? Not all nuclear reactions yield energy, just as not all chemical reactions produce energy. For example, a medium-weight nucleus like that of iron cannot be made to release energy by any process we knew, either by splitting the nucleus or building it up. There are two general types of reaction that can release nuclear energy. One is the splitting of a heavy nucleus such as that of uranium 235 into two nuclei of almost equal weight. The other is the combination of two or more light nuclei such as those of hydrogen into a heavier nucleus. To account for the vast production of energy in a star, we must assume a process that involves a sizable fraction of the atomic nuclei present in the star. This, of course, rules out the possibility that the stars are fueled by the fission of uranium or other heavy elements, since the stars contain relatively few heavy nuclei. So we can safely assume that the stars produce energy by the combination of light elements through the collisions of their swiftly moving nuclei.

The building-up mechanism requires very high temperatures. It is relatively easy to make small numbers of atomic nuclei undergo nuclear reactions in the laboratory by bombarding them with particles accelerated to high energies by a cyclotron or similar machine. But the amount of energy created is insignificant, because compared with the input of energy needed to accelerate the bombarding particles the energy liberated by the bombarded nuclei is small. This is due to the low percentage of hits by the relatively few projectiles on their tiny nuclear targets. At the tremendous temperatures in the interior of a star, however, a large fraction of the nuclei possess the high velocities necessary to produce nuclear reactions. Moreover, this condition continues indefinitely, for the great mass of hot material surrounding the interior of the star prevents the interior from losing too much of its heat by radiation. The energy released from the nuclear reaction produces the high temperature in the star, and the high temperature in turn enables the atomic nuclei to come together and release their energy. Therefore thermonuclear reactions can go on indefinitely, and a self-sustaining reaction is produced.

When astrophysicists had got this far, the way was prepared for formulating a theory. The problem was to reconstruct a system of chain reactions among light nuclei that would account for the rate of energy output by the stars. Its solution was achieved principally by the physicist Hans A. Bethe of Cornell University. The reasoning was such a superb application of scientific method that it deserves a detailed account.

It was evident, as a result of an analysis first performed by R. d'E. Atkinson of the U. S. and F. G. Houtermanns of Germany, and later extended by George Gamow and Edward Teller of the U. S., that the probability of a nuclear reaction decreased sharply with increasing charge; that is, it would be very much greater among nuclei of small electrical charge than among those of larger charge. Thus protons, the nuclei of hydrogen atoms, with but a single positive charge, would be expected to play the most important role in the production of energy. Bethe and, independently, the German physicist C. F. von Weizsäcker, carefully examined all the known nuclear reactions involving protons. The relevant nuclear reactions could be divided into two classes: 1) those in which only protons are consumed; 2) those in which other nuclei also are consumed. Bethe and von Weizsäcker were able at once to eliminate the second type of reaction as a source of energy for most stars. Among the light elements, only lithium, beryllium and boron would react fast enough with protons to give any appreciable energy production. (Helium cannot react with hydrogen, for the resulting nucleus is unstable.) Reactions consuming lithium, boron and beryllium might be responsible for the energy production in some young stars, such as the red giants, but these elements are too rare to supply energy for more than a very limited period for the older stars such as the sun. Thus a lasting source of energy could be found only among the reactions that consume protons alone.

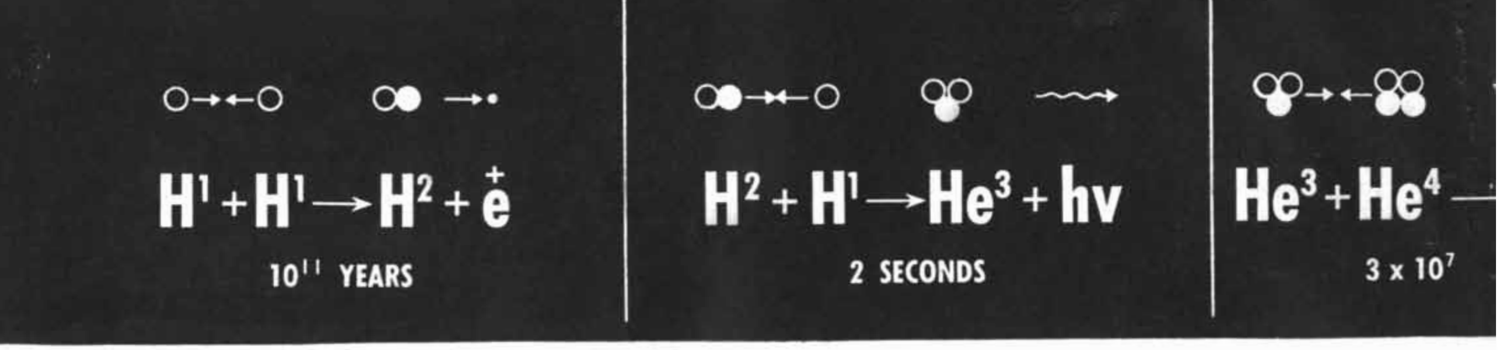
There are essentially two possible sets of such reactions. One starts with the direct combination of two protons, and is known as the proton-proton set of reactions. The other, using carbon nuclei as catalysts, is called the carbon cycle. Both sets of reactions lead to the formation of helium nuclei out of protons.

LET us consider the carbon cycle first. It starts when an energetic proton deep in the interior of the star collides with a nucleus of carbon 12, the common isotope of carbon, with such force that it overcomes the electrical repulsion of the carbon nucleus. According to Bethe's calculations, under the temperature-density conditions in the interior of the sun each proton undergoes such capture on the average about once in 40,000 years. When the carbon nucleus captures the proton, it is transformed into a nucleus of radioactive nitrogen 13, and simultaneously emits a gamma ray, which eventually finds its way out of the star with a degraded energy. About 10 minutes after the radioactive nitrogen 13 nucleus is formed, it spontaneously emits a positron (a particle with the same mass as that of the electron but with opposite charge) and becomes stable carbon 13. After moving around for some time in the hot gas in the interior of the star, the carbon 13 nucleus in turn captures a proton in about 7,000 years to form a stable nitrogen 14 nucleus plus a gamma ray. About a million years later, on the average, the wandering nitrogen 14 nucleus captures a proton and is changed into a radioactive oxygen 15 nucleus plus a gamma ray. In about two minutes the unstable oxygen 15 gives off a positron and becomes nitrogen 15. About 20 years later comes the climactic reaction in the cycle: the nitrogen 15 nucleus captures another proton. But this time the result is not a simple capture accompanied by gamma-ray emission. Instead, the product splits into two large parts—a nucleus of carbon 12 and a nucleus of helium 4.

Since the creation of a positron is equivalent to the destruction of an electron, the carbon cycle in effect converts four protons and two electrons into a stable helium nucleus. But the helium nucleus possesses only 99 per cent of the mass of the four protons from which it was formed. The one per cent difference in mass has been released in the form of energy, and the energy release is enormous. It is measured in terms of the Einstein formula for the equivalence of mass and energy, in which the energy produced in ergs is equal to the loss of mass in grams times the square of the velocity of light in centimeters per second ($E=Mc^2$).

One of the key facts about the carbon cycle is that the carbon nuclei are not consumed; for every carbon nucleus that enters the cycle one is reproduced at the end. This is very important for the economy of stellar-energy production, since hydrogen is much more abundant than carbon in stars, thereby providing nuclear fuel for a longer period of time. In most stars hydrogen is by far the most abundant element, with the possible exception of helium.

The proton-proton set of reactions synthesizes a helium nucleus by another complex series of transformations. According to calculations by Bethe and Charles Critchfield (now at the University of Minnesota), two protons first combine into a deuteron and a positron in the extremely long average time of 100 billion years (again assuming the temperature-density conditions characteristic of the central region of the sun). About two seconds after the deuteron is formed, it captures a proton to form helium 3 plus a gamma ray. In about 30 million years the helium 3 combines with a nucleus of helium 4 already present in the star to form beryllium 7. The latter changes into lithium 7 in about one year through the capture of a free electron. About one



PROTON-PROTON **reactions begin when two protons (H^1) collide to form heavy hydrogen (H^2) and release a positive beta particle. A given proton is likely to enter into this reaction only once in 10^{11} years, but in a large**

minute later lithium 7 combines with another proton and splits into two helium 4 nuclei. Hence, as in the case of the carbon cycle, the proton-proton reaction serves as a source of energy by effectively transforming into radiation the binding energy of the helium nucleus with respect to four protons and two electrons.

THE carbon cycle and proton-proton reactions are now accepted by most astrophysicists as responsible for the energy production of most stars. The principal purpose of this article is to survey the reasons which have led to the acceptance of this conclusion. To begin with, all the nuclear reactions in the carbon cycle have been observed and measured in the laboratory; in fact, in stating the average times of the various reactions, we have used some very recent experimental data obtained by R. N. Hall and W. A. Fowler at the California Institute of Technology and C. L. Bailey and W. R. Stratton at the University of Minnesota. The proton-proton set of reactions cannot be confirmed experimentally, because its initial step, the combination of two protons to form a deuteron and a positron, has too low a probability to be measured in the laboratory. However, it is very likely that the theory upon which its estimated probability is based can be trusted.

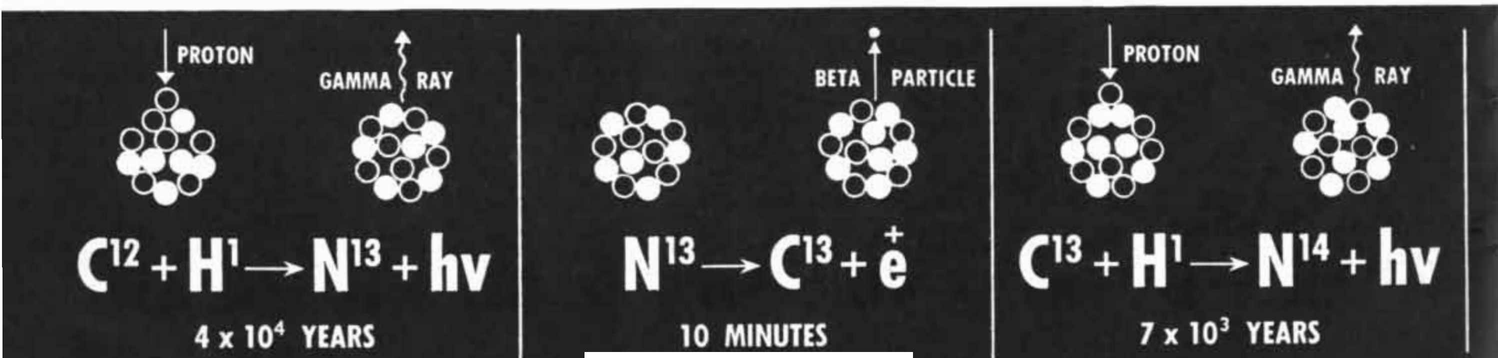
The astrophysicist's test of any hypothesis about what takes place in a star depends mainly on the analysis of certain relations among the various types of stars. Under favorable circumstances he has three pieces of information about a star: its mass, its luminosity (the amount of energy it emits per second) and its radius. When the stars for which these data are available are classified and plotted on a chart according to the mass-luminosity-radius relations (*see diagram on page 42*), certain regularities become apparent. Most of the observed stars belong to the so-called "main sequence," a group in which, as one goes up the scale from the less massive to the more massive stars, the luminosity and the radius increase fairly regularly with the mass. The luminosity, however, increases at a more rapid rate than does the radius, so the main-sequence stars range from hot, luminous blue giants to cool, faint red dwarfs.

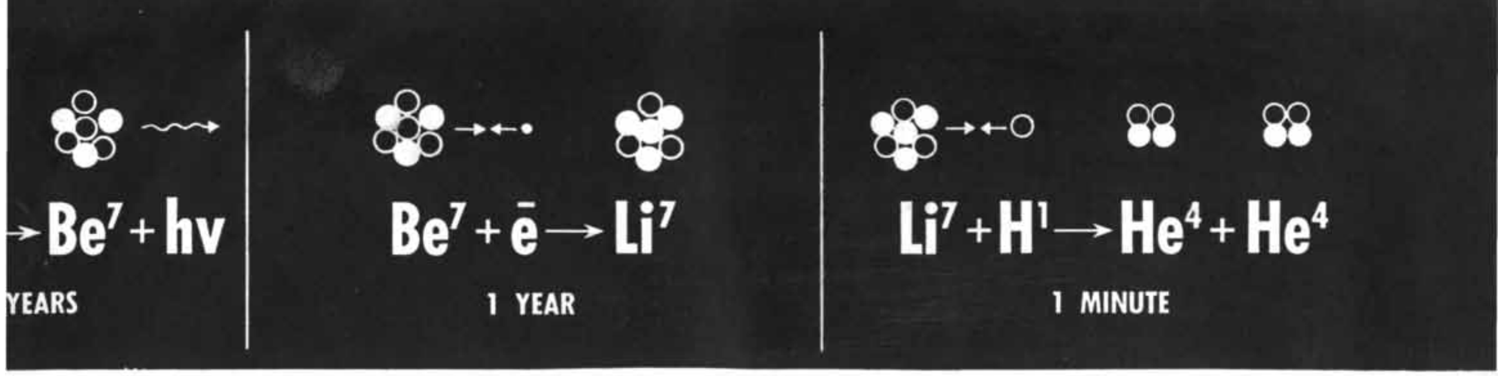
We shall confine our attention to stars of the main sequence. According to an old hypothesis of the astronomers H. Vogt of Germany and Henry Norris Russell of the U. S., when the mass and chemical composition of a star are known, it should be possible to predict theoretically the star's size, luminosity, internal temperature and distribution of density. A correct prediction of the luminosity depends on a proper choice of the mechanism of energy production. The dilemma arises from our inadequate knowledge of the chemical composition of a star. We have only incomplete information, obtained by spectroscopic analysis, about the composition of the surfaces or atmospheres of stars, and none at all about their internal make-up. The assumption is usually made that the internal composition does not differ in essential respects from that of the surface.

Fortunately it turns out that the exact details of chemical composition, except for hydrogen and helium, are not too important when we deal with the reactions among atomic nuclei stripped of electrons—the state of affairs prevalent in stellar interiors. We can treat hydrogen and helium apart from the other elements. One proceeds then as follows: Since the thermonuclear reactions that yield energy are extremely sensitive to temperature, one can assume that the energy production takes place in the inner core of the star, the zone of highest temperature. From the observed mass, luminosity and radius of the star, one can calculate the distribution of its internal temperature and density. In this manner it is found that the sun, for example, has a central temperature of about 20 million degrees C., a central density of about 100 grams per cubic centimeter and a hydrogen concentration by weight of about 35 per cent. The central temperatures of the stars in the main sequence are roughly proportional to the mass and inversely proportional to the radius; they range from about 30 million degrees for the blue giants down to about 15 million degrees for the red dwarfs. While the largest stars are only twice as hot as the smallest, their luminosity is greater by a factor of 100,000, which confirms the assumption that the process of energy production must be extremely sensitive to the temperature and hence that the energy is produced in the inner core of the star.

Once the temperature-density distribution inside a star is known, one can calculate the rate at which energy is produced by the temperature-stimulated collisions among the nuclei involved in a given process. In other words, one can predict how much energy the process in question should yield, given the abundances of the nuclei participating in it. When one makes such calculations, using the abundances of carbon and nitrogen

CARBON CYCLE **begins when a proton collides with the nucleus of a light isotope of carbon (C^{12}). In these six reactions carbon is transmuted into nitrogen, nitrogen into carbon, carbon into nitrogen, nitrogen**





number of protons many such events take place. In the succeeding four reactions hydrogen is transmuted into helium, helium into beryllium, beryllium into lithium, lithium into two helium nuclei. Gamma-ray symbol: hv.

shown by spectroscopic analysis of the stars, it turns out that in the case of the main-sequence stars brighter than the sun, the carbon cycle releases nuclear energy at just about the rate that those stars are observed to emit radiation energy. Thus the theoretical predictions agree with the observations, providing good evidence that the carbon cycle is actually the source of energy in these stars. In the case of main-sequence stars fainter than the sun, the same calculations indicate that the source of energy is not the carbon cycle but the proton-proton set of reactions. In the sun itself, either the carbon cycle or the proton-proton reactions or both would give the observed rate of energy production.

NOW the significant fact is that on the basis of such calculations no other nuclear reaction or set of reactions comes close to giving the observed rate of energy release for a star in the temperature range of 15 to 30 million degrees. For example, at a temperature of the order of 20 million degrees, nuclear reactions involving boron, the element next lighter than carbon, would give an energy production at least 10,000 times too large, while the next heavier element, oxygen, would yield an energy output about 100,000 times too small.

Thus the carbon cycle and the proton-proton set of reactions fit the observed facts in a unique way: they consume only the most abundant element in the stars—hydrogen—and they give the right energy evolution at temperatures consistent with the equations of stellar equilibrium for the various main-sequence stars. Perhaps the most conclusive evidence for the carbon cycle is that the rate at which it proceeds is extremely sensitive to temperature, which is precisely in accord with the observed facts on the dependence of luminosity on temperature in the case of main-sequence stars brighter than the sun. There is no equivalent evidence for the proton-proton set of reactions, because the observational data on the red dwarfs is too meager.

It is possible to approach the problem from the other end, as the author and Martin Schwarzschild of Princeton University independently have done. One uses the same equations of stellar equilibrium, but instead of taking the numbers for the chemical composition of the star as known, one assumes that the carbon cycle is the correct process and solves the equations for the chemical composition. This procedure makes it possible to determine a star's helium content, otherwise unobtainable. By this method the California Institute of Technology astrophysicists R. F. Christy and J. O'Reilly obtained the following numbers for the sun: hydrogen content, 66 per cent; helium content, 31 per cent; heavy elements, 3 per cent; central temperature, 17.5 million degrees; central density, 163 grams per cubic centimeter.

THERE are some puzzling discrepancies and difficulties in the carbon-cycle theory. For example, the French astrophysicist E. Schatzman found that he could not obtain a solution of the equations of stellar equilibrium for the large stars with masses more than 10 times that of the sun. This would mean that these giant stars do not produce their energy by the carbon cycle. However, Schatzman did not use the latest probabilities for the reactions in the carbon cycle and he made certain approximations in his calculations, so his results are not decisive. On the other hand, they may be a reflection of the fact that the very massive stars of the main sequence possess such great luminosities that even the carbon cycle can supply their energy only for relatively short periods of time.

Another difficulty has to do with a discrepancy in the relative abundance of nitrogen and carbon in the stars. According to the latest experimental work on the carbon cycle, the lifetime of nitrogen 14 is about 50 times as long as that of carbon 12. Since both lifetimes are small compared with the age of most stars, the two elements should establish an equilibrium, and we would expect to find nitrogen 50 times as abundant as carbon in the carbon-cycle stars. Actually, however, spectroscopic observation of the atmosphere of the sun shows that nitrogen is only three times as abundant as carbon there. Such a discrepancy would cast doubt on the belief, generally held by astrophysicists, that the elements are mixed uniformly throughout a star.

These difficulties are not sufficiently serious, however, to vitiate the theory. The arguments in favor of the carbon cycle and the proton-proton set of reactions as the sources of energy in main-sequence stars are too weighty. But the difficulties do underline the fact that there are still many unsolved problems in the fascinating study of what makes the stars shine.

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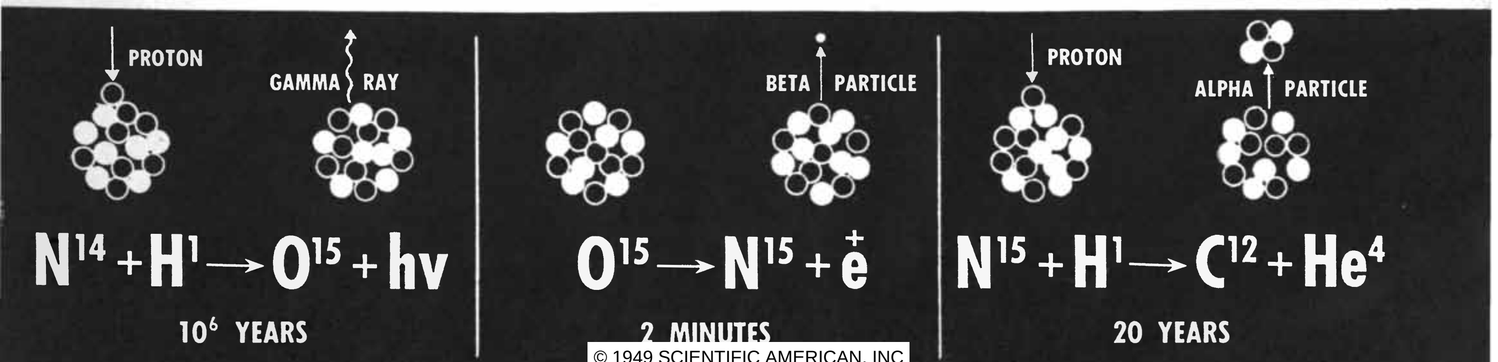
into oxygen, oxygen into nitrogen, and nitrogen into carbon and helium. The net effect of the whole series of reactions is to convert four hydrogen nuclei into one helium nucleus with the release of energy.



CO-EDITORS Brimble (*left*) and Gale step from the curb in front of Macmillan and Co., Ltd., the great English book-publishing house that also publishes *Nature*. Gale came to the magazine in 1920; Brimble in 1931.

"NATURE"

The renowned British scientific journal is a faithful mirror of international science

IT is frequently said that science transcends nations. If the statement is true—and in spite of past and present barriers to international understanding there is every reason to believe that it is—the scientific journal which most clearly expresses this supranational unity is the British magazine *Nature*.

The pages of *Nature* are a weekly reflection of the preoccupations of scientists in many disciplines and in many parts of the world. Perhaps a third of its space is devoted to unsolicited communications. An unexceptional recent issue contained letters from Britain, Australia, Norway, Barbados, the U. S., France, the Netherlands, Canada and Fiji. The subjects ranged from the physical "Electron Pair Creation by a Spherically Symmetrical Field" to the biological "Germination of Zygospores in Chlamydomonas." In addition to letters *Nature* publishes solicited articles and book reviews by outstanding authorities in all fields of science.

In spite of its international content *Nature* remains formidably English. Its front cover, like that of many other English magazines, is adorned with advertising. Its octavo pages are chastely economical of white space. Its editors are not named on its masthead. Beneath its title is a pleasantly traditional quotation from Wordsworth: "To the solid ground of nature trusts the Mind that builds for aye."

Nature has been published since 1869 by Macmillan and Co., Ltd. Its first editor was Sir Norman Lockyer, an eminent astronomer who discovered helium in the sun 30 years before it was discovered on earth. Its second editor was Sir Richard Gregory, another astronomer who was principally responsible for making the magazine international as well as English. When Gregory retired in 1939 he was succeeded by the present co-editors, Arthur J. V. Gale and L. J. F. Brimble.

Not all of *Nature* may be easily read by laymen or even by scientists. Many of its letters and some of its articles and book reviews are directed to the specialist. There is no issue, however, that does not contain much of interest to anyone who is interested in science.

OFFICES OF NATURE, which look out over London's St. Martin's Street, have always been crowded with contributions. Although the magazine is a weekly, it regularly sends proofs of the material it publishes to the authors for final correction. Co-editors Brimble (*right*) and Gale also edit technical books for Macmillan.

The American Languages

Although most Americans speak English, U. S. speech falls into distinct regional patterns. Some of these have been compiled in a new Linguistic Atlas of the Eastern states

by Hans Kurath

WE are not accustomed to think of the U. S. language as a Babel of tongues, but if one were to make the experiment of assembling individuals from a number of different localities and listening carefully to their speech, he might note some rather curious results. For example, a Rhode Islander might speak of a "dandle," a Marylander of a "cocky-horse," a coastal North Carolinian of a "hicky-horse," a western North Carolinian of a "ridy-horse," a Block Islander of a "tippity-bounce," a Cape Codder of a "tilt," a native of the lower Connecticut Valley of a "tinter," a Hudson Valley native of a "teeter-totter" and a Bostonian of a "teeterboard." All of these expressions mean the same thing—a seesaw—yet it is entirely possible that some of the nine persons would not know what the others were talking about.

American English has a surprising wealth of such localisms. The casual foreign visitor is inclined to lump them all together as "Americanisms," and to suppose, erroneously, that they are generally current throughout the U. S. More sophisticated observers are aware that New England, the South and the West show certain differences in speech, but usually they have only the vaguest notions of the actual location of these regionalisms. As a matter of fact, the expressions commonly identified as "New Englandisms" are apt to be current only east of the Connecticut River; "Southernisms" more often than not are confined to Virginia or to certain sections making up the old plantation country of the South; "Westernisms" may be common only in the Spanish Southwest or the cattle country. On the other hand there are regions with equally distinctive speech patterns that have largely escaped notice; a notable example is the broad Midland area embracing Pennsylvania and the Ohio Valley, where the vocabulary and pronunciation are as different from those of New England and the South as the latter are from each other.

Since 1931 the writer and a group of associates have been making a study, under the auspices of the American Council of Learned Societies, of local and regional speech differences in the eastern United States. We now have the data for a "Linguistic Atlas" providing a systematic record of the currency of selected words and expressions in the coastal states from Maine to Georgia and in Pennsylvania, West Virginia and eastern Ohio. As in all scientific studies, the immediate purpose was simply the collection of facts, without which a historical interpretation of American linguistic usage is impossible. In this case the results shed considerable light on U. S. migrations, settlement areas, trade areas, culture areas and other aspects of human geography and population history.

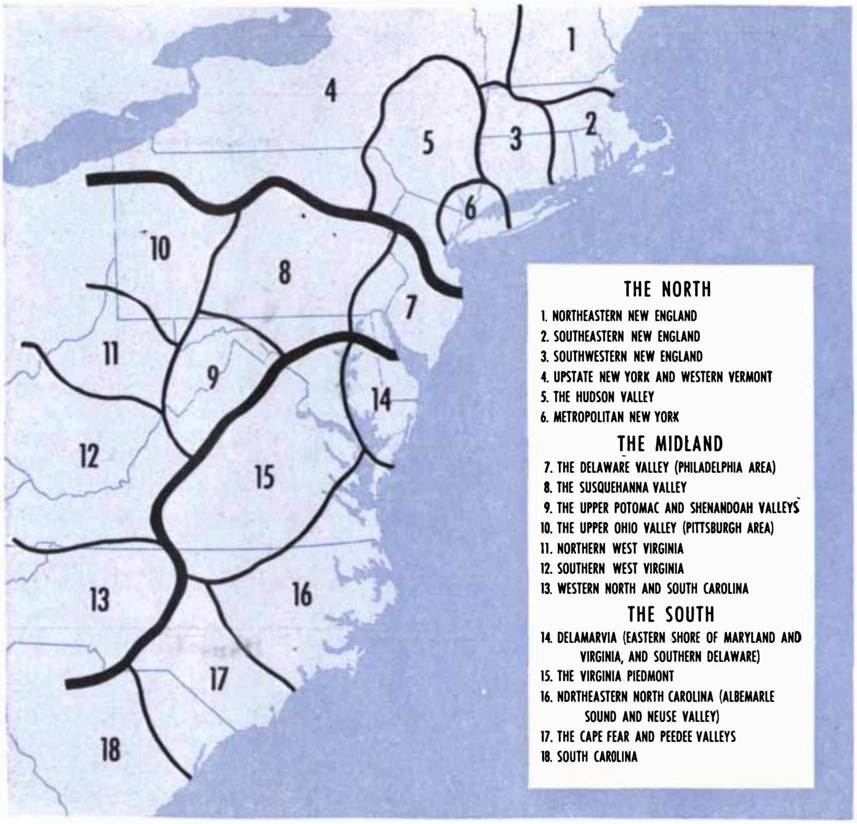
In making the survey we used the sampling method. Trained linguists went to nearly every county in these states and in each interviewed two persons—one old-fashioned and unschooled, the other a member of the middle class who had had the benefit of a grade-school or high-school education. They also interviewed one or more cultured persons in each of the larger cities. The interviewers spent from 10 to 15 hours with each individual to record his habitual usage on well over a thousand points. Most of this field work was done by Bernard Bloch, Raven I. McDavid and the late Guy S. Lowman, Jr.

All together more than 1,200 persons were interviewed, and full information was obtained, among other things, on the diffusion of some 400 local or regional expressions. A map was plotted for each expression. The boundary enclosing the area in which a given expression is current is known as an isogloss. Wherever a large number of isoglosses enclose a common area, *i.e.*, wherever the people share many folk expressions that are not current elsewhere, obviously they delimit a major speech boundary.

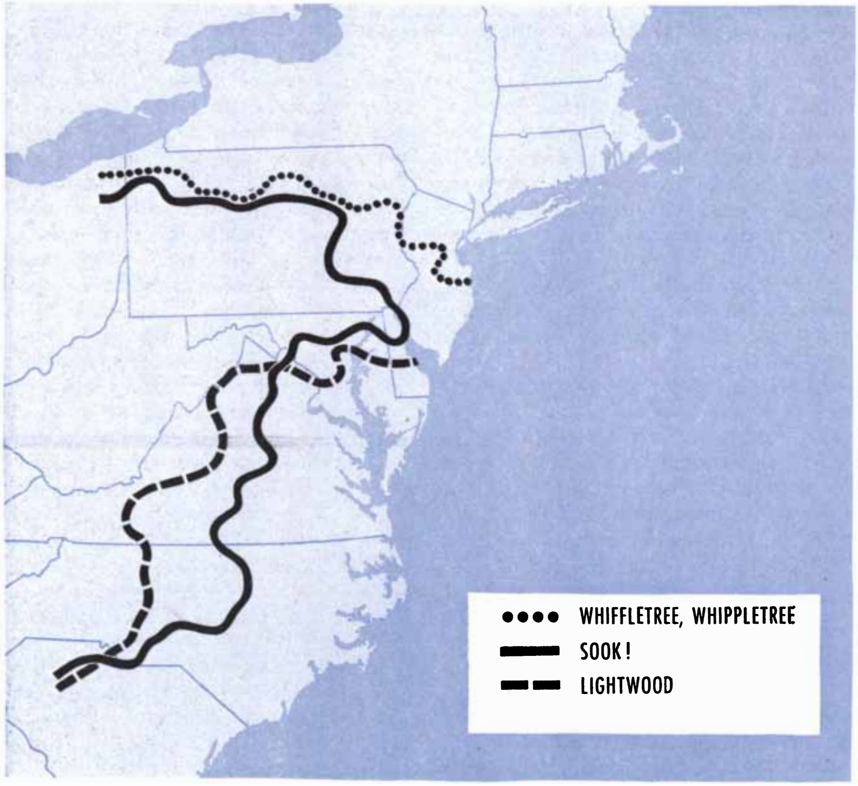
These studies showed that the eastern section of our country is divided into three speech areas of first importance—the North, the Midland and the South. These major areas are distinguished by certain region-wide expressions. They are split, however, into a number of subareas, each with its own local folk words and peculiarities of diction. The map at the top of the opposite page shows these major and minor boundaries. The Northern region in general includes the New England settlement area, reaching west to the Great Lakes, and the Dutch settlement in the Hudson Valley. Within it are no fewer than six distinct subdivisions: the people of northeastern, southeastern and southwestern New England, metropolitan New York, the Hudson Valley and western New York have inherited from their forebears or developed certain definite speech differences. Similarly the Midland, corresponding in general to the Pennsylvania settlement area, is segmented into several speech areas, of which one of the most distinctive is the section west and north of Philadelphia settled by the Pennsylvania Dutch. Natural geographical barriers have a great influence on population movements, and hence on language, as is demonstrated by the fact that the crest of the Alleghenies in Pennsylvania divides the eastern and western parts of the state into distinct speech areas. In the South one can find differing varieties of Southern speech in the Chesapeake Bay area, the Virginia Piedmont and the eastern sections of the Carolinas. The speech boundaries in the South tend to be sharper than in other regions, because its populations have clung more closely to the soil.

NOW there are certain key expressions that characterize each major region. You can identify a person as a Northerner if he says pail for bucket, swill for garbage, whiffletree or whippletree for the bar to which a horse is harnessed, comforter or comfortable for a heavy quilt, brook for stream. A Midlander can generally be identified by his use of the word blinds for window shades, skillet for frying pan, spouting for roof gutters. A Southerner characteristically says light-bread for wheat bread, clabber for curdled sour milk, hay shock for haycock, corn shucks for corn husks, lightwood for kindling, rock fence for stone fence, and of course "you-all." In some cases the three regions have three distinct expressions for the same thing. Thus salt pork is commonly called salt pork in the North, side meat in much of the Midland and middlin meat in much of the South. A Northerner generally calls a dragonfly a darning needle; a Midlander is likely to call it a snake feeder or snake doctor; a Southerner, a snake doctor or mosquito hawk. Corn bread is known as johnnycake in the North and corn pone in the Midland and South. To call a cow in the pasture, a Northern farmer cries "Come boss!" or "Co-boss!"; a Midlander calls "Sook!"; a Southerner calls "Co-ee!" or "Co-wench!" In New England farmers call a bull a critter, sire, toro or top cow; in the Midland they most often call it an ox, male cow or sire; in the South, a steer, male cow, beast or brute.

It is usually possible, however, to place a person much more precisely, to connect him with a particular area in his region. The areas that have been settled longest have the most distinctive speechways. Use of the word fritter for griddlecake and funnel for stovepipe spots a New Englander as a "Down-Easter." (In most of New England a funnel for pouring liquids is called a "tunnel.") The expression cleavestone peach for freestone peach, apple grunt for apple dumpling and porch for the kitchen ell place a man on Cape Cod. Dandle for seesaw and eace worm for earthworm put him on Narragansett Bay. If he calls a thunder shower a tempest and a pet lamb a cade, he is from Cape Cod or Narragansett Bay. If a New Englander says ivy for mountain laurel and angledog for earthworm, he lives in the lower Connecticut Valley. If he calls a coal hod a coal scuttle, a haystack a hay barrack and cottage cheese pot cheese, his home is in the valley of the Hudson or the Housatonic. In Maine children coast belly-bumper,



LINGUISTIC MAP of the Eastern states divides them into three major areas, each distinguished by regional expressions. These are subdivided into smaller areas that are characterized by localisms of their own.



ISOGLOSSES are boundaries that define the limits of a given usage. The expression whippletree is used north of the dotted line; the cow call "Sook!" west of solid line; lightwood for kindling east of broken line.

in the upper Connecticut Valley belly-bunt, around Massachusetts and Narragansett Bays belly-bump, on the lower Connecticut belly-gutter and in the Hudson Valley belly-wopper.

IN the South one finds even sharper local differences in speech. Around Chesapeake Bay alone there are several distinct speech areas. Thus a cowpen is called a cowpen on the Maryland Western Shore, a pound on the Eastern Shore, a cuppin in the Virginia Piedmont and a brake in the Norfolk area on the south side of the Bay. A freestone peach is named an open peach on the Eastern Shore, an openstone peach on the Western Shore, a soft peach in the Virginia Piedmont and a clearseed peach in the Norfolk area. The Carolina Shore has at least five different speech areas. In various localities of the Carolinas a storeroom is known as a lumber room, a plunder room or a trumpery room; a vest is called a wesket or a jacket; bacon is known as breakfast bacon, breakfast strips or breakfast meat; a screech owl is a scrich owl, a scrooch owl, a squinch owl or a shivering owl; the pig call is "Chook!", "Wookie!", "Vootsie!", "Goop!" or "Woopie!"

How can we account for the existence, and particularly the persistence, of so many regional and local expressions? We must first understand clearly that there are social "isoglosses" as well as geographical ones. Three levels of speech can be distinguished in the U. S.: 1) cultivated speech, which is most widespread in urban areas; 2) common speech, the language of the large middle class; 3) folk speech, which is found in rural areas. Cultivated speech tends to be national or regional in character. The homely expressions that we have been considering come mostly from the second and third levels. They are the speechways of relatively unschooled people who read little, travel little, and acquire their language largely by ear from the older generation in their immediate vicinity.

Our studies indicate that the different places of origin of the colonial settlers, geographical barriers, colonial isolation, expanding frontiers and transportation facilities, trade, social stratification, educational facilities, religious activities and political activities have all played their parts in localizing or disseminating linguistic usages. The colonists who settled the Eastern seaboard were a heterogeneous group to start with. Even among those from the British Isles a great variety of dialects, peasant and urban, were spoken: there were Yorkshiremen, Lancashiremen, Kentishmen, Hampshiremen, Ulstermen, and a small minority who spoke the dialect of the upper classes of London.

In the course of several generations in the New World each colony developed its own unique blend of provincial dialects, adding to the old-country speech a few expressions taken from the Indians and others invented as names for unfamiliar plants and animals found in their new environment. As the settlements expanded westward, the frontiersmen developed new blends of speech, dropping many of the more local expressions but retaining the more widely used regional expressions. Thus west of the Alleghenies and the Appalachians speech is less diversified than in the East and speech boundaries are less clearly defined. It is this lack of clear boundaries in the central states that is largely responsible for the fiction that a "general American" type of English exists. Actually three regional types of English are spoken in the Middle West—the Northern type in the Great Lakes Basin and upper Mississippi Valley, the Southern type in the Gulf States, and the Midland type in the valleys of the Ohio and its tributaries and along the middle course of the Mississippi.

Speech areas are not stable; they expand or shrink. The nucleus of an expanding area's growth is usually a large metropolitan center or a dominant social class whose speech is regarded as superior. In the East the cities of Boston, New York and Philadelphia have been important centers of expanding areas in speech. Boston, which has dominated eastern New England since the days of the Massachusetts Bay Colony, reached the heyday of its linguistic influence in the middle of the 19th century, when the literary and intellectual accomplishments of its writers and scholars gave it a hearing not only in New England but throughout the country. Metropolitan New York has had a striking effect upon the speechways, particularly in pronunciation, of the surrounding areas; its unique speech has supplanted New Englandisms and other local expressions on Long Island, in southwestern Connecticut, in eastern New Jersey and in the lower Hudson Valley. The linguistic influence of Philadelphia has spread westward to the Susquehanna Valley, southward almost to Baltimore and southeastward into Delaware and the Maryland Eastern Shore.

The shrinking speech areas in general are those that lack a prominent population center and fall under the influence of one or more adjoining areas of expansion. Examples of such areas are Narragansett Bay, central New England and the Virginia Tidewater, which is coming under the domination of the expanding Piedmont area. To students of language the speechways of a shrinking area provide important clues to usages of the past; those of an expanding area, to developments of the future.

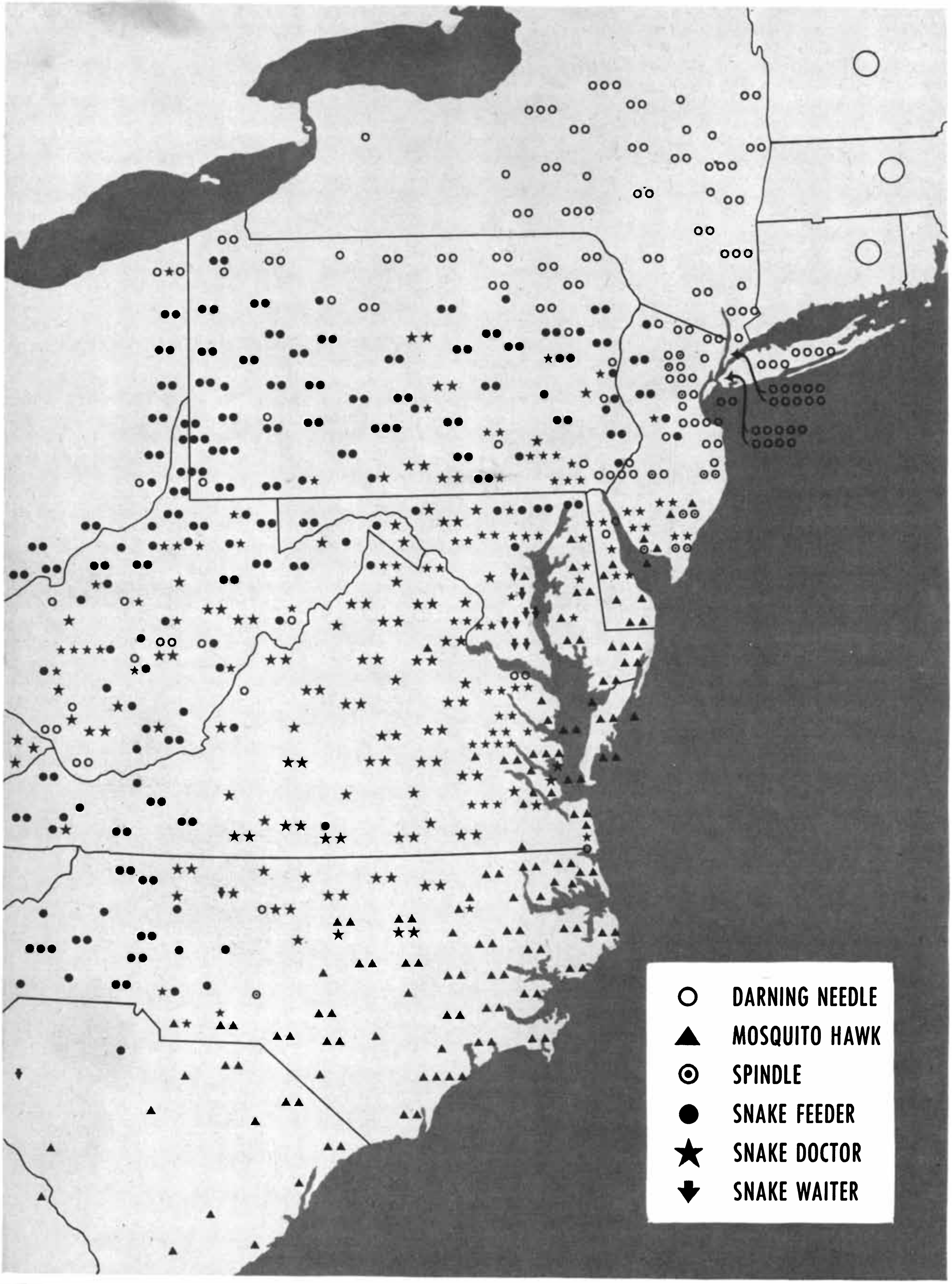
What kind of development can we expect? Will our regional and local dialects eventually be smoothed out to a standard American English? There are important leveling forces at work, of course: the schools, the printed page, the radio. Our study makes it possible to trace in considerable detail the trend from local to regional to national usage of certain terms. Thus seesaw, in spite of the many local synonyms for it, is gaining more and more currency as the national term. Although the V-shaped clavicle of a fowl is still commonly called pully-bone or lucky-bone in many sections, wishbone is well along the road to ascendancy everywhere. The term andirons is superseding dog irons and firedogs; frying pan is prevailing over skillet and spider; cottage cheese is overcoming such localisms as curds, sour-milk cheese, pot cheese, Dutch cheese, clabber cheese and smearcase; shades is gaining ground over blinds and curtains.

Nevertheless, local and regional expressions are not likely to disappear entirely from our language. Many of them survive because they stand for local or regional phenomena. It is very doubtful, for example, that we shall ever have a nationally accepted term for griddlecakes made of corn meal. For one thing, they are rarely served in the Wheat Belt. It is difficult to detect any trend toward a national name for them: they are still known by a wide variety of expressions, such as johnnycakes, johnnikins, corn cakes, corn dodgers, hoe cakes, ash cakes. A similar situation exists with regard to wheat cakes. The term pancakes is generally known throughout the Eastern states, but in eastern New England they are almost always called griddlecakes, around Philadelphia hot cakes, west of Philadelphia flannel cakes and south of the Potomac battercakes or battycakes.

THE leveling forces are not quite as powerful among the folk as one might suppose. The common man hears a Babel of dialects over the radio and in the movies. He understands them, may even mimic them, but he does not acquire them. Often he is likely to regard their use in everyday speech as an affectation.

One can safely say that in some ranges of our vocabulary local and regional expressions will survive, and new ones will come into being. In the arts, the sciences and other enterprises that are organized on a national scale, the terminology tends to be nation-wide, and in our social and political life we most commonly use words that have at least regional currency. But the vocabulary of the intimate life of the home will remain rich in local and regional expressions for generations to come.

Hans Kurath is professor of English at the University of Michigan and director of the Linguistic Atlas.



DRAGONFLY is called by various names in various parts of the Eastern states. Each symbol on this map represents interviews with residents of a locality. The larger symbols at the upper right indicate that darning needle is the term generally used throughout those states. Usages were recorded for many selected terms.

THE OPOSSUM mimics death with considerable virtuosity. Its jaw hangs down; its lips are drawn back from the teeth; its eyes are open and glassy.

PLAYING 'POSSUM

The American marsupial is only one of many animals that feign death. The physiological reason for such behavior may bear upon some similar states in man

by Carl G. Hartman

IF you hunt opossums in the daytime you search their favorite retreats such as hollow logs or tree trunks. In rocky places you can find them in cracks and crannies in the ground. Unless you are foolhardy or exceptionally skillful, you do not reach into the hideout with bare hands, as did a hunting companion of mine in the limestone hills of central Texas. This virtuoso could run his hand slowly along the side of a burrow until he felt soft fur; then with a quick, viselike grip he would pinion the opossum and draw it forth. Ordinarily you provide yourself with a tough forked stick, with which you can twist a hold in the opossum's dense coat. You can then pull out the creature in spite of its strong resistance.

While the opossum is still in its retreat it does not "play 'possum." It faces the entrance, its powerful jaws armed with long canines. Your efforts are met with angry growls from the depths of the recess. But once you have pulled the opossum out of its den it gives up, and so long as you are near it lies still as death.

You may hunt the opossum at night, when it waddles about foraging for food. The dogs are trained to follow the opossum's trail and to ignore all others. Presently the dogs stop and in dog language let you know that the hard-pressed opossum has taken to a tree, at the base of which they await you. One man in your party must climb the tree and either catch the opossum by the tail or, if it is out on a limb, shake it to the ground. There the dogs pounce upon it. You may imagine you hear the cracking of bones, and it seems all over with the poor creature. But the dogs are deceived by the pacifism of the prey. Its mouth is open; its tongue droops; its open eyes have a deathly stare. No motion is detectable except a shallow breathing that you notice if you are a sophisticated hunter of opossums. The other members of the party may think that the opossum is dead and urge you to bag it and send the dogs on another chase. But if you withdraw to a distance and remain quiet for perhaps 15 minutes you will see the opossum's ears quiver and its eyes blink as it cautiously raises its head. If there is the slightest noise the opossum will feign death again; if all remains quiet it will slowly rise to its feet and waddle away.

Although "playing 'possum" is a proverbial term in the U. S., the phenomenon is by no means limited to this American marsupial. The feigning of death is known throughout the animal kingdom, and certain aspects of it may be observed in man himself. The experimental study of the cataleptic state in animals will do much to explain similar states in man. For this reason we should place the death-feigning of the opossum in its proper context as a natural phenomenon in mammals, birds, reptiles, amphibia and many kinds of animals without backbones.

THE opossum's method of counterfeiting death is practiced by some Australian marsupials and some members of the dog family, notably the fox, whose reputation for cunning is partly based upon its skill at dissimulation. In his delightful *Naturalist in La Plata* W. H. Hudson discusses the death-feigning pampas fox, *Canis azarae,* as well as the Argentine opossum *Didelphis azarae*. He is inclined to judge the fox the better actor of the two. "A fox caught in a trap," says Hudson, "fights savagely at first but by-and-by relaxes his efforts, drops to the ground and apparently yields up the ghost. The deception is so well carried out that dogs are consistently taken in by it, and no one not previously acquainted with the clever trickery, but would at once pronounce the creature dead, and worthy of some praise for having perished in so brave a spirit. When one withdraws a little way from the feigning fox, and watches him, he will see the deceiver get up slowly and cautiously when his foes are at a safe distance. The fox, however, need not be touched but only taken unawares to cause him to fall into a swoon, as when a man on horseback comes suddenly upon him."

Naturalists have observed almost identical behavior in the dingo or wild dog of Australia. This rapacious animal is the only sizable Australian representative of mammals higher on the evolutionary scale than the marsupials. One description of the dingo's "going dead" is almost a paraphrase of Hudson's account of the fox: "The poor brute will keep up the pretense even when its head has been broken. Some cases are known where such an animal has been left for dead, with its head half cut through; but during the night it has managed to crawl away into its native haunts without having given one sign of life during the whole time it was being beaten to death." The descriptions of the opossum, fox and dingo also apply to birds. An owl held captive for 15 hours fell into a swoon whenever anyone approached; a turkey buzzard brought down by a hunter disgorged the contents of its crop and fell over as though dead.

Reptiles readily simulate death. In his *Habits and Adaptation of Reptiles* the noted Harvard University zoologist Thomas Barbour furnished the following examples: "*Varanus exanthematicus*, a lizard from the Congo, turns on its back and, seizing one of its paws in its mouth, lies perfectly still in this apparently uncomfortable position. Another classical example is the hog-nosed snake, which turns over on its back, opens wide its mouth, hangs out its tongue, and looks as if it has just died in agony. The only mistake it makes is that, if it is reversed, it promptly turns over on its back again. The giant toad *Bufo superciliaris* from Equatorial Africa assumes any position in which it happens to be placed." Phylogenetically it is a far cry from toad to opossum, but how alike the behavior!

AMONG the vertebrates some of the best dissimulators are those that are protectively colored. Flush a mother quail leading her brood; she will suddenly emit a warning cry and fly away in a manner intended to invite pursuit. The chicks "freeze" on the spot and, by virtue of their color, blend unseen with the dry leaves of the woodland.

All these creatures are high in the hierarchy of animal life compared with invertebrates such as Crustacea, spiders and insects. If you touch the leaf of a potato plant covered with potato beetles, they instantly roll off and lie still for varying lengths of time. It is the slow-moving insects, however, that are the most impressive actors. Leaflike locusts and grasshoppers and the bizarre walking sticks remain "frozen" for hours at a time. The leaflike locust of Nicaragua uses this same stratagem to defend itself against the raiding hordes of the driver ant Eciton. The ferocious ants advance in armies that leave nothing alive in their path. Even insects that can escape by flight are endangered, for above the ant army fly birds on the lookout for them. Thus the heavy flying locusts, grasshoppers and cockroaches have little chance of escape. But the leaf-imitating locust stands motionless among the ants, some of which even run over its legs.

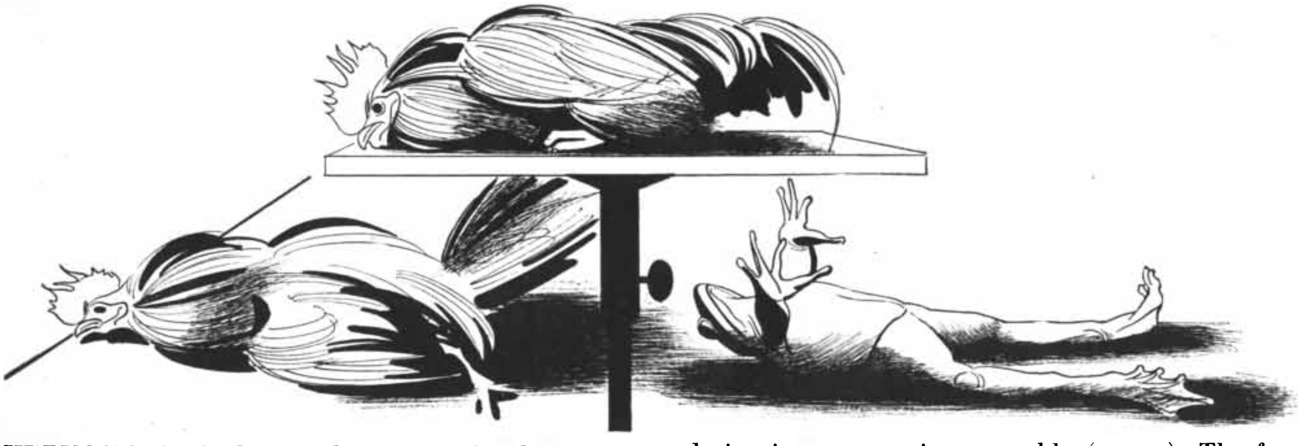
So it is clear that death-feigning is widespread in nature. Descriptions of behavioral peculiarities, however, do not explain them. Words explain even less. It is characteristic of the unscientific and uncritical treatment of any subject that descriptive terms are substituted for explanations; the simulation of death is peculiarly encumbered with such shortcuts to mental satisfaction.

The terms for death-feigning are many and may be classified under several headings. At the least scientific level most of the terms are mere synonyms. There are the popular expressions "going dead," "playing dead" and the more stately "counterfeiting death." The early naturalists who wrote in Latin used the term "mortuum simulit." An elegant modern word derived from the Latin is "letisimulation." A similar term derived from the Greek is "thanatosis." But since "death-feigning" implies that one is able to read the mind of the animal and attribute to it conscious purpose, we must look upon such expressions merely as handy figures of speech.

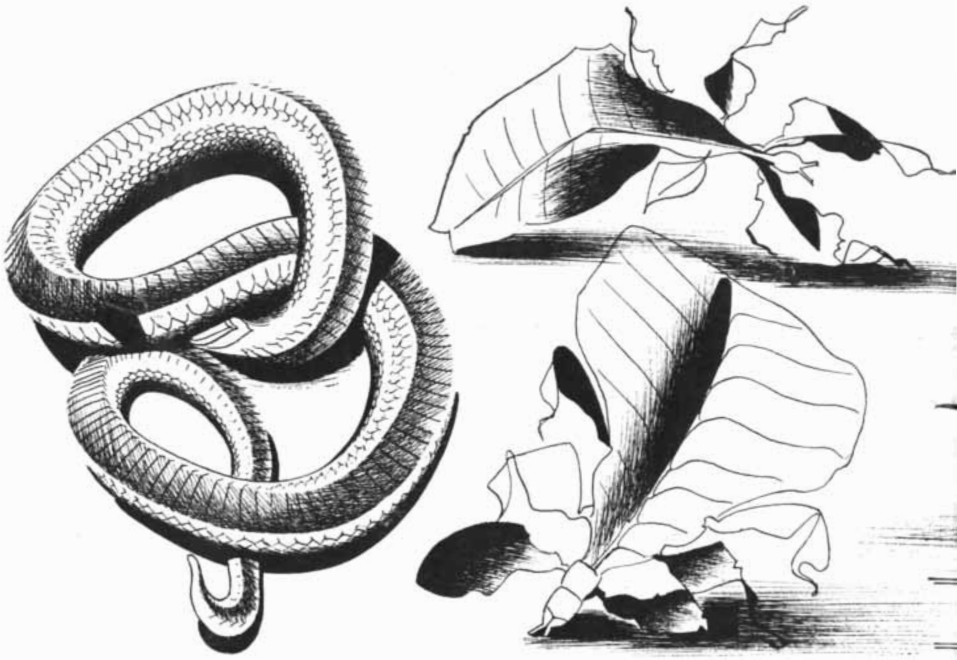
A second category of expressions consists of vague explanations that are consistent with actual observation. Such are "freezing" or "immobilization reflex." Then there are a number of terms that attempt to be more specific. The observed tetanic condition of the muscles in death-feigning has produced such names for the phenomenon as "tonic immobility," "catalepsy" and the German "Starrkrampf reflex." Some use the term "hypnosis" to describe it, suggesting the possible mental basis for the phenomenon. "Akinesia," which implies only that the animal is powerless, is best in line with the thesis to be developed in this article. All these expressions, however, are makeshifts and merely define areas of ignorance.

Among the naturalists who try to explain death-feigning some account for it as an evolutionary development based on its biological usefulness: animals instinctively imitate death because they can thereby escape danger. The individuals that escape are, by and large, those that live to reproduce and so, by natural selection, the habit of feigning death is perpetuated and perfected. There is ample experimental proof that certain organisms are gobbled up by their enemies when they move but are passed by unharmed when they remain motionless. The walking stick is a classic example. Confine it in a cage with a bird; you will find that the instant the insect makes the slightest movement it is attacked. In bright light the walking stick is most vulnerable, and under such conditions it best simulates a twig. When its muscles are in tonic contraction the insect remains for long periods in the most astonishing postures.

PROBABLY the earliest experimenters with tonic immobility were the peoples of the East. Motion pictures have dramatized the art of the cobra-taming



HYPNOSIS of a chicken may be accomplished by setting its head beside a line drawn on the ground (*left*) or by placing it on a rotating turntable (*center*). The frog may be similarly immobilized by turning it on its back.



SNAKES AND INSECTS also simulate death. The hog-nosed snake lies on its back when frightened (*left*). The immobile leaf insect may be set in

Hindu. The explanation is simple enough. If the erect serpent is deftly caught behind the head and gently pressed, it becomes stiff and will remain so for a considerable time. Moses made use of the trick to impress Pharaoh:

And the Lord said unto him, What is that in thine hand? And he said, A rod. And He said, Cast it on the ground. And he cast it on the ground, and it became a serpent; and Moses fled before it. And the Lord said unto Moses, Put forth thine hand, and take it by the tail. And he put forth his hand, and caught it, and it became a rod in his hand. (*Exodus.* IV,2-5)

We know that hens and roosters may readily be hypnotized. It is only necessary to lay the animal on its back and hold it gently but firmly. The muscles relax as you gradually loosen your hold. A rotating turntable is said to hasten the process. Guinea pigs likewise lend themselves to immobilization experiments. The subject is smoothly but quickly inverted from a prone to a supine position, preferably in an apparatus made for the purpose. W. T. Liebman recently reported in *Science* that he has been able to train guinea pigs to prolonged hypnosis, so that some, like the walking stick, will remain in most uncomfortable positions for as long as two hours.

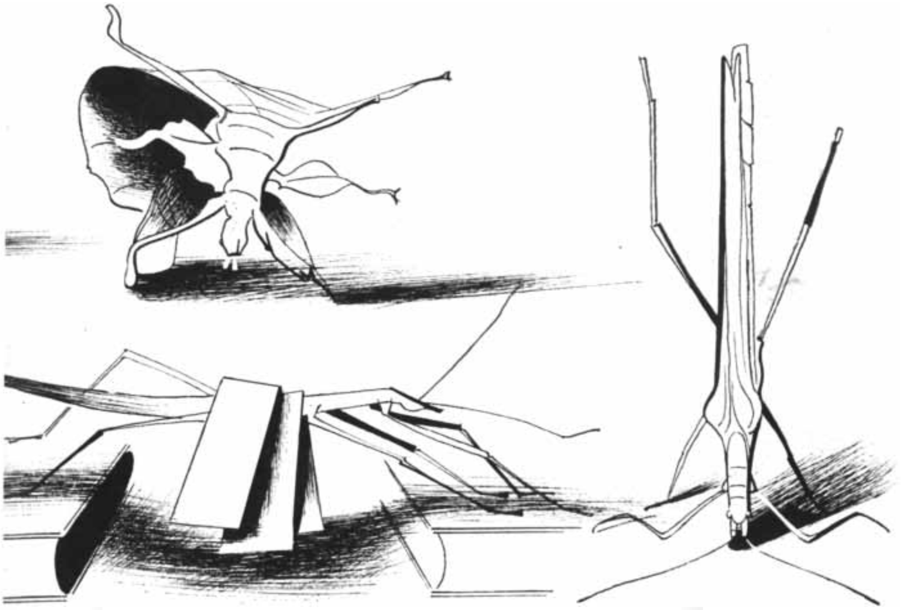
Lizards and frogs are notoriously easy to put under a "spell," as many a boy can tell you. Here again the subject is turned over on its back and—so the traditional directions have it—is stroked on its chest. This makes the demonstration more professional. The stroking may be helpful but it is not essential.

The most spectacular of such performances are given by insects and other arthropods. The slender water strider Neides may be put into a cataleptic state by a light tap on the thorax. The leaf-mimicking Phyllium will maintain the most bizarre attitudes for hours in response to either mechanical stimuli or intense light.

Aside from the stiffening due to a considerable if not maximal increase of muscular tone, little is known of what goes on in the body of the creatures described. In the rabbit and the guinea pig the pulse and respiration are more rapid. Since the position they assume is that of an animal attempting to right itself, it is likely that their higher nerve centers are involved. On the other hand, one may recall the behavior of frogs and toads that are decapitated while mating. The embrace of the brainless male endures for hours or even days, once the muscles are set in the mating act. Normally the male relaxes his hold on the female in response to the characteristic croak that she emits when she has finished the deposition of eggs.

If we compare experimental animals induced to assume the catatonic state with wild animals in a similar state, as when the opossum plays 'possum, we see little difference. The reflexes are inhibited; the muscles are taut, so that the animal is stiff or at least like soft wax.

Many naturalists who have reflected on the problem believe that this state may be explained as the symptoms of fear. Fear is an emotion with which we are acquainted by introspection; and since our actions when we are frightened mirror those of animals in similar situations, we feel that we are on safe ground in attributing death-feigning and other forms of catalepsy to fright. On closer



any position (*left center and upper right center*). The walking stick is so rigid that it will not bend under weight and can be stood on its head.

analysis, however, the explanation is inadequate. In man fear is not essential to the cataleptic state; it can be brought on by hypnosis. Moreover, there are few signs of fear in the experimental animals brought into exaggerated and continuous bodily tonus by turning or stroking. In most cases the reactions to a sudden stimulus are too rapid for conscious emotion to control them. In a near-collision while driving an automobile you do not get the full benefit of conscious reactions until you are a half-mile down the road and adrenalin begins to act; it is then too late to be afraid.

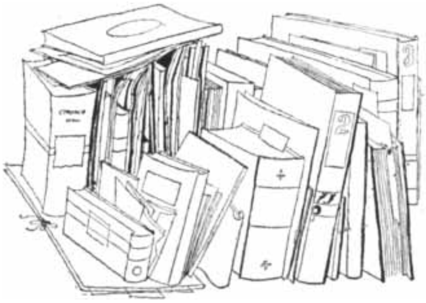
PERHAPS we can get closer to an analysis of the phenomena we are considering by examining in more detail the reactions of the potato beetle. It sits on the leaf of the potato vine; touch the leaf and the beetle drops like a pebble. The insect falls into the most perfect cataleptic fit imaginable. A tiny fraction of a second changes an active living being into a creature as helpless as the clod of dirt beside which it lies.

The reaction must, I think, be mediated by the nervous system and result from changes in the brain and ventral ganglia. The changes come on explosively and pass off gradually. One is tempted to assume that in the nerve centers there are certain labile substances that are harmless in themselves but which serve as precursors to substances that paralyze. A touch or a beam of light causes nerve impulses which act as percussion caps to set off the charge. The new substances so stimulate the motor nerve fibers that the muscles indiscriminately contract, causing the stiffening of the body characteristic of the cataleptic state. To return to the potato beetle, we see that after a time the beetle recovers and resumes its feeding. The paralyzing substances possibly diffuse out of the nerve cells or perhaps, like such substances as adrenalin, pituitrin and acetylcholine in our bodies, are destroyed by the appropriate enzymes.

The theory is highly mechanistic. It follows, if the theory is correct, that the animal feigning death cannot help itself, any more than the sensitive plant can help closing a leaf that is touched. The muscles are literally congealed, if not with fear, at least with a substance elaborated by the nerve cells. There is a parallel in adrenalin, which is secreted by gland cells that are modified nerve cells. Thus the opossum faints and cannot help itself, and it is vivid but anthropomorphic to speak of it as a "cunning rascal" or an "adroit cheat."

Some may insist that we should except the fox, the opossum, the bird and, above all, man from the operation of so mechanistic a process, and confine the application of the theory to the insects and other lowly forms that seem perfectly helpless in the throes of a cataleptic fit. Yet the more I see of animals that simulate death the more I doubt that there are fundamental differences among the species. As the great Harvard physiologist Walter B. Cannon first proved, even human beings, when frightened or angry, are under the sway of chemical substances in the blood and the nervous system.

Carl G. Hartman is director of the division of physiology in the Ortho Research Foundation.



BOOKS

An examination of the link between modern physics and the ideas of cause and chance

by Sir Edmund Whittaker

NATURAL PHILOSOPHY OF CAUSE AND CHANCE, by Max Born. Oxford University Press ($4.50).

THE notions of cause and chance belong to a field where the man of science meets the philosopher and the theologian. *Natural Philosophy of Cause and Chance,* which represents the Waynflete Lectures delivered by the physicist Max Born at Oxford University in the spring of 1948, approaches the subject from the scientific side. It may be said at once that no contribution of recent years can compare with it in importance. The idea underlying the work is that certain words associated with metaphysics, such as "causality" and "indetermination," can be studied most profitably by considering their use in theoretical physics. For of all fields of thought, theoretical physics offers the most favorable combination of clarity and precision with significance and depth.

This assertion will not pass without contradiction from some schools of metaphysicians who hold that metaphysics is autonomous and supreme, and that no light can be thrown on metaphysical concepts by any amount of progress in the natural sciences. Most of the objectors do indeed admit that the beginnings of knowledge must be derived from sense impressions; but they claim that the only perceptions of the external world which are needed are of the most elementary character, such as are experienced in childhood. With these as starting points, they assert, the mind can think out metaphysical principles about Reality, Being, Becoming, Causality, Necessity, Contingence, Substance, Infinity and the like which are rigorously and eternally true and altogether higher in status than the tentative and approximate conclusions of science.

In criticizing the metaphysician's line of argument, the man of science points out in the first place that most of the speculative philosophical systems of the past—notably Thomism, Kantianism and Hegelianism—when applied to natural philosophy lead to conclusions that are demonstrably false. As a matter of history, each of these systems did much harm in obstructing the progress of true knowledge. The Thomists rejected every doctrine characteristic of modern science—the earth's rotation, the Newtonian dynamics and the atomic theory—while the Kantians succeeded in vetoing non-Euclidean geometry for nearly half a century and the Hegelians long prevented the acceptance of Ohm's law. Hegel himself gave a proof that the number of planets could not exceed seven in his *Dissertatio philosophica de orbitis planetarum,* which by an uncommon piece of bad luck was published almost simultaneously with the astronomer Piazzi's discovery of an eighth planet. It is not to be wondered at that even the mild-mannered James Clerk Maxwell once referred in public to "the den of the metaphysician, abhorred by every man of science." Professor Born takes much the same attitude: "Metaphysical systematization," he says, "means formalization and petrifaction."

It is hardly possible at this time of day to maintain that the infantile kind of observation on which the classical philosophies were founded is a sufficient foundation for assertions that must stand the scrutiny of modern science. The infantile observation is indeed often misleading; deceptively simple appearances may conceal highly complex realities. For instance, the apparent continuity of a gas is merely a consequence of the coarseness of our vision, which is incapable of distinguishing the separate molecules of which the gas is constituted. Surely it is folly to ignore such accurate knowledge about the external world as is actually at our disposal, when we know that any true philosophy must be capable of assimilating it as part of the general scheme.

Many modern philosophers (*e.g.,* Alfred North Whitehead), profiting by the warnings of history, have resolved to make sure that all is well in the province of natural philosophy before they venture further afield into general metaphysics; it is to facilitate this part of their work that Professor Born has written the present volume. Its aim is to help in adjusting our modes of thought to the facts of external nature. The metaphysical principle with which it deals first is the one commonly stated in the form, "Everything that happens has a cause."

The notion of cause, as studied in Hume for instance, pictured an event called the cause which produced another event, later in time, called the effect. In general the cause was thought of as active, the effect as passive. These notions are inadequate for use in modern science. Consider, for example, two bodies revolving around each other in accordance with the law of gravitation, *e.g.,* the two components of a double star. If we ask what is the cause of the motion of star A, we are told that it is the gravitational attraction proceeding from the other star B; while if we ask what is the cause of the motion of B, we are told that it is the attraction exercised by A. The attraction is reciprocally given and received, and we cannot attach the notion of cause specifically to one of the stars and the notion of effect to the other. The traditional philosopher may try to get around this difficulty by considering the configuration of the whole system at one instant as the effect of its configuration at a previous instant, so that the configuration at the earlier instant would be the cause. But even then a satisfactory reconciliation with the old notions has not been reached. The differential equations of the motion are unchanged if the sign of the variable representing the time is changed, and therefore we see that all the motions can be reversed. That is, the system will work backward just as well as forward; the later situation determines the earlier just as the earlier determines the later, the relation between the two states being symmetrical. It is just as true to say that the later is the cause of the earlier as that the earlier is the cause of the later. The plain truth is that the old conception of cause breaks down altogether in this instance: the word cause has no meaning at all.

We are now in a position to understand the true nature of the metaphysical principle, "Everything that happens has a cause." It was a primitive and blundering attempt to formulate the belief that nature is ultimately intelligible. When we ask what has replaced it in the light of fuller knowledge, the answer, so far as physics is concerned, is "the existence of laws of nature." The notion of cause is replaced by the notion of law. Instead of the causal relation, we have the conception of a continuous succession of events logically connected with one another by an underlying principle, which admits of being formulated in mathematical symbolism. Thus, in the new outlook, mathematics is the key to the interpretation of the universe.

Professor Born proposes to retain the word causality, but in an entirely new sense. He uses it to express the dependence of one physical situation on another, which may be either earlier or later. The nature of this dependence can only be found empirically: there can be no question of any *a priori* metaphysical principle, and in fact the nature of the dependence is found to be quite unlike anything imagined before the beginning of the present century. This is seen when we compare the old with the new physics.

In physics as it was understood from the time of Newton to the end of the 19th century, the state of a closed system at one instant was determined precisely and completely by its state at another instant. Prediction was possible in every detail; there was absolute determinism; the world was just a colossal machine. The break with this conception, which has been brought about in the present century, may be illustrated by the theory of radioactivity. An atom of radium may remain unchanged for a very long time—the average duration of the quiescent phase is over 2,000 years—but there comes a moment when the atom disintegrates, sending out an alpha particle and becoming itself transformed into an atom of a different element. There is a definite probability that an atom which is still unexploded at the beginning of a year will explode during the year, but that is the only kind of assertion we can make in advance about an individual atom.

To bring into relief the peculiar character of this unpredictability, let us compare it with something else that is unpredictable, namely, the result of the tossing of a coin. We cannot say beforehand whether it will come down heads or tails. The reason is that we know nothing about the operation except that the coin is a circular disk with two faces. We do not know the precise velocities of translation and rotation that were communicated to the coin by the thumb of the operator, nor the exact mass and figure of the coin, nor the density and resistance of the air, nor the height of the point of projection above the ground. If we knew all these things, and were able to perform rather elaborate calculations with lightning speed, then we should be able, by using the laws of dynamics, to predict whether the coin would fall heads or tails. Thus there is no real indeterminacy in the occurrence; our practical uncertainty is merely a consequence of our being ignorant of some of the data that are required in order to make a prediction.

MAX BORN, the author of the book reviewed on these pages, is a distinguished German theoretical physicist who has lived in Britain since 1933.

The question is: Ought we to regard the uncertainty as to the time of explosion of a radium atom as being of the same character as the uncertainty in tossing a coin? Is it due merely to ignorance of some of the factors that determine the explosion?

Let us recall that a radium atom is defined as an atom whose nucleus is formed of 88 protons and 138 neutrons. Is this a complete specification? In other words, are all radium atoms identical? If our test of the identity of two things is that they behave exactly alike when subjected to the same conditions, then clearly all radium atoms are not identical, since they have different lifetimes. Now in the definition of radium nothing was said about the relative positions or velocities of the protons and neutrons in the nucleus. It might therefore be conjectured that these positions and velocities are the further data that are required in order to determine the instant at which the explosion will take place. In this view, the disintegration of a radium atom would be deterministic: the notion of chance as it occurs in this connection would be precisely the same as the notion of chance in connection with the tossing of a coin. In both cases it would be our ignorance of some of the data determining the event that hindered us from making predictions.

Plausible though this interpretation may seem, it is now known to be false. John von Neumann of the Institute for Advanced Study in Princeton, N. J., has shown (and French investigators have confirmed) that there are not, and cannot be, any hidden features in the radium atom, a knowledge of which would enable us to predict the time of its disintegration. There is a true indeterminacy in the occurrence, qualified only by the knowledge of its probability.

This revolutionary upheaval in natural philosophy does not, however, destroy the concept of causality in Born's sense of the word. In modern quantum theory, we cannot predict individual events; we can only state their probabilities. And when we speak of a situation in physics as being known, we mean that a set of probabilities is known (*e.g.*, regarding the positions and velocities of the particles concerned). There are exact laws connecting the set of probabilities at one instant with the set of probabilities at a subsequent instant; that is, the knowledge we can possess at one moment fully determines the knowledge we can possess at a later moment, so that there is still dependence between one physical situation and another. There is still causality in Born's use of the term, although there is not determinism. Cause, in the old sense, is no longer supreme, and chance has taken its place, at any rate as regards individual events in the microscopic world. If, however, we are dealing with an aggregate consisting of a great number of elementary particles, the state of the aggregate is described by quantities which have a statistical character, and these statistical quantities behave in a way that is practically deterministic.

The proof of the absolute indeterminacy of the radium explosion is an amazing result, for it contradicts not merely the principle of determinism but also an idea held by almost all modern philosophers, which they call the Principle of Sufficient Reason. This principle states that nothing takes place unless there is a sufficient reason why it should occur rather than not. The principle of indeterminacy, on the other hand, shows that there are continually being introduced into the world genuinely new elements which have no antecedents. Perhaps this is not such a shock to preconceived ideas as it would have been a generation ago. The theory of the expanding universe has made us familiar with the fact of the continuous creation of space. Some of the recent theories of cosmogony involve also a continuous creation of matter, while the theological doctrine of divine grace and the philosophical doctrine of free will imply that new elements are perpetually entering the world through the channel of human decisions. In the universe as it is now conceived, completely new things are being created all the time.

Professor Born's Waynflete Lectures mark a substantial advance in the development of a sound philosophy, and the book is of the highest interest and value to anyone who has the knowledge necessary to enable him to read it. It is much to be regretted that most professional philosophers will not be found in this category, for Professor Born assumes on the part of his readers a considerable acquaintance with statistical mechanics and quantum theory. The moral seems to be that anybody who wants to become a professional philosopher should first take an honors degree in mathematical physics.

Sir Edmund Whittaker is professor of mathematics at Edinburgh University.

MODERN ARMS AND FREE MEN, by Vannevar Bush. Simon and Schuster ($3.50). The new book by Dr. Bush has received notice that is usually reserved for the latest work of a celebrated writer of fiction. This is not surprising, for Dr. Bush is a leading contemporary figure of science, and the topic that occupies a good part of the book, namely war and weapons, has a persistent fascination for our unhappy period.

Dr. Bush has had a full career and is surely qualified to discuss science, technology and warfare. As wartime director of the Office of Scientific Research and Development, and later as first chairman of the Defense Establishment Joint Research and Development Board, he had a major part in guiding a military research program involving thousands of scientists and hundreds of millions of dollars, an effort without precedence both as to magnitude and result. He has had access to drawing board, plan, laboratory and testing field; he is closely acquainted with scientific and military leaders; he knows the importance that scientific and military evaluation groups have assigned to weapons in being and in course of development. What he has to say about the shape of a future war deserves an attentive hearing.

The book, however, includes many matters in which the special competence of Dr. Bush is less obvious. The latter part of the work is devoted to such themes as economics, labor, education, private enterprise, government, bureaucracy, communism, cosmogony, human history and human destiny. In his many-sided professional life as an educator, public servant and scientific executive, Dr. Bush has no doubt encountered many practical problems in most of the areas he discusses. It is a large task, however, for any man to survey the entire social, economic and political scene in a hundred-odd pages. Nor is the task of the reader made easier by Dr. Bush's frequent indulgence in generalities and flat Yankee judgments.

Dr. Bush feels, on the whole, that our economic and labor problems can be solved by good will and less government. Labor and management should learn to give up their selfish "quarrels." We must discover how "to keep a free enterprise system on an even keel"; how to remain "on prosperous middle ground between a spiral of inflation and the sort of full-fledged depression that nearly wrecked us not long ago." A "fundamental problem is to prevent special interests from raiding the treasury, unbalancing our budget and destroying the national credit"; "patriotism and judgment of a high order in our legislative halls" will enable us to "distribute our product wisely." We must avoid the "welfare state" with its "class of loafers supported by taxation" and its "horde of bureaucrats extracting heavy taxes from all who are at all prosperous in order to furnish paternalistic care and control to all who are less so. They take two dollars from Jones to furnish one to Smith and make Smith stand in line to get it." We must not "throttle new enterprise by shutting off the source of venture capital and enmeshing in the red tape of bureaucracy the new small pioneering concerns that should be encouraged to build the great industry of the future"; we must preserve the patent system, tax and regulate, but without going "too far," and eschew "driving ourselves . . . down the path that England has started to follow . . . to state socialism." There is "no doubt whatever that the people of this country would have none of it were they to face the issue squarely." There is page after page of this, most of it very well-meaning but also meaning very little. It is not that Dr. Bush is conservative that one finds disturbing; it is rather that his conclusions are offered without proof and without pause in a sustained tendentious flow resembling a sermon rather than a reasoned exposition.

His military opinions are more sharply conveyed, although even these are often diluted by indirection and qualification. Dr. Bush believes that the technological trend toward the end of the last war moved increasingly to the side of the defense. On land the offensive was steadily blunted by counterweapons such as rockets, proximity fuzes and recoilless guns. This "deadlock of the first war might well reappear if antagonists substantially equal from the standpoint of skilled use of ample technical devices met again at a long land frontier." In a future war the Navy's principal role will be important but much less "spectacular" than heretofore. Its main task will be that of protecting the sea lanes against that formidable scourge, the modern submarine equipped with the schnorkel and long-range torpedoes. Dr. Bush is no air-power fanatic; he does not fall into a hypnotic trance when the B-36 is mentioned; his cool appraisal of the effectiveness of jet fighters, rockets, short-range guided missiles and radar in rendering "obsolete" the strategy of mass aerial bombing must make some enthusiasts in the Defense Establishment quite unhappy. Any appraisal of prospects for the future of air warfare is at best a highly tentative and conjectural affair, but Dr. Bush brings the various factors to light. If his conclusions are somewhat equivocal, the entire analysis is nevertheless valuable for its honesty and detachment.

As for the key question regarding the change in warfare brought about by atomic bombs, Dr. Bush is vague. The book was written before the announcement of the Soviet bomb, and it suggests that this crucial event is still a few years away. (". . . no other nation will have a stock of atomic bombs tomorrow.") However, Dr. Bush says flatly that the atomic bomb cannot be considered an absolute weapon and thus strikes at the strategic concept advocated by air-power extremists. He considers the difficulties of delivering atomic bombs over the targets of a "fully alerted" enemy, and dismisses, at least for the present, the feasibility of substituting long-range guided missiles as carriers in place of piloted aircraft. A full-scale atomic war could hardly be launched without a few thousand bombs in the stockpile, many more than are now available, or soon likely to be. Furthermore, as Dr. Bush explains very clearly, the cost of making bombs and building the requisite number of carriers would entail an extremely heavy drain on raw-material resources, the labor pool and industrial fabricating capacity. The U. S. and perhaps the U.S.S.R. could manage such an expenditure, but they could scarcely sustain it over a long period. If too much reliance were placed on this single phase of warfare; if, in other words, there were no quick victory and the war turned into what Dr. Bush prophesies will be "a tough slugging match," what then?

We would win the next war, Dr. Bush confidently asserts, but to do so means an immense preparedness program and keeping the nation at all times on a quasi-military footing. He is aware that the demands raised by these circumstances are in conflict with the requirements of a peaceful and progressive nation. Yet his optimism is unshaken and unbounded. In the present armaments race he envisages that we must and can "attain immense strength of every sort . . . such mounting strength that armed prosperity can proceed to more arms and more prosperity [and] in such a race this country need not suffer." Apparently he has no fear that an armaments race would itself inevitably lead to war, much less that democracy may stifle and perish in its suit of armor. Indeed Dr. Bush is a hard man to frighten. As evidence of this, one may juxtapose his appalling description of a future war and his rosy assurances for the future.

JAMES WATT AND THE HISTORY OF STEAM POWER, by Ivor B. Hart. Henry Schuman ($4.00). THE ALCHEMISTS, by F. Sherwood Taylor. Henry Schuman ($4.00). Recent additions to *The Life of Science Library*, an informative if somewhat undistinguished series addressed to the general reader. Both Hart and Taylor are experienced science popularizers, and each volume is a straightforward, competent job, attractively illustrated. On the subject of alchemy, it may be noted, the several volumes by John Read (SCIENTIFIC AMERICAN, May, 1949) are much superior to Taylor's account.

THE NATURAL HISTORY OF MOSQUITOES, by Marston Bates. The Macmillan Company ($5.00). A biography of one of the world's leading nuisances. Dr. Bates rounds up an immense amount of literature in this systematic, authoritative presentation of the life history of the mosquito, its relations to other organisms and its role as a disease carrier. A valuable bibliography adds to the worth of a book which, though written for the specialist, contains material of interest to anyone who has ever spent a month in the country or even New Jersey. Mosquitoes, you will be glad to know, are found almost everywhere.

HISTORY OF ANCIENT GEOGRAPHY, by J. Oliver Thomson. Cambridge University Press ($9.00). From the twilight conjectures of the "phantom peoples," through the brilliant period of Greek geography, into the darkness of medieval science, a comprehensive account of how the ancients envisaged the earth on which they lived. Based on a scrupulous re-examination of source materials and a critical survey of later works, Thomson's book covers the descriptive as well as the more important theoretical side of his subject. A learned, often absorbing contribution to the study of geography and the history of science.

THE AMATEUR

Conducted by Albert G. Ingalls

SHOWN on the opposite page is what Norman J. Ulam of 1590 Bonnie Brae St., Warren, Ohio, a member of the Mahoning Valley Astronomical Society, describes as "my first attempt at making a telescope." On general and detailed examination it proves to be a finer instrument than many of us could make on our third attempt—or perhaps our tenth. The more it is studied the better it rates, not only mechanically but in appearance—two qualities that need not conflict, but are not too often joined.

"The main idea," Ulam writes, "was to design a mounting that would allow the 4¼-inch objective lens, made for me by one of the old-timers of telescope making, J. W. Draper of Warren, to work unhampered by the 'buggy whip' action found in so many telescopes. The mounting is as rugged as it looks. It seems a shame," Ulam continues, "to see an amateur glass pusher work many long hours producing a mirror or objective lens that is perfect, and then nullify his beautiful results by hanging the gem in a mounting that vibrates like a hummingbird's wing. Yet 90 per cent of all telescope mountings are not rigid enough."

From time to time readers of this department urge that if only the need for rigidity in telescopes were pointed out, telescope makers would stop making limber mountings. Perhaps these readers are optimists; at any rate, many workers refuse to heed the warning, possibly through a lack of instinctive feeling for mechanics. The book *Amateur Telescope Making* does point out that common standards of rigidity, as in ironing boards or portable music stands, are far below minimum for telescopes. Many ordinary things that look rock-steady—for example, a two-inch post driven into the earth—would be found to be vibrating in the breeze if we set up a microscope close to them.

The eight-foot-high pier of the Ulam telescope weighs a ton, and half of it is underground. The polar and declination axes are each made of one-inch drill rod, turning within ample housings. The tube is of stainless steel painted dark gray, with fittings of bronze and brass.

"The eyepiece focusing arrangement," Ulam points out, "does not consist of a direct rack and pinion, as these often are jerky, but is compounded with a 24-tooth worm gear on the pinion shaft, all running in little ball bearings. The tube to which the rack is attached slides in two adjustable-tension stuffing boxes packed in hard felt. This arrangement gives a very smooth-running fine-focus action that is light to the touch."

There is, however, an advantage in the focus control of any optical instrument that permits sweeping rapidly past the optimum point and returning to and on past it in a series of in-and-out movements of decreasing amplitude, before the mind forgets and before the eye can try to assist accommodation and thus bring about residual muscle strain during observation. Can any reader contribute data on the physiological optics of focusing optical instruments?

The finder of the Ulam refractor is itself a useful telescope of two-inch aperture ($f/9$) that gives a beautiful image of wide field. It has its own rack-and-pinion adjustment.

The finest mechanical features of the Ulam telescope are those shown in the detail drawings made by Roger Hayward. Ulam writes that "the clock drive is housed beneath the mounting in a compartment fabricated of ¼-inch steel plate, the door on one side and the window on the other being of ¼-inch Plexiglas. Inside is a small light. The drive uses a $^1/_{150}$-horsepower synchronous motor (Bodine Electric Company, Chicago) rotating at 1,800 revolutions per minute, with a built-in speed reduction to 300 r.p.m. It operates on 110-volt, 60-cycle current from a flexible cord which is laid across the lawn from the residence whenever the telescope is in use. There are no spur gears in the drive, all speed reductions being by worm gears, most of which were cut on my nine-inch lathe by following Russell Porter's instructions in *Amateur Telescope Making—Advanced*. The large gear was made with a half-inch 20 tap.

"A part of the nearly vertical drive shaft is a pair of home-made universal joints that replace a flexible steel cable that caused periodic leaps in the drive. As these joints operate through a very small angle (five degrees) they give a smooth flow of power. Objects stay in the center of the field of the eyepiece for as long as three hours without apparent lag or lead. This doesn't take into consideration the correction for atmospheric refraction, but it is more than good enough for visual work. Every shaft in the telescope is mounted on ball bearings, mostly taken from a war-surplus bomb sight."

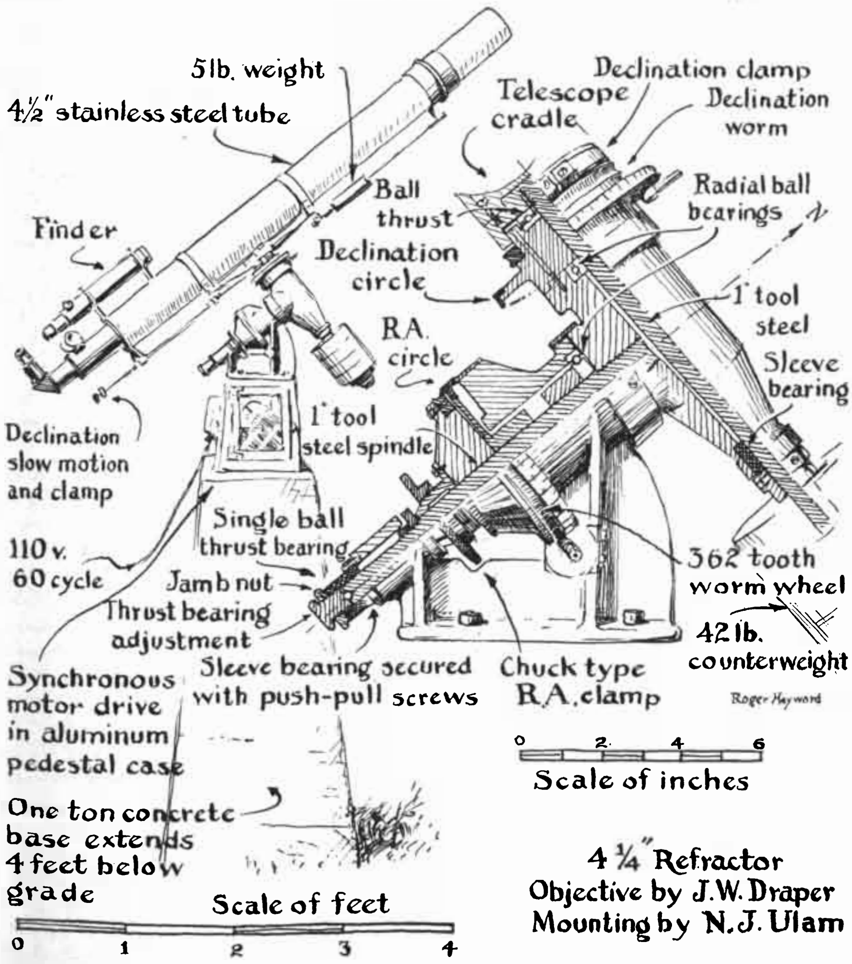
The features along the two axes of the Ulam telescope are well worth detailed study, and the drawing of them is published because of its value to others who plan mountings. Along the polar axis, beginning at the bottom, are: 1) a single-ball thrust bearing and adjustable sleeve bearing; 2) a six-jaw drive clutch or clamp similar in principle to a drill chuck, its tension regulated for either driving or intentional slipping by the large, thin, threaded nut shown; 3) a conical cast aluminum member to which is attached the main-drive worm wheel with 362 teeth; 4) the hour circle, divided into four-minute intervals of time (small enough for visual use, since the finder takes up where the circle leaves off).

Along the declination axis, beginning at the bottom, are: 1) the 42-pound counterweight; 2) a bronze sleeve bearing; 3) a ball thrust bearing; 4) declination circle divided to half degrees; 5) a worm gear, with slow motion worked by hand, by a long rod from the eyepiece end of the telescope; 6) a clutch or brake similarly worked by a rod just behind the first rod in the drawing; 7) the tube cradle.

The head casting of the mounting is made of aluminum, as are all the castings, and the patterns have been preserved. "I would be glad to furnish details of this telescope to any who may want them," Ulam states, "and also to hear suggestions for better design, as there are many changes I would make on another mounting, and many places where I did dumb things. Some have said that I put too much work on this telescope."

If the builder was having fun all along, then it would be difficult to show that he put too much time on his telescope. Theoretically a telescope is a means, not an end, but this logic applies poorly to a hobby in which fun is where you find it.

TO reduce the reflection of light inside optical instruments, including refracting telescopes, lampblack is usu-



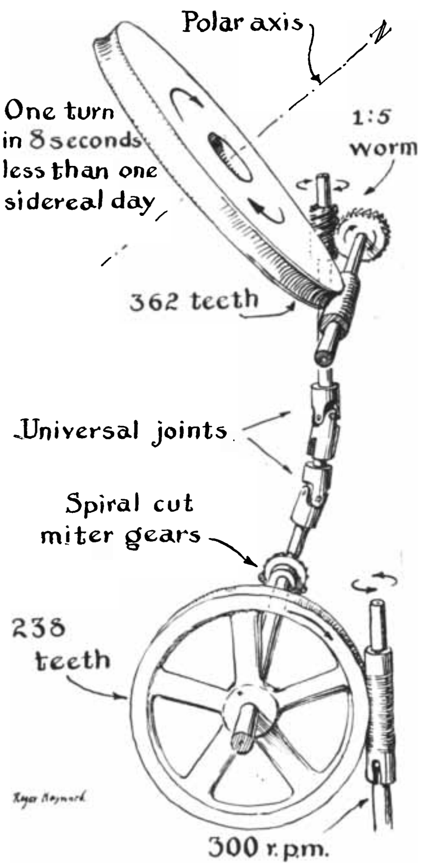
The Ulam refractor and details of its mounting ally applied in some liquid vehicle or by direct smoking. This is called flat-blackening. Another method of flat-blackening is described by Louis J. Rick, Secretary of the Black River Astronomical Society, 685 N. Ridge Road, Lorain, Ohio. "We amateurs here have made experiments with black flock for the insides of several refractor tubes. This produces a velourlike finish that absorbs the light and is darker than the inside of a pocket."

What is "flock"? In a small poll taken among those first encountered, all the women polled knew the answer, but none of the men, including the writer, had even heard of it. This ignorance was relieved by the answer to a query sent to Coast Industries, flock manufacturers, 1509 West Manchester Ave., Los Angeles 44, Calif., who wrote: "Flock is composed of tiny filaments, precision-cut to size and length from either rayon or cotton strands, and then dyed. An adhesive is spread on a surface and the flock is shot on with force so that it is deeply imbedded. For telescope tubes we recommend cotton flock, since rayon flock is shiny. Flock samples are enclosed." These look like mouse hairs cut to one millimeter length and dyed. Applied flock has the appearance of suède or velvet.

"Flock is available at larger paint stores," Rick writes, "or Coast Industries will supply three ounces, enough to cover 15 square feet, for $1. It is applied to surfaces, usually for decorative purposes, with a special spray gun. We couldn't get the gun inside the telescope tubes and work it there too, so we spread an even coat of tacky varnish (we found that shellac and lacquer set too fast) and threw in a handful of flock. By rotating and patting the tube vigorously with the palm of the hand, an even, thick coat of flock was made to adhere to the inner surface. This was allowed to dry 24 hours, and the surplus flock was then blown out for use on another telescope."

William A. Brandt of Upson Downs, Kutztown, Pa., a professional instrument maker, says he has used flock, but applies it electrically. A suède finish is made in that manner. One lead from a high-voltage transformer of perhaps 20,000 volts, such as a neon-sign transformer, is attached to the surface to be flocked. The other lead is attached to a sheet of metal, standing on insulators, several inches below this. The work is gradually moved toward this electrode. At the correct distance, the alternating electric field causes the particles of flock to dance up and down. They arrive endwise at the adhesive surface and stick fast—all parallel. Extreme caution must be observed because of the high voltage. Brandt suggests rotating the telescope tube on rolls during the process, with the long lower electrode not touching the inside of the tube.

Commenting on this more elegant electrostatic method of flocking a telescope, Rick states: "When we first decided to try flocking we recalled an article on the electrostatic deposition of abrasives in the manufacture of sandpaper and emery cloth. But before we could find that article someone suggested the simpler method already described, and this worked very satisfactorily. The remarkable part of it was the way the flock stood on end to stick to the adhesive coat—possibly because of an electrostatic charge on each filament of it. The results were so good that we decided an electrical method



Ulam's drive train

would give too little improvement, especially considering its lethal high-voltage aspect."

AMATEUR telescope makers customarily measure and keep track of the increasing depth of the curve during grinding by wetting the mirror, shifting a light about near the center of curvature and observing the behavior of its reflection. By this method the practiced worker can locate the center of curvature within half an inch. But he can seldom feel sure he is correct; the method is inexact and inelegant. An alternative method of locating the center of curvature, by estimating the sharpest focus of light from illuminated holes in a sheet of tin, may give no more exact results. Both methods leave the worker with an insecure feeling. So he tries making a metal or glass template to fit against the curve, and for once feels he has hold of something definite and quick—perhaps forgetting to count the time needed for making the template. Often, however, it proves that the template was made wrong; it is far from easy to make an accurate template.

So he next dreams of owning an optician's spherometer, which measures the depth of the curve mechanically, precisely and in almost a jiffy. With this he will be sure to feel that he is on the right track all the time. Thus the conductor of this department rubbed his hands in anticipatory pleasure when, some 20 years ago, he was told that a spherometer was headed his way. This proved to have been owned and long used by the professional optician C. L. Petitdidier of an earlier generation; it is inscribed with his signature. Its radius is two inches and its central screw reads to a ten-thousandth of an inch. Unfortunately, the faith that this pretty plaything would provide exact answers proved to be another of life's illusions. It is easy to set it time after time within one scale division or .0001-inch, and to avoid bias by working "blind," that is, with averted vision, using only a light sense of "feel" against the edge of its dial, and noting at the same time whether the legs or the central screw bear an undue share of the weight. Yet in spite of these and other precautions, such as trying it off-center in case the mirror might not be spherical, the spherometer has never equaled the less elegant methods of finding the depth of the curve.

It finally was found that too much was being expected of this type of spherometer; the chief source of inaccuracy lay in the design itself. As F. Twyman says in his book *Prism and Lens Making*, a closer measurement may be had if a complete ring, or inverted cup, is substituted for the three isolated legs. Others have noted the same superiority, and it therefore seems justifiable to recommend the ring type of spherometer over the leg type.

After the war Lieut. A. F. Bzura, then stationed on Iwo Jima, and later of the Rome, N. Y., Army Air Field, was tinkering with the mathematics of a slide rule when he hit on what might be called a special spherometer that eliminates the necessity of substituting in the formula $d=r^2/2R$ (more precisely, $R=(r^2+d^2)/2d$ or $d=R-\sqrt{R^2-r^2}$) to derive R, the radius of curvature. The reciprocal of the dial reading is itself the focal length of the mirror—*provided the spherometer is given a ring diameter of four inches.* Example: Dial reading, .02-inch. Mentally divide .02 into 1. Quotient, 50. Focal length therefore 50 inches. Armchair geometricians will be able to find a theoretical error in this convenient special-case relationship for a four-inch spherometer; the exact answer is not 50 inches, but 50.005 inches. This discrepancy is not of sufficient size to stop the heart of the practical optical worker.

Recommended, therefore, is the Bzura spherometer with a ring—or else plodding along with the same old wet-mirror tests which, after all, serve pretty well. Perhaps it boils down to about this: A spherometer is a pretty thing to have.

In the September, 1949, Scientific American, page 63, second column, in the description of the Johnsonian telescope the second M in the formula for width of flat should have been F. In the illustration on the same page, p/p′ should have been p′/p, and above it 3″ should have been 3.

An article in the August number of *American Forests* contains a hint for a new and different, even unique, amateur astronomical group. Since 1904, 10 men in Colorado Springs (not amateur astronomers) have spent their Saturday afternoons together hiking in the nearby mountains, and their evenings eating and swapping discussion around a campfire, without drawing up a constitution, without choosing a president, first or second vice-president, treasurer or other officer, except informally the custodian of the coffee pot, without reading the minutes of the last meeting or even choosing a name. In order to write about them, a local reporter about 20 years ago called them The Saturday Knights. But their "organization" has lasted 45 years.

Still another source of puzzling scratches on optical surfaces is suggested by Walter C. Durfee of Boston, Mass.: grinding too long without rotating the mirror. This, if continued, produces a deeper curve on one diameter of the mirror than on the one at right angles to it. The curves on tool and mirror tend to change from spheres to cylinders and the mirror is astigmatic. Then, when the mirror finally is rotated, it no longer fits the tool but bears at only two points at the edges. Greatly increased pressure there leads to crushing, glass edges bite into glass faces, and scratches occur.

This source of scratches was suggested by the behavior of a surface that was purposely ground astigmatic. Scratches occurred in very great numbers and to very great depth and were arranged in groups at opposite sides of both disks.

The same question was discussed from the opposite side in this department last July, where it was said that turning the mirror with each stroke seemed superfluous, and once in 16 strokes was suggested. This still leaves an unexplored gap between 16 and, say, 1,600 strokes. Planned, controlled experiments directed toward precise delimitation of this single question would be of interest to all mirror makers. Interesting by-product findings might turn up.

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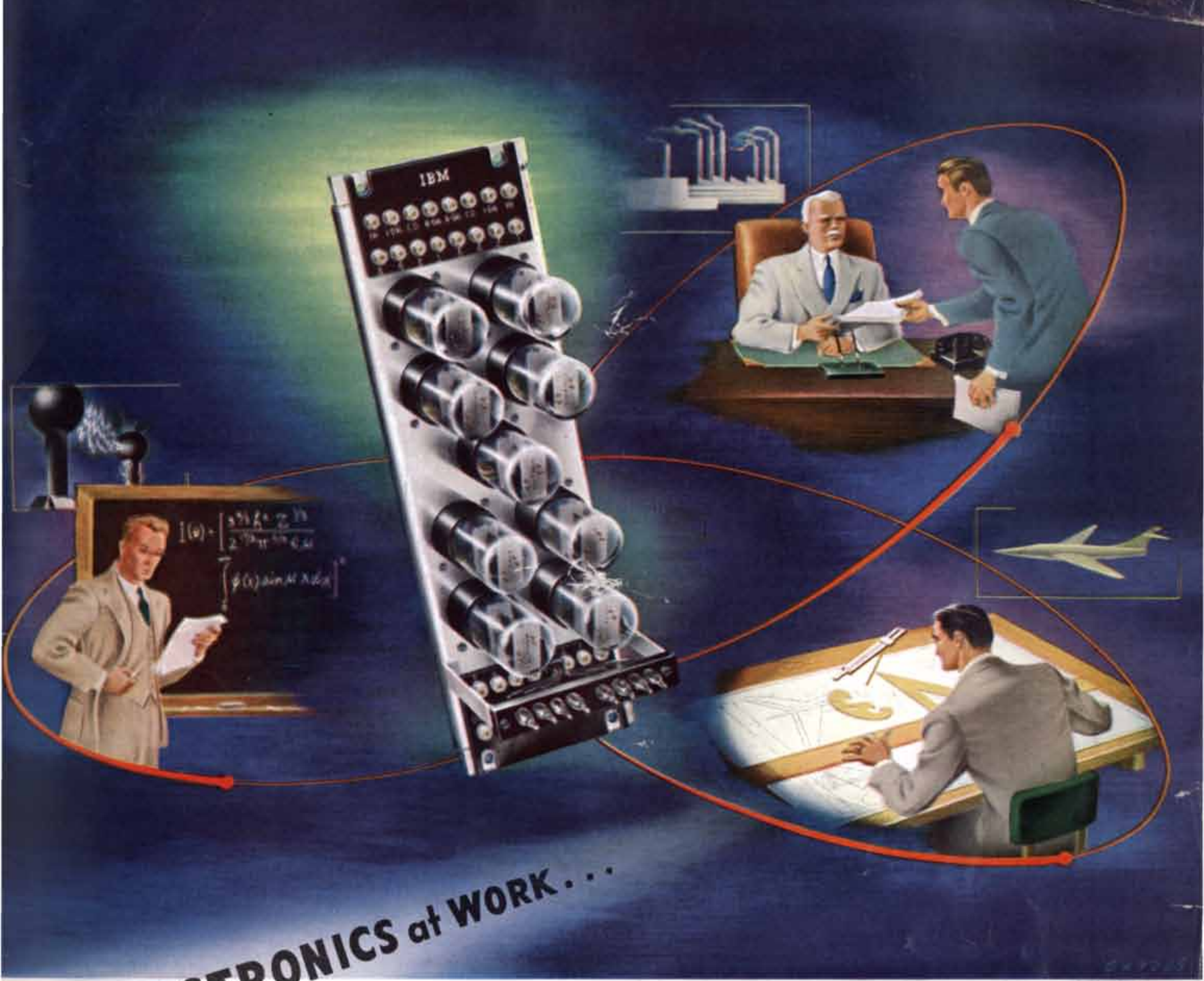

ELECTRONICS at WORK . . .

A BUSINESSMAN needs a report on his company's production and inventory position, and he has to have it faster than ever before.

A SCIENTIST, working in the atomic energy field, needs to know the exact effect of relativistic mass increases in the slowing down of fast electrons.

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