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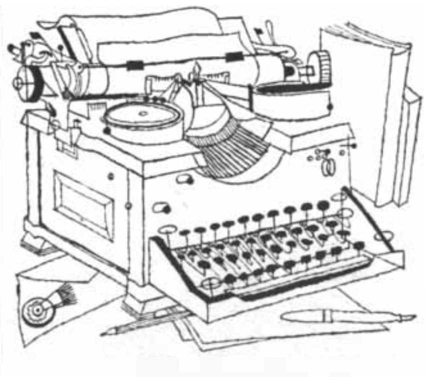
LETTERS



Sirs:

I read with particular interest in your April issue Edward S. Deevey, Jr.'s article on "The Probability of Death." As an actuary, I was particularly interested in the comparison of mortality data for human beings and for various other forms of life. My comments below are just to complete the record and to help keep it straight.

Your article stated that Hydra "appears to die without regard to age; no one age is more exposed to the risk of death than another, and the l_x curve is a straight line." The plot of survival against age is also shown as a straight line in a chart. Now if the l_x curve is a straight line, then d_x must be a constant independent of age, and $q_x = \frac{d_x}{l_x} = \frac{k}{l_x}$. Since **k** is a constant and l_x decreases with increasing age, q_x increases with increasing age. Thus, the probability of dying in a given time interval increases directly with increasing age. In this particular and personal sense, the risk of death does increase with age. . . .

In referring to life-table functions other than l_x, d_x, and e_x, Dr. Deevey states that "if one were to sell insurance to fruit flies one would need to know the expectation of life (e_x), better described as the mean subsequent life span." This is correct if interest on money is left out of account. In calculations affecting human beings, however, interest is generally taken into account as well as mortality, and in this case e_x cannot be used. Such calculations must take into account the actual distribution of deaths by age, and the simplifying assumption that all lives survive for exactly e_x and then die would lead to incorrect results.

After correctly pointing out that "profits" of life insurance companies are customarily shared with policyholders, Dr. Deevey somewhat inaccurately remarks that "until 1948 all American insurance premiums were calculated on a life table worked out in 1868." As early as 1907 certainly, and perhaps earlier, the premiums of certain nonparticipating (without dividend) policies were based on more recent experience. Under participating policies, dividends are the means whereby the gross premium charged is adjusted to reflect actual cost. Since 1863 dividends have been based on tables reflecting current mortality experience and thus the actual cost of these policies has been based on current mortality. The table to which Dr. Deevey refers is probably the American Experience Table, compiled by Sheppard Homans and first published in 1868. It is true that until 1948 many policies issued contained specific reference to this table, but this was in a manner that had little or no effect on the cost of insurance.

GORDON D. SHELLARD

Ridgewood, N. J.

Sirs:

In fairness to Professor F. London we wish to explain more fully the interpretation of our recent second-sound velocity measurements in the adiabatic demagnetization temperature range. It was implied in the department "Science and the Citizen" of your April issue that the failure of Tisza's theory to account for the velocity increase below one degree K. also affected the original London hypothesis of liquid helium II as a condensed Bose-Einstein gas.

In fact the London hypothesis is unweakened by our results. Tisza, on the other hand, posed the low-temperature dependence of second-sound velocity as a crucial test of certain of his own special assumptions. This was the issue intended, not that between the Landau two-fluid roton model and the London two-fluid condensation model.

That Tisza should attribute (phonon) entropy to the superfluid component on

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the framework of the London hypothesis and thus expect a velocity decrease detracts in no way from London's viewpoint. *The Landau assumption presumably supported* (purely alternatively) *by our measurements is thus the apparent absence of thermal energy within the superfluid.*

Our position in this admittedly complicated situation remains as explained in our original Letter to the Editor of *The Physical Review* on September 15, 1949: "This (result) should not necessarily be taken as evidence against London's original hypothesis." In fact the recent experiments of D. Osborne *et al* showing non-superfluidity in He^3 are exceedingly strong evidence for the condensation theory. Rather one would expect that a reformulation of Tisza's second-sound picture would be desirable, based on the Bose-Einstein hypothesis, but with the assumption of no phonon entropy carried by the superfluid. We added: "In the upper temperature range Tisza's analysis appears completely adequate." Actually in the upper temperature range (1.4 to 2.2 degrees K.) where the special entropy assumptions are not so critical, Tisza's results fit surprisingly well and are superior to Landau's.

JOHN R. PELLAM
RUSSELL B. SCOTT

National Bureau of Standards
Washington, D. C.

Sirs:

A few of your readers may desire a little more information about the illustrations that accompanied my article entitled "The Hydrogen Bomb" in your March issue.

The caption for the illustration at the lower left on page 12 of the March issue states: "Energy required to bring nuclei together so that they release energy is plotted against . . . two coordinates." This satisfactorily describes the case of the light nuclei, which are represented on the left side of the illustration. It does not include the heavy nuclei, which are represented on the right side. Here energy is required not to bring the nuclei together against the forces of electrical repulsion, but to cause a disturbance leading to fission.

The caption for the illustration at the lower right on the same page, plotting the energy released by the fusion of deuterium and tritium against temperature, says: "The vertical coordinate is energy in calories per second." It should be said that the energy is in calories per second *per gram* of reacting materials *at a density of one gram per cubic centimeter,* or that of water.

LOUIS N. RIDENOUR

University of Illinois
Urbana, Ill.

SCIENTIFIC AMERICAN

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JUNE 1900. "An ocean depth of 5,260 fathoms, or 31,560 feet, has been found by the United States steamer 'Nero,' which has lately been engaged in making soundings between Guam and Manila. In November, 1899, the 'Nero' reported a sounding of 4,900 fathoms about 500 miles east of Guam. The deepest ocean sounding heretofore reported was 30,930 feet, northeast of New Zealand in the South Pacific."

"In our issue of July 15 of last year, we referred to the proposal of Mr. F. U. Adams to sheathe a railroad train with a view to proving that atmospheric resistance could be greatly reduced, and the speed proportionately increased, by building a train with something of the wedge-shaped ends and smooth and continuous lines that characterize the models of steamships. Thanks to the enterprise of the Baltimore and Ohio Railroad, a full-sized train has been equipped on the lines suggested, and a series of trials is now being made. The results are without a parallel, and may be taken as establishing a record in high-speed railroad travel. The most surprising records on this trial (which are such as may well strain the credulity of railroad men) were obtained over the 20.1 miles from Annapolis Junction to Trinidad, which were covered at the rate of 78.6 miles an hour."

"Observations of the eclipse of May 28, 1900. The Naval Observatory fitted out three expeditions under the general supervision and control of Prof. S. J. Brown, the astronomical director of the Observatory. Perhaps the largest collection of scientists was at Wadesboro, N. C., where were the observers from the Smithsonian Institution, Princeton University, the Yerkes Observatory and the British Astronomical Association. The party from the Smithsonian Institution was in charge of Mr. C. G. Abbot, and was accompanied by Dr. S. P. Langley, the secretary of the Institution, and several others. Dr. Langley said: 'The bolometer was used for the first time in this eclipse, and by its aid the heat of the corona was successfully observed.' "

"A new type of phonograph is shown at the Paris Exposition, this being the invention of a Danish engineer, Valdemar Poulsen. It works upon an entirely new principle, and the record, instead of being made in wax by a stylus, is made upon a steel wire by the action of a magnet. The magnet is connected with a telephone transmitter and battery, and the sound waves cause a variation in intensity of the electromagnet, and this in turn acts upon the steel wire passing before it, leaving a permanent impression. When the action is reversed, the wire reacts upon the magnet and the sound is heard in the telephone. The magnetic trace may be obliterated by passing a continuous current in the electromagnet and turning the cylinder."

"The Peary Arctic steamer 'Windward' was ready to come out of the dry dock on June 9 at St. John's, Newfoundland. The expedition will sail from Sydney about the first of July and go to Etah, North Greenland. At Etah, Lieut. Peary's winter quarters, instructions will probably be found, and if not, they will be awaited. If Lieut. Peary has succeeded in carrying out his plans, that is to say, if he has discovered the North Pole, he will return with the ship."

"Prof. Loeb, of the University of Chicago, has made interesting experiments upon the artificial fertilization of the eggs of sea urchins, and the production of larvae after an immersion of two hours in a solution of magnesium chloride and sea water. The sea water and the instruments were carefully sterilized."

JUNE 1850. "The report of the committee of the National Convention, recently in session at Cincinnati, mentions that the medical schools in our country are too many, the students too numerous, the professors too few and incapable, the quantity of instruction too limited, the quality too superficial, and the preparatory training insufficient. Yet are our lives entrusted to the persons who are pronounced capable after this kind of instruction."

"The 'Advance' and the 'Rescue,' the vessels fitted out by the munificence of Mr. Henry Grinnell of this city for the Arctic expedition in search of Sir John Franklin, sailed last Friday at noon for their destination among the icebergs and eternal snows of the North. These vessels are under the regulations of the Navy, in order to ensure discipline and provide against desertion. It was a touching sight to behold those ships sail down the Bay, with the benevolent object in view of extricating from frozen seas a man and brother, though of another country and clime."

"The United States and Great Britain have concluded a treaty to construct a canal through the Isthmus of Darien, to unite the Atlantic and Pacific Oceans. The two governments have made a compact to take charge of Central America. The treaty is honorable to both governments."

"The Milwaukee 'Sentinel' contains a notice of the new town of Appleton, which has sprung up as if by magic during the last year, in the northern part of that State. It is situated on Fox River, about thirty miles south of Green Bay. Last year, in February, the 'shanty' of Mr. Smith, the agent, was the only tenement in the town. Now, the 'Sentinel' says, 'it boasts of upwards of one hundred buildings; a post office, enjoying a daily mail connection with Milwaukee; one of the best hotels in northern Wisconsin; three saw-mills; an academic building, the germ of the future university, and a population of five hundred or more industrious, frugal, temperate Yankees.' "

"The Census Law for 1850 has been published, and it is very comprehensive. The information which it proposes to embrace includes population, profession, color, occupation, place of birth, number of marriages, deaths, the persons who can read and write, deaf, dumb, blind, insane, slaves, fugitives and manumitted, the acres of land improved and unimproved, the cash value of each farm; the products of industry and the values; the number of criminals; the cost of labor. And indeed every species of social statistics which can make those kind of tables valuable as sources of public information and reference."

"Gay-Lussac, the eminent chemist, died in Paris on the 9th of May in his 73d year. There is hardly a savant in his study, or a manufacturer in his factory, but is indebted to Gay-Lussac for some invention, some method, some apparatus, some scientific suggestion, which facilitates his labors and renders his result more perfect."

This picture was taken in the Bridgeport office of The Southern New England Telephone Company, one of the 22 operating telephone companies which the Laboratories serve through the Bell System.

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THE COVER

Reproduced on the cover is a photomicrograph of a crystalline protein (*see page 32*). The protein is the enzyme ribonuclease. The crystals are enlarged 60 diameters and are illuminated by polarized light. They were prepared by Moses Kunitz of the Rockefeller Institute for Medical Research at Princeton, N. J., who in 1939 first isolated ribonuclease in crystalline form. This color photomicrograph of the crystals was made by Julian A. Carlile of the Institute.

THE ILLUSTRATIONS

Cover by Julian A. Carlile

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12-15	Eric Mose
17	Courtesy L. C. Dunn
19	Donald Moss
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32	Arda Alden Green and Gerty T. Cori of the Washington University Medical School. From the technical paper "Crystalline Muscle Phosphorylase: I. Preparation, Properties, and Molecular Weight." *The Journal of Biological Chemistry*; Vol. 151, No. 1; November, 1943. Courtesy Carl F. Cori (*top*). Wendell M. Stanley, Rockefeller Institute for Medical Research. Courtesy Radio Corporation of America and Wendell M. Stanley, University of California (*bottom*)
34-35	Irving Geis
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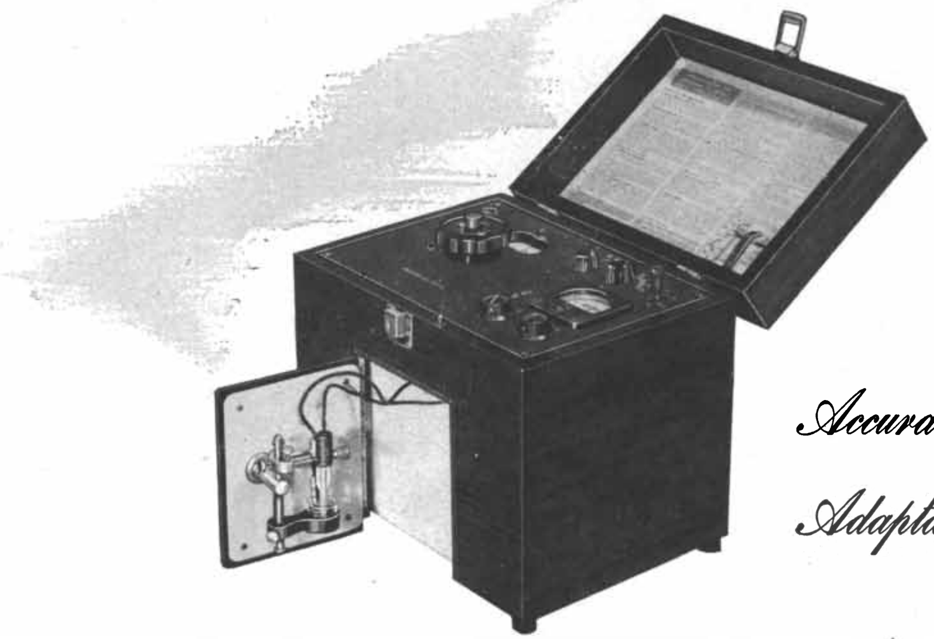

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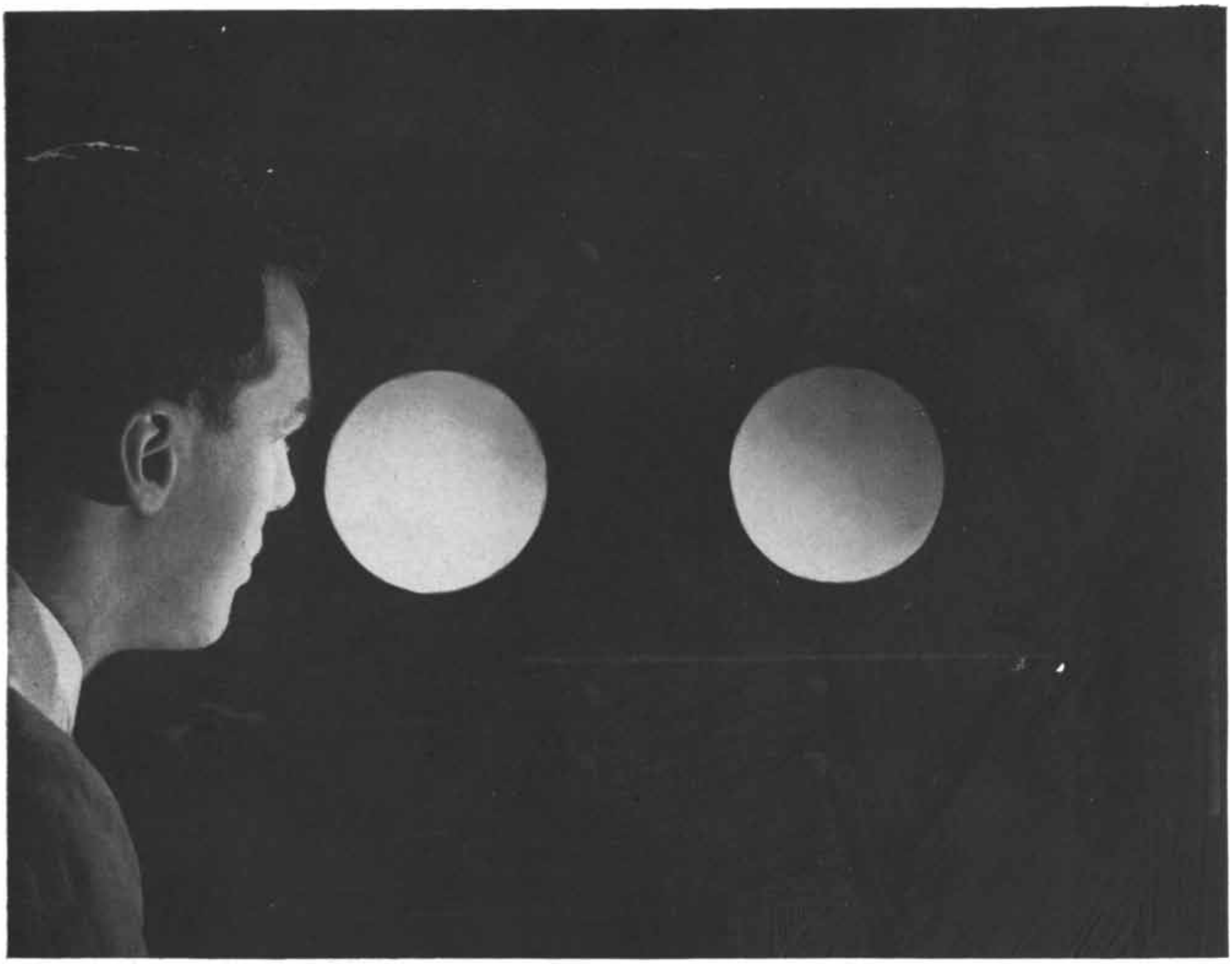

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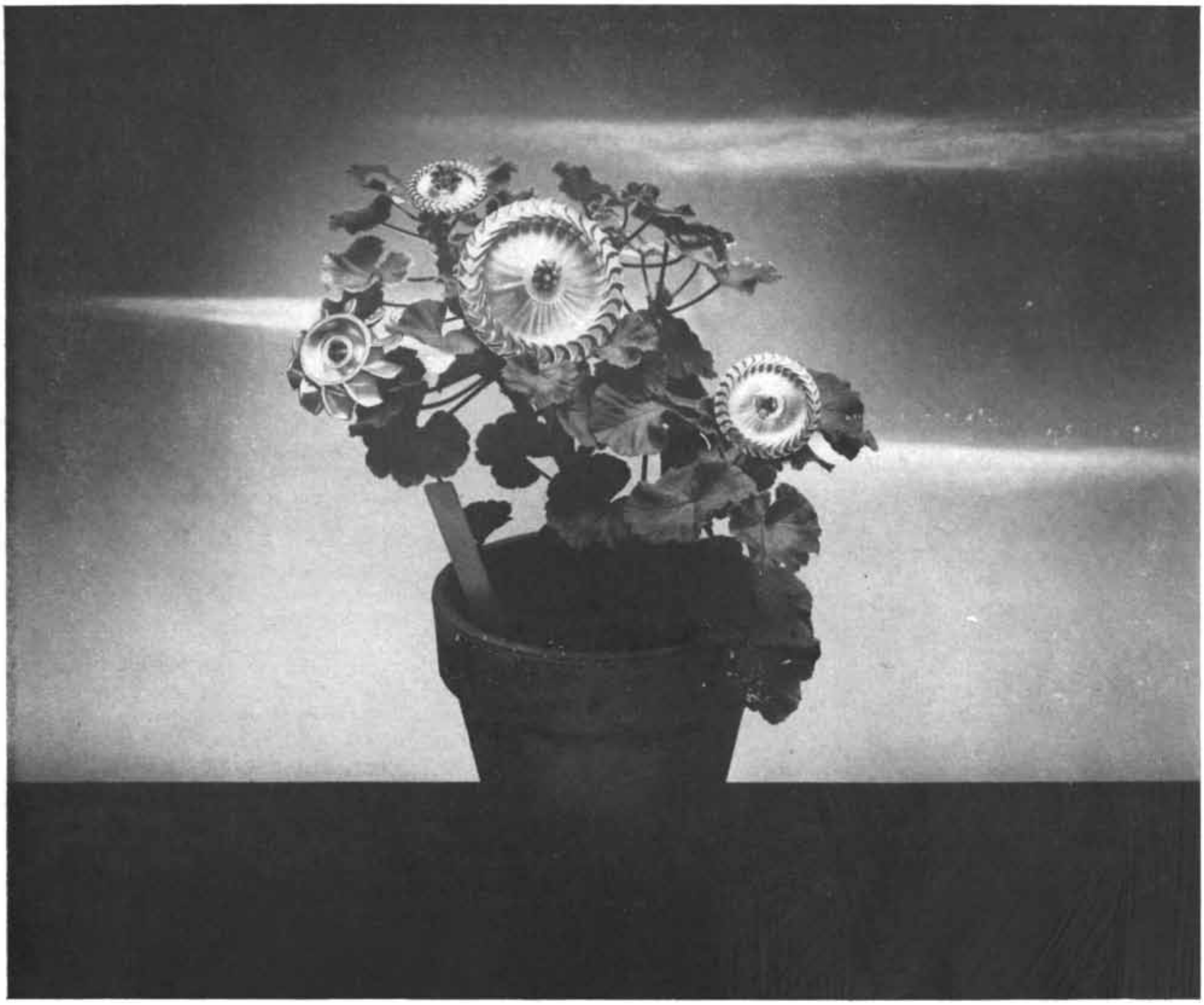

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SCIENTIFIC AMERICAN

JUNE 1950 VOL. 182, NO. 6

The Hydrogen Bomb: IV

What is the problem of organizing an effective civil defense against it? The last in a series of four articles on the thermonuclear weapon

by Ralph E. Lapp

THE three preceding issues of this magazine have presented critical appraisals of the hydrogen bomb. In the March issue Louis N. Ridenour examined certain technical aspects of the new weapon and considered how it would affect our national security. In the April issue Hans A. Bethe developed the theory of thermonuclear weapons and by skillful argument from this background highlighted the moral issues related to the use of the superbomb, concluding his article with a plea that the U. S. pledge itself to use the bomb only if attacked with the same weapon. In the May issue Robert F. Bacher examined the relative worth of the H-bomb in comparison with other weapons, and discussed the need for public information on the subject. This article will concentrate upon the critical problem of defense against weapons of mass destruction, in particular the defense of our cities.

The cities of the U. S., with their teeming masses of people and exposed industrial plants, afford targets of great attractiveness and high vulnerability to this type of weapon. In fact, we are the only nation that possesses any substantial number of target systems compatible with the destructive potential of the hydrogen bomb. The bitter irony of the H-bomb is that, as between us and the U.S.S.R., it is a superior weapon in the hands of the Russians. Thus we are now engaged in an all-out race to develop the one weapon that will be most effective when used against us. In a certain sense we are like the man who lives in a tar-paper shack and develops a flame thrower to protect himself. Any monopoly that we may gain in creating this weapon will certainly be of short duration. It is to be expected that both the U.S.S.R. and the U. S. will develop fusion-type bombs within five years, and that still other nations will produce them later.

After the end of World War II our leaders placed reliance for U. S. military security on a simple formula—the combination of the strategic bomber and the atomic bomb. This neat package of the B-36 and the A-bomb gave us a delusion of safety, and such eminent authorities as Winston Churchill and General Omar Bradley expressed the view that except for the threat of the A-bomb the Russians would have overrun Europe. There can be no doubt that it was a factor in stemming the Soviet expansion, but the threat of the A-bomb, even when we alone possessed it, did not succeed in confining the sphere of the U.S.S.R. to its 1945 boundary lines. Clearly the Russians were not blackjacked into good behavior by the A-bomb. And it is equally clear that neither A-bombs nor H-bombs will stop the Red Army in the field, for these weapons are designed for strategic application.

Government officials were gravely worried when our atomic monopoly was ended on September 23, 1949. There began a search for something to fill the place of the A-bomb. Perhaps our leaders should not be too much criticized for their precipitous decision to invest in the H-bomb project as a material means of security; it is tempting to choose a cheap and easy solution. But democracy suffered a severe setback when this momentous decision was made in secret. The issue should have been debated by the Congress in open session. National security demands that the people be kept fully informed of the state of our security. The problem of national defense is now more a civilian problem than a military one, although this fact seems to be overlooked in the Washington whirlwind. Overconcentration upon the weapons of war can involve grave danger to our security. We can delude ourselves into thinking that these weapons would make us invincible. It has been said that there are a thousand causes of war, but one of the most basic is the conviction that you can win it. National defense involves a delicate balance in the use of our natural resources, our money and our energy. We can invite disaster by neglecting our defenses and appearing weak. On the other hand we run the risk of war if we parade our armor too brazenly and rely upon it to the exclusion of peaceful negotiations.

The U. S. is endowed with the most modern information systems in the world, and yet the average citizen is bewildered by a lack of reliable facts on modern weapons. Even the simplest facts about atomic hazards and defense have not been made clear to the public. Mr. Average Citizen has a number of very basic questions that have gone without official answers; instead he has been deluged with sensational, contradictory and irresponsible rumors. Some say that the average American lives in a vacuum so far as the A-bomb is concerned, but it is more correct to say that he lives in an atmosphere supercharged with half-truths, wishful thinking and sheer poppycock.

Certain Congressmen have discovered a peacetime application of atomic en-

ELEVEN U. S. CITIES, according to a recent estimate, have populations of one million or more. The large number of such cities appears to render the U. S. more vulnerable than other nations to thermonuclear weapons.

CITY SIZE (Thousands)	NUMBER OF CITIES	POPULATION PER SIZE GROUP (Millions)	(per cent of Total U. S.)
5-10	968	6.7	5.1
10-25	688	10.0	7.6
25-50	213	7.4	5.6
50-100	107	7.3	5.6
100-250	55	7.8	5.9
250-500	23	7.8	5.9
500-1000	9	6.4	4.9
Above 1000	5	15.9	13.1
Totals	2068	69.3	52.7

DISTRIBUTION OF POPULATION in cities, according to the 1940 Census, emphasizes vulnerability of the U. S. Numbers in the black area apply to "unsafe" cities that might make economical targets for hydrogen bombs.

ergy: it can be used as a political football. These headline-hunting statesmen have become expert at kicking the atom around. Not content with snooping in tin cans for a few U-235 atoms, they have attacked scientists in a campaign of vilification and shackled physicists in "security" chains. Nothing could be told to the American people for fear of giving atomic secrets to the enemy. The timid Atomic Energy Commission meekly bowed to these vociferous few and suppressed or condoned the suppression of information essential for action on the problem of civil defense. The result is that at this date, nearly five years after Hiroshima, almost no action has been taken on this critical problem. Even the Hopley report, the public treatise on civil defense issued in 1948 after an official investigation, contained almost no facts about the effects of atomic weapons.

The Joint Congressional Atomic Energy Committee is holding hearings on the problems of civil defense, and some of the confused testimony before this committee shows that we are now reaping the rewards of our extreme secrecy. As Fletcher Bowron, Mayor of Los Angeles, told the committee: "The cities have no idea what to do about civilian atomic defense at present." It goes without saying that Mayor Bowron will never be able to talk his Chamber of Commerce or his civic leaders into supporting extensive measures for civil defense unless he can convince them that these measures will be effective. If civic leaders find the proposed steps unattractive, they may seize upon weird tales about atomic horrors to argue against doing anything.

Some scientists have donned the robes of the prophets of doom and preached the gospel that radioactivity will lay scourge to vast land areas and there will be no place to hide from this peril. Other persons with less scientific background have voiced the belief that an H-bomb will touch off a reaction that will burn up our atmosphere or even convert our earth into a glowing sun. Bethe's article on the effects of thermonuclear weapons is most authoritative in dispelling these fears, but it must be given to civic leaders in official form if it is to be accepted as gospel. With regard to the hazard of prolonged radioactivity, this unique characteristic of atomic weaponry has been much exaggerated. As an instrument of aggression it is probably no more effective than chemical warfare and less damaging than incendiary bombs. The weapons of modern war are terrible enough without adding embellishment to them.

Is there any defense against the H-bomb? To this question one can give the same answer J. Robert Oppenheimer supplied when asked in a Senate committee hearing if there was a defense against the A-bomb: "There are, and there will be, no specific countermeasures to atomic weapons." No magic ray or similar means will cause a fusion bomb to be detonated prior to its predetermined time; it is futile even to speculate about this type of defense. We can, however, apply the same methods of interception against an H-bomb as against a conventional bomb of TNT. The most probable carriers of H-bombs will be the high-speed, long-range bomber and the rocket-launching submarine. The backbone of any military defense against a carrier consists of an ever-alert and efficient detection network closely linked to a properly manned and equipped corps of fighters and guided missiles. But General George C. Kenney, head of the U. S. Air Force's Air University, recently stated: "Our radar system is not and cannot be very extensive for several years, and even then will be exceedingly expensive to install, maintain and operate. The so-called airtight radar fence does not exist here or anywhere else."

Even if the radar detection net were perfect and manned every second at every point around the perimeter of our defenses—at remote Alaskan bases, on picket ships at sea—we would still have the problem of getting interceptors into action in time. This means having adequate numbers of modern intercepting planes everywhere ready to take off at a moment's notice. Since these planes must be superior in technical performance and tactical operation to the invading bombers, we must keep ahead of the possible enemy in technical development and have the latest types of planes constantly in production and available in heavy force at the interception bases—not on the drawing boards or on order.

As James B. Conant observed in a memorable address at the National War College, we must be prepared for a "superblitz." It is almost a hopeless proposition for a country such as ours to keep itself continually geared to the tempo of readiness to combat a superblitz, yet this is the nature of the peril. In atomic war the enemy will not make a halfhearted initial attack; he will certainly obey the adage: "When you strike at a King, you must strike to kill." We cannot hope for years of grace, such as we had the last time, to develop counterweapons; nor will the war of the future wait for our munitions assembly lines to get under way. In short, in a world armed with superbombs industrial readiness is of paramount importance; mere plans for mobilization will not suffice.

Thus our planning objectives must be quite different from those of World War II. Despite the self-evidence of this fact, our planners continue to work on a preatomic basis. Weeks of work go into a detailed strategic analysis of such facilities as the Sault Ste. Marie locks and the Panama Canal. In the event of war, these would be the least of our worries. Once war broke out we would not be concerned with such minor questions as the transportation of iron ore from Duluth or the mass production of jeeps. All our planning must focus upon the first few days and weeks of conflict.

Such planning is difficult in the extreme, yet it has elements of simplicity. For example, in military defense preparations we need not concern ourselves too much with the primary heavy industries; we can concentrate attention upon the security of the critical industries that make an immediate contribution to our war effort. The only effective method of reducing the vulnerability of these industries is to disperse them. The National Security Resources Board has recommended such dispersal. It said: "If the industrial facilities of the U. S. were effectively dispersed, that fact alone would make an incalculable contribution toward the maintenance of peace because of the prohibitive expense of any enemy attempt to destroy this country's ability to defend itself. Dispersion could contribute significantly toward outlawing war."

Fortunately the current trend toward decentralization of industry is in harmony with this philosophy. The National Industrial Conference Board recently reported: "There is a trend toward locating manufacturing plants in smaller cities and towns. Cities and towns with 10,000 to 100,000 population are reported to be the most popular places for plants established from 1940-1947. Only one third of the plants built or acquired since 1940 are in cities of 100,000 and over."

There have been several widely publicized relocations of industry in the interests of defense; a prime example is the move of the Chance-Vought Corporation from Bridgeport, Conn., to Dallas, Tex. The city fathers in Bridgeport were not happy about this relocation, and they immediately set to work to persuade other industries to move to their city. Ironically, they approached two rocket and aircraft companies! Dispersion of industry will certainly be resisted by many forces. Fortunately not all industry has to be moved, but even a partial relocation will be an enormous undertaking. Viewed on the time scale of a few years, it is an impossible undertaking. On a longer time basis, however, it is by no means impossible, nor would it be prohibitively expensive, as many have intimated. Much of our industrial plant is replaced or built anew each year. At the current rate of new construction, our entire present industrial plant, capitalized at about $125 billion, will be replaced in two decades. Thus in 20 years most of our industries could be dispersed without a cent of cost to the Government, except for public works and services that it might offer as inducement to persuade certain industries to relocate in special areas. A very few installations that warranted underground construction might be partially subsidized by the Government.

A MORE serious problem than relocating industry is the task of dispersing our largest cities. The atomic weapons are uniquely designed for killing massed humanity. A single H-bomb of appropriate size could wipe out the metropolitan area of New York. Senator Brien McMahon, Chairman of the Joint Committee on Atomic Energy, has warned that an H-bomb attack "might incinerate 50 million Americans—not in the space of an evening but in the space of a few minutes." Anyone can see the grounds for the Senator's admonition by looking at a map of what we may call the heart of America—roughly the northeastern quarter of the U. S. Ten states in this area contain almost 65 million people, 43 per cent of our total population. And within these states over 25 million people are concentrated in just 10 metropolitan areas. It is this superconcentration of people in a few localities that makes the U. S. a peculiarly vulnerable target for attack with superweapons. Since 1940 this concentration has become even more marked.

There is no real assurance that the vulnerable heart of America can be defended successfully. A surprise attack with three dozen superbombs could almost fulfill the dire prediction voiced by Senator McMahon. And no nation, however great, would retain the determination to fight after it had lost one fourth of its total population. So for defense against atomic weapons there is no alternative but to undertake the dispersion of our largest cities and to halt abruptly the growth of many others.

How can we do this? A glance at an aerial photograph of a modern city such as New York, with its tremendous investment of wealth in a few square miles of land, is sufficient to show the staggering dimensions of the problem. Can we really hope to do anything about such a conglomerate of skyscrapers as rear up in Manhattan? About the only answer to this question is to say that New York must start getting better by not getting any worse. As buildings become obsolescent in New York they should be torn down and not replaced. The Government could discourage skyscraper building in Manhattan by cutting off all Federal aid to additional construction there. The same would apply to such cities as Chicago and Philadelphia, which are not quite as hopeless as New York but still represent an overcritical assembly of plants and people.

What is the critical size for a city in

atomic warfare? One may say that a city can be considered on the target list for the H-bomb if its population exceeds 500,000. Cities in the 100,000 to 500,000 class represent less attractive targets for the H-bomb but would be targets for A-bombs. Taking the 500,000 figure as a minimum H-bomb target, we find that 27 U. S. cities, with a total of 40 million people, make the target list. Thus one out of every four Americans would be under the shadow of the H-bomb.

Ridenour has already pointed out that the size of the H-bomb will depend upon the intentions of its designers. The designers can scarcely be expected to produce H-bombs of many different sizes to fit the areas of the specific target cities. More likely a standard H-bomb will be developed. If this bomb is designed for complete destruction of most of our 27 largest cities (all except the very largest), it will be of a size equivalent to about 500,000 tons of TNT. Thus it would be about 25 times as powerful as the 1945 Nagasaki A-bomb, which was stated by official sources to be equivalent to 20,000 tons of TNT. The difference between an A-bomb and an H-bomb as a weapon against a large city is that the former knocks the heart out of the city whereas the latter levels the entire city. Damage by blast and fire would be the principal causes of destruction; only a limited central part of the target, if it were a metropolitan area, would be within the range of lethal radiations of neutrons and gamma rays. The detonation of three dozen bombs of this size over cities in the U. S. would not produce a serious health hazard from prolonged radioactivity.

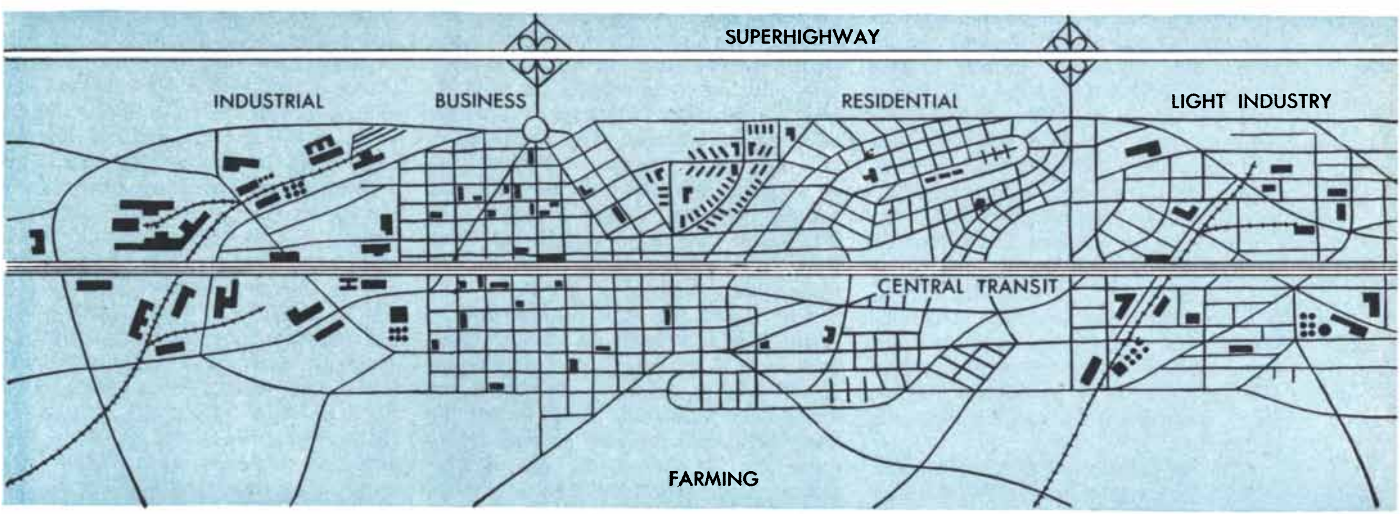
IT IS OBVIOUS that if our largest cities could be dispersed into smaller communities, our nation would assume a much less vulnerable posture. One can raise the immediate objection that such a plan is doomed to failure because of the astronomical costs involved. The newly appointed director of the Office of Civilian Mobilization, Paul J. Larsen, told the Joint Committee on Atomic Energy: "The dollars and cents cost of decentralizing some 200 cities in the United States having populations of 50,000 or more would probably be in the neighborhood of $300 billion." Obviously precipitous or Government-dictated dispersion of these cities would be just as disastrous to our nation as the explosion of three dozen H-bombs.

But over a longer range the problem is not quite as formidable as it may seem. More than one million houses and associated community facilities are now being built annually in the U. S. This is the equivalent of 80 cities of 50,000 people. A large fraction of this new construction is to be located in metropolitan areas, but it need not be, and for safety's sake it should not be. By proper guidance and inducement many of these homes could be located according to a plan that would bring about a much less vulnerable distribution of our population. At the current rate of home construction a large part of the population could be relocated in a few decades. The U. S. population is growing at a rate which exceeds all prewar estimates. Joseph S. Davis of Stanford University now predicts that by the end of the century the nation's population will be about 200 million. Planners today must take a long-range view of dispersion so that 50 million Americans yet to be born will live under less hazardous conditions than exist now.

As a long-range objective the goal of dispersion planners is to encourage the development of more cities in the 50,000 population class. There are now over 100 cities of about this size. There are about 2,000 towns in the population bracket from 5,000 to 50,000. The dispersion goal would be to allow half of these 2,000 towns to reach the 50,000 mark, with a minimum distance of 15 miles between towns. The strategic relocation of our industrial plants could automatically produce such a result, for once industry decentralizes, populations follow suit and new communities arise at private expense.

There are of course many advantages to limiting the size of cities apart from those of national defense. It would go a long way toward ridding us of the worst evils of our huge metropolises, such as traffic congestion, the high cost of civic government, slums, organized crime, excessive noise, polluted air and the like. Some sociologists have suggested that the optimum size for a city is probably 100,000 or less. Thus there are many factors which suggest that the trend of the future should in any case be away from the huge metropolitan area to the smaller community.

LOOKING very far into the future, population planners can devise new types of cities that will enable people to enjoy the advantages of city life without running the risk of living in a target area. Cities may be built in linear form extending for miles on end in a continuous thin strip. This "strip city" pattern not only would provide an admirable answer to atomic bombs but could solve the urban transportation problem. Such a city would require only longitudinal transit. Superhighways could parallel the city, and a rapid-transit facility could run through the heart of it. By limiting the width of the strip to less than two miles, and by controlling the height of buildings, the population could be well spread out. The city might be laid out in 10-mile sections, each with a population not exceeding 50,000. It is con-



STRIP CITY is the city planner's ideal defense against thermonuclear weapons. A hydrogen bomb could knock out only a section of the strip. Moreover, the city is organized in such a way that a single bomb would be unlikely

ceivable that a strip city might extend for hundreds of miles clear across a state.

This ultramodern city would make little distinction between the farmer and the urbanite. People living on the strip would be close to the country, while rural workers would be only a short distance from the advantages of city life. The strip city would adapt itself to high-speed transportation in a manner which no city today can approach. People could live in a residential zone of the strip, work in another zone 20 miles or 20 minutes away, and at night seek entertainment in the cultural zone, which might be only 10 minutes away on the high-speed central transit.

Such a pattern would allow us to make use of the vast space available in this nation. In the struggle for survival against the weapons of mass destruction space is our ally. Today over 50 million Americans live on less than one per cent of our surface area. Herein lies our extreme vulnerability to the hydrogen bomb. We need not seek to shield ourselves from disaster by building homes underground. There is plenty of space for dispersion to afford security, and this does not mean that one has to build in the Rocky Mountains or in Death Valley.

In the meantime we must consider the shorter-range problem in civilian defense—the next five to 10 years. Here the problem is essentially one of planning against disaster: the measures to be undertaken to protect civilian populations in case of attack. Any large-scale measures undertaken in this direction should take a realistic view of the probable hazards. Practically nothing has been done on this phase of civilian defense, and now that we seem closer to the edge of peril there are growing signs of jumpiness among Government agencies. Lack of coordination between agencies and failure to view the picture as a whole are evident in the daily press releases from Washington. From the Pentagon comes the incredibly quixotic recommendation that 150,000 aircraft spotters be appointed. Another agency announces an atomic-defense Geiger counter for civilian use in detecting dangerous amounts of radioactivity. Such projects reveal a fundamentally trivial approach to the problem. Any real civil-defense program will require an organization comparable in authority and in annual budget appropriations to the National Military Establishment. Protective shelters, emergency medical relief, adequate fire lanes, personnel training and a host of other measures must be considered in this phase of civil defense. To consider the problem of just one city such as Washington, D. C., is to see clearly that drastic measures are required. The concentration of Government agencies in Washington places thousands of officials critical to the conduct of our national defense in a vulnerable area of a few square miles. Construction of adequate shelters for these people, not to mention the rest of Washington's population, will be no small job; it will be interesting to see how long the appropriate Washington committees will take to decide the simple question of what thickness of concrete is adequate for these shelters. It would seem that the immediate solution to this problem is to disperse many of the Government agencies that have no real reason for location in the city. The nation's capital city is one location where immediate dispersion is plainly indicated.

In the last analysis dispersion is the only defense; all other measures can only be palliative. Dispersion, by rendering the success of an enemy attack less likely, blunts the sword of the aggressor. It will not provide absolute security, but no more effective defense has been proposed. In a very real sense we can regard any investment in dispersion as a kind of national life insurance. Dollars spent on industrial relocation and civilian dispersion will be visible in modern factories and healthy communities. One can scarcely say the same for the billions spent each year on ships, planes and guns. We are currently budgeting $14 billion for the National Military Establishment; yet for this tremendous outlay we receive only a thin shell of protection. Indeed, Dwight D. Eisenhower has warned that even with this expenditure we have "already disarmed" to a dangerous extent.

LOOKING back from the middle ground of the 20th century we see two long and bitterly contested wars, the second more terrible than the first. Looking ahead, every man of peaceful intent wonders whether the curtain of the future will rise to reveal the specter of a third, more destructive war. Will it require a cataclysm of near-extinction to make men the world over realize the utter futility of armed combat? Will we not be allowed to apply our energy and resources to peaceful pursuits? Is civilization to be denied the wonderful benefits with which the treasure chest of science is so abundantly stocked? Ultimately the real answer to the H-bomb lies in the words of Franklin D. Roosevelt to the united nations in 1942: "Our earth is but a small star in the great universe. Yet of it we can make, if we choose, a planet unvexed by war, untroubled by hunger or fear, undivided by senseless distinctions of race, color or theory."

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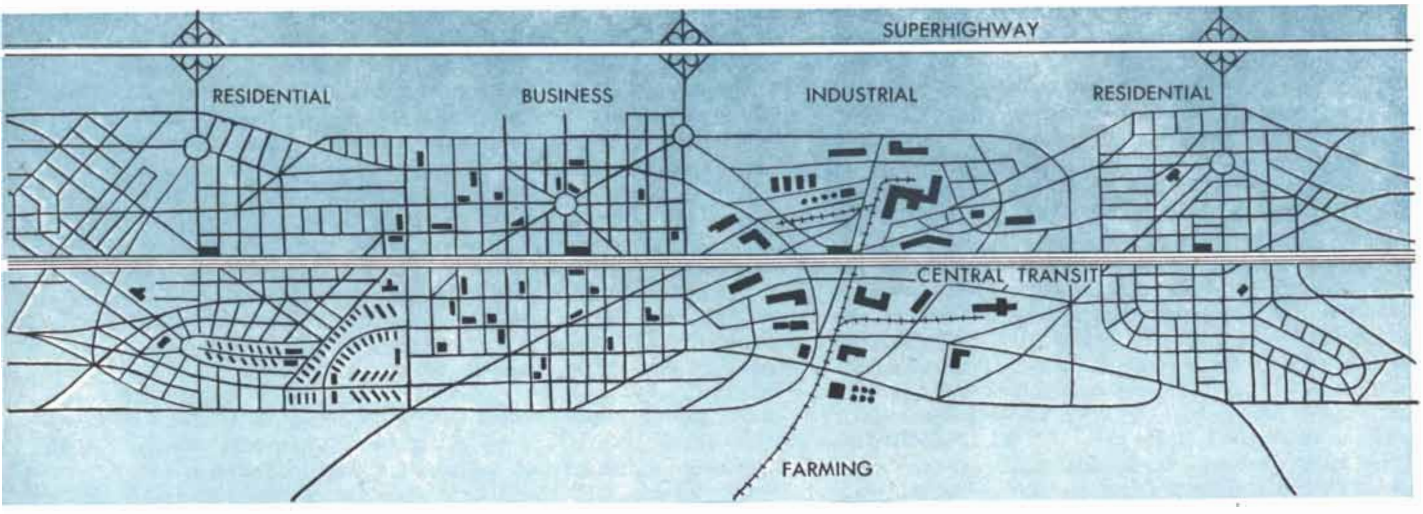


to knock out an organizational nerve center. Industrial, business and residential sections of the city alternate. The strip city also has the advantage of being readily available to the adjoining countryside and vice versa.

GENETIC MONSTERS

The abnormal descendants of normal animals are significant experiments of nature. The geneticist studies them to learn the role of the gene in both abnormal and normal development

by L. C. Dunn

FOR CENTURIES the appearance of freaks and monsters among the newborn young of man and of other animals prompted men to explanations as fantastic as the abnormal forms themselves. Individuals born with one eye or no eyes at all, with two heads or no head, with limbs fused or duplicated, or with any of the almost endless variety of bizarre abnormalities possible in man were regarded as jokes of the gods, as changelings substituted by fairies for the normal baby, as hybrids of the miscegenation of man and animals, or at the least as evidence of psychic influence of some sort exercised by the mother on the unborn child. Today biologists have come to recognize congenital abnormalities as sources of important clues for understanding development and heredity. The abnormalities are no longer regarded as baffling freaks but as revealing experiments of nature.

The change in view was due largely to two French biologists of the early 19th century: the father and son Saint-Hilaire. They classified the monsters of men and animals in such a way as to reveal some of the main processes that had gone wrong in the development of the embryo. By the end of the century another Frenchman, Camille Dareste, had brought the study of abnormalities, called teratology, to the stage of experimental work in the laboratory.

Thanks to these pioneers and to a whole intervening generation of embryologists we can now hope for reasonable answers when we ask: "What is it that makes development go wrong and produce misshapen or defective individuals at birth?" We need answers to this question to help us understand how it is that in the great majority of cases development goes right. The fact that a baby is occasionally born with 12 fingers is a mystery of only the second order; the primary wonder is that the normal embryo should count so accurately and nearly always stop at 10 fingers.

The early growth of any animal is an almost explosive affair in which the single cell formed by the union of sperm and egg divides into two, the two into four, and so on until the number of cells has multiplied into thousands or billions. This great energy could result in a riot of growth, but it doesn't. Somewhere, somehow, discipline and order are imposed upon it. What we want to know is how this control is exercised. More particularly, since each new individual carries its own control mechanism within itself from the moment of its origin, we want to know how its hereditary constitution determines this control.

EMBRYOLOGISTS have known for a long time that a control imposed from within the embryo can be relaxed or altered by changing the environment of the egg or embryo. If, for example, the fertilized egg of a sea urchin is put into sea water that lacks calcium salts, the first cells into which the egg divides fall apart, and each of the first two cells may form a whole individual instead of the right and left half of a single individual, as they would have if the cells had remained together. Similarly by dividing an egg into two parts in its early stages we may get identical twins or joined (Siamese) twins out of the same material that would have made one individual. If two out of one is wonderful, how much more so is it to make one out of many—to unite a billion cells into a single organism?

The mechanism for development that the egg carries within itself traces eventually to two cells, one from the mother and one from the father, which united at fertilization. Within each of these cells modern genetics has revealed a microcosmic organization of thousands of elements: the genes. They are arranged in a characteristic order on the larger elements, the chromosomes, of which each human egg and sperm contains 24. The particular kind of order that marks each species is imposed by the particular concatenation of genes in its cells. Mice and rats, men and monkeys, all share a general vertebrate order, but each species differs from the others in the details, because some of its genes are different. The particular pattern of genes maintains itself quite faithfully because at each cell division each gene produces a copy of itself.

It happens occasionally within every species that one gene does not duplicate itself quite precisely and the daughter cell gets a defective copy of it. If the gene involved controls the development of pigment in hair, eyes and skin and the new individual gets such a changed gene from each parent, it will be an albino, with white hair and pink eyes. Such a change is a mutation, and the individual showing the effects of it is a mutant. Probably the first blond human being was a mutant, and the first man with a white forelock, or with short fingers, or with hemophilia; all of these traits and many others are known to arise by mutation. When we stop to think about it, we should expect nearly all present mutants to be abnormal in one way or another, for the species has settled on a certain delicately adjusted combination of genes which has proved to be normal through thousands of generations of natural selection. But the converse, that all congenital abnormalities are necessarily due to mutation; is not true; many other events—accidents, diseases, injuries—may produce the same kind of abnormality as mutation. For example, if a mother has an attack of German measles early in pregnancy, certain characteristic abnormalities, especially of the eyes, are likely to arise in the embryo.

In man it is always difficult and sometimes impossible to determine whether a particular congenital abnormality is due to mutation or to some other cause. This is because in the human species genes from many lines of descent are intricately mixed, and the variability of response to environmental conditions is maintained by the fact that relatives avoid mating, which avoids the bringing together of like genes that would tend to make the children uniform. But experimental animals can be inbred in the laboratory to produce pure strains, and when abnormalities appear in these it is an easy matter to determine whether or not they are due to mutation. The laboratory mouse turns out to be excellent material for the study of hereditary abnormalities.

Let us take the case of the first abnormality that was thoroughly studied at the Columbia Genetics Laboratory. Nellie Dobrovolskaia-Zavadskaia, a Russian-born surgeon working at the Curie Institute in Paris, reported in 1927 that she had found in a strain of normal mice a mutant with a shortened tail. The offspring of this mouse inherited the defect, and some of them were brought to our laboratory in 1930. Here Paul Chesley found that when two such short-tailed mice were bred together, about a quarter of the embryos regularly became monsters of so extreme a kind that they died by the 10th day of the 20-day gestation period. The short-tail condition was shown to be due to one defective gene. When this gene was inherited from one parent, the tail began to grow in the embryo, but the end of it died and disappeared before birth. When the defective gene was inherited from both parents, the embryo was a grossly defective monster.

The prescription for producing this new type of monster was simply to mate a short-tailed female to a short-tailed male and about 11 days later to dissect out the embryos from the mother's uterus. Some of the embryos usually were shorter and smaller than their litter mates, and on closer examination these were found to lack not only the tail but the hind limbs and in fact the whole hinder end of the body. The embryonic spinal cord was most irregular, and the regular arrangement of muscle segments corresponding to the spinal elements which is a fundamental characteristic of vertebrate structure did not arise at all. The trouble was traced to a little rod of tissue, the notochord, that underlies the developing backbone in very early stages. When this was absent or defective, as it was in all embryos with two such genes, the later structures that depended upon the notochord failed to organize properly. The structure from which the spinal cord normally develops remained merely a more or less unregulated neural tube, and defects appeared in other parts of the body. We knew then that this particular gene, when normal or unmutated, somehow played a role in the development of the particular structures affected by the defective gene.

Long before this it had been shown by operations on amphibian embryos that the material that goes into the notochord acts as a focal material, a kind of organizer on which other tissues depend. The mouse observations showed that the organizer relationship is controlled by genes. This suggested a method for the controlled production of abnormalities in mammals. Instead of performing an operation on the early embryo (which in mammals is impossible), we could get a gene to do the operation for us. Mutations could thus provide the means for regularly producing abnormalities during embryonic development, abnormalities which previously could be found only by hit-or-miss dissections of large numbers of pregnant females.

From this beginning several members of the laboratory have carried the work much further. We found it especially

ONE MUTATED GENE produces abnormalities in the skeleton of a newborn mouse. The tail of the mouse is abnormally short. There are other defects in the spine.

TWO MUTATED GENES associated with the same characteristic produce much more serious abnormalities. The tail and a section of the spine are missing entirely.

profitable to examine the early development of embryos that we knew were going to die at some definite later stage. For example, about 10 years ago Charles Danforth sent us some short-tailed mice which had appeared in one of the strains in his laboratory at Stanford University. He thought they might be like our short-tailed mice from France. They turned out to be quite different. When we bred together two of the "Danforth shorts" we regularly found three kinds of offspring at birth: about half had short tails like the parents; about a quarter had normal tails; and the remaining quarter, although alive and apparently healthy at birth, had a complex of abnormalities and always died within a day or so after birth. We found that the offspring with normal tails had inherited a normal gene from each parent; the short-tailed ones had inherited a new mutation from one parent; and the abnormals had inherited a newly mutated gene from each parent—a combination that proved lethal.

The abnormal baby mice that died so promptly and regularly were the ones that captured our interest. A study of them and of the way in which such abnormalities arose during embryonic life was made by Salome Gluecksohn-Schoenheimer. Dr. Schoenheimer had spent her student years studying experimental embryology at Freiburg University in the laboratory of Hans Spemann, who was later awarded a Nobel prize for his discovery of the principle of embryonic induction. She was thus prepared to test in the more difficult and less accessible embryo of the mammal some of the ideas that had arisen during the course of experimental studies on amphibians such as frogs, newts and salamanders.

The abnormal "lethal" young from the Danforth mutation, of which we observed several hundred, had very striking defects. They were always entirely tailless and lacked the vertebrae of the lower back, so that the spinal cord there was uncovered—a condition known as *spina bifida,* which is found occasionally in human babies. Moreover, they had no rectum or anus and no urethral opening, so there was no means of getting rid of wastes either from the intestine or kidneys. On top of this embarrassing defect, they had no kidneys—or at most a single, abnormal displaced kidney—and a host of other abnormalities.

The question Dr. Schoenheimer asked was: "How does it happen that so essential an organ as a kidney is missing in these animals at birth, and how is that internal defect connected with the absence of such an inessential feature as a tail?" The answer had to be sought from the defective embryos, which long before birth could be recognized by the lack of external openings. A careful study of such embryos showed a complex series of interdependent steps something like the following: When there are severe abnormalities in the posterior spinal region, the "signal" that triggers the formation of the tubules of the ureter (which connect the kidney with the bladder) frequently is absent, and the tubules fail to develop from the little buds from which they normally arise. The development of the kidney in turn depends on signals transmitted by contact from the developing ureter; when this contact fails, the organs do not develop. In early normal embryos there is a little vestibule, the cloaca, which eventually separates into the rectum and the urethra. In abnormal embryos the cloaca does not develop far enough to separate, due to weakness or absence of the signal from the tubule. Consequently no rectum, bladder or urethra forms, and in the absence of contact of these with the surface of the body no openings develop.

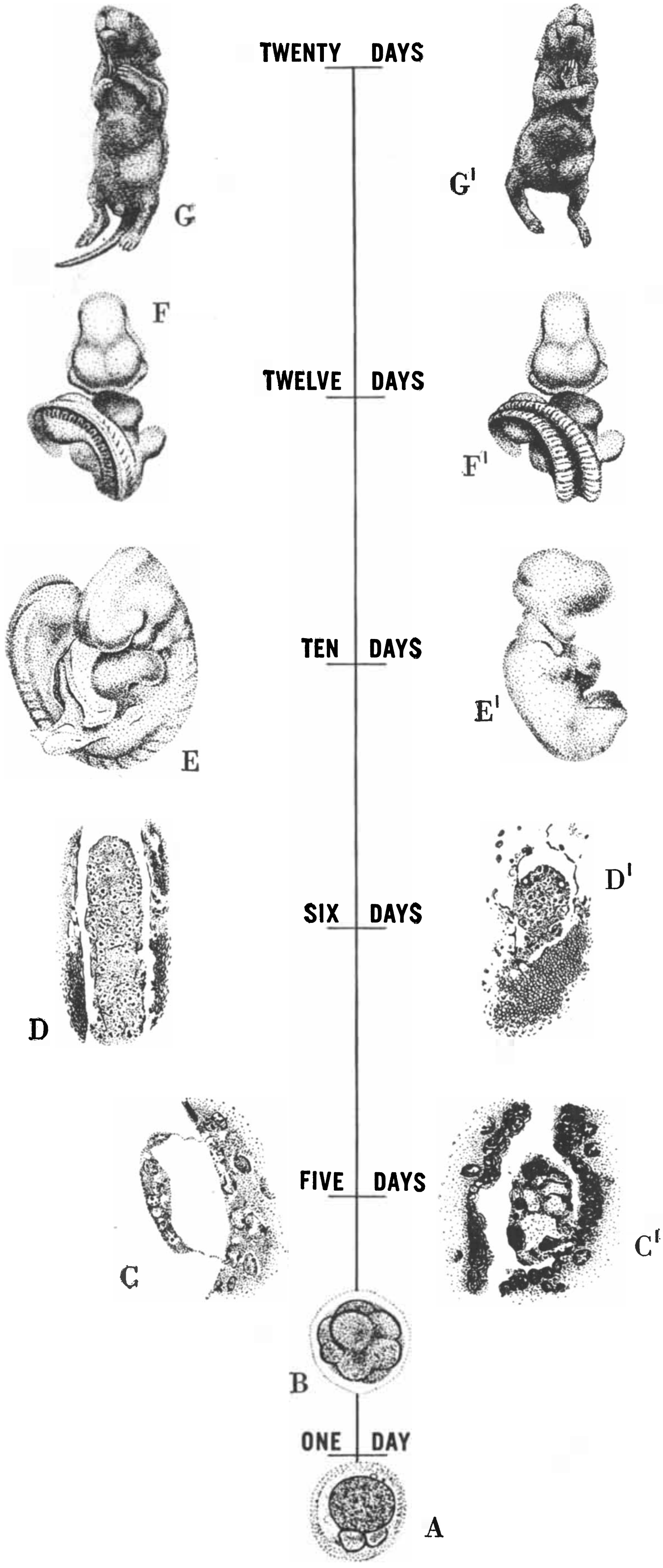
A sequence of events in development may be likened to a train of dominoes standing on end. Tip over the end domino and they all fall; tip over an intermediate one and only those to the right or left will fall. You can arrange such a train with branches in various ways, so that in one case a disturbance will take the left turning while the branch at the right remains upright, or in another the fall of a key domino will communicate the disturbance simultaneously to several branches that diverge at one point from the main line. The effect of a mutation on the chain of development, in which one event sets off the next, has an obvious resemblance to this dominoes game. In the case of the embryo, however, it is always difficult to set off a chain reaction from the first domino, since knocking out the first, before the processes of development have begun to differentiate and branch off usually changes or stops the whole development. It is only those cases in which the first step is not also the last that provide material for study.

RECENTLY steps a little nearer to the first have been observed in a mouse mutation that throws some light on the origins of twins and double monsters. Some years ago we received a letter from an old friend, Sidney P. Holman, proprietor of the Sunshine Mousery, then at Manatee, Fla. On his letterhead were listed the strains of mice he was breeding, and one of them was named "dominant waltzer." The only waltzing mice we knew of at that time were genetic recessives. So we asked Holman about his dominant waltzers and in reply he sent us some. Some of them waltzed all right, but what impressed us most about them was their angular, kinky tails, some of which were forked or doubled at the ends. The waltzing character was inconstant and has not yet been analyzed. The kinky character turned out to be due to a new dominant mutation. This mutation, first studied by Paul David and Ernst Caspari at Lafayette College, proved to have an early lethal effect on the embryo. When kinky females were mated to kinky males, embryos that inherited the kinky mutation from both parents regularly died after less than half the gestation period had passed.

Dr. Schoenheimer examined some embryos of this type before their death, and she found that what Holman had recognized first as a waltzing mutation and we later as a kinky-tail mutation was actually a twinning mutation. The embryos showed unmistakable evidences of doubling: they had two or more spinal axes, double hearts, additional bits of embryonic tissue indicating partial doubling of other organs, and in some cases formed complete twins. There seemed little doubt that some of the embryos with this mutation had begun their existence as single individuals but had divided later into two or more parts, each of which had become established and had lived for a time as a separate embryo. None of the double monsters or twins lived very long.

The most important clue to this puzzling phenomenon was the discovery of little lumps of unorganized tissue outside the main embryo in some of these abnormal mice. The bits of tissue somehow had escaped from the organizing influence which in a normal embryo confers oneness on all the cells. From such an escape it would seem only a step for the free piece of tissue to develop the ability to persist and form a whole duplicate embryo. The essential effect of this mutation was to force or permit one part to live not by the rules of the whole but by its own rules. This of course was excellent evidence for the existence of the rules themselves. One may say that the mutation, by revealing a defect in the control mechanism which Spemann has called the "organizer" or inductive influence, proved that this organizer is controlled by genes.

The little knowledge that has been acquired about the natural processes by which monsters arise among mice tends, of course, to make it unnecessary to resort to supernatural explanations of human monsters; the same general principles of development and heredity are equally applicable in mice and men. But the old beliefs are firmly entrenched, and the studies of a mere half-century will not cause the myths of millennial age to disappear. The truth is that we are charmed by myth even when it runs counter to reason. We will not readily surrender the attractive idea that somewhere in the world sirens and mermaids exist. Actually we do not invent such ideas out of whole cloth; our supernatural creatures are often born of natural phenomena. This is strikingly shown in



NORMAL AND ABNORMAL mice are compared at various stages of their development. The drawings on the left side of this diagram show several stages in the development of a normal mouse. The drawings on the right side show genetic abnormalities that may appear at the corresponding stages. A is the fertilized mouse egg. B is the egg after three cell divisions. C is a section through the normal egg after five days, when it is implanted in the uterus. C^1 is a section of an abnormal egg bearing two mutated genes that prevent its further development. D is a section of the normal embryo after six days. D^1 is a section of an embryo bearing two mutated genes that also prevent further development. E is the normal embryo after 10 days. E^1 is an embryo bearing two mutated genes that cause it to lack an entire hind end. F is the normal embryo after 12 days. F^1 is an embryo bearing two mutated genes that prevent the proper closing of the neural tube. G is the newborn normal mouse. G^1 is a newborn mouse bearing two mutated genes that cause a complex of abnormalities (absence of tail and excretory openings) which lead to death.

the great source book on abnormalities compiled by the German pathologist E. Schwalbe. Schwalbe's work shows a photograph of a human infant born with one leg, and compares with this a drawing based on the description by the ancient Greek philosopher Lycosthenes of one of the Skiapods, a race of one-legged men who he said hopped about the northern shores of the Black Sea. What could be more natural, knowing man, than to see the idea of the Skiapods arising not from Lycosthenes' imagination but from his sight of a flesh-and-blood Skiapod born in his own village?

IN our own laboratory we have discovered sirens—*i.e.*, creatures with legs fused together—among mice. And in the month when our first mouse Skiapod was described in print there appeared in the *Anatomical Record* the photograph of a female human infant, a true siren, with the same peculiarities, both internal and external. It would not stretch the imagination greatly to found upon such observed freaks a race of sirens and to endow them with the qualities to be desired in sirens. What really stretches the imagination is to devise a system of connected, reasonable and verifiable ideas by which the origin not merely of sirens and other monsters but of normal animals can be understood. That is a long way yet.

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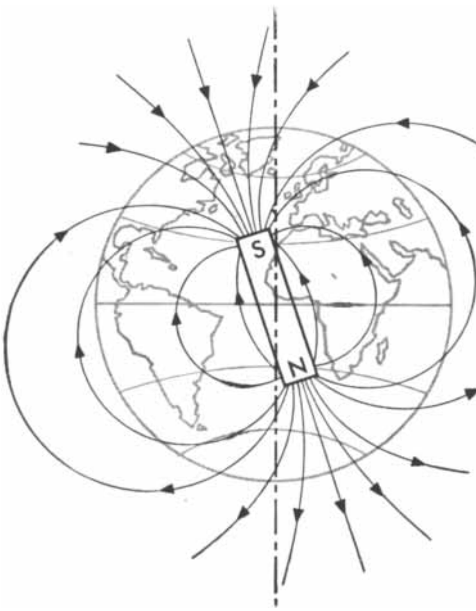


HUGE MAGNET could account for the earth's magnetic field, although it is suggested only to illustrate the problem of investigating the origin of the field. The south pole of such a magnet would lie in the Northern Hemisphere of the earth, since the north pole of a compass needle points toward the south pole of a magnet.

The Earth's Magnetism

For centuries man has used but not understood it. Recently two theories have been put forward in order to explain its origin

by A. E. Benfield

LARGE modern oceangoing vessels carry a good deal of equipment for the purpose of telling the captain where his ship is and on what course he is sailing. Besides the standard, old devices, such as the sextant and the like, an ocean liner's bridge nowadays is likely to have a directional radio receiver, a radar set, an echo-sounder, a gyrocompass. The captain, if he is not too busy, can probably explain how most of the equipment works. True, he may not know all the ins and outs of the newfangled stuff, and if he does you may find it hard to follow his reply, but at least you and the captain both know that there are experts who really understand the theory and practice of radar sets, directional radio beams, echo-sounders and gyrocompasses.

The ship will also have, of course, an old-fashioned magnetic compass. If you ask what makes *it* work, the captain will probably look a trifle surprised; he may reflect that it is a pity some men have never been Boy Scouts. After all, magnetic compasses have been used since long before the time of Columbus. He will probably explain that the earth has a north and a south magnetic pole; that a line joining them would coincide roughly with the axis of the earth's rotation; and that his magnetic compass points in the horizontal direction of the lines of force of the resulting magnetic field. But now, should you press him further, and ask *why* the earth has a north and south magnetic pole, or what mechanism creates this useful, familiar magnetic field, the captain won't know the answer. And you can be absolutely sure that he doesn't know, because nobody knows.

It is rather curious that, although the earth's magnetic field has been used by navigators for centuries, its origin and existence are still unexplained. There are theories about it, of course, but no theory has yet been generally accepted as correct. At the present time several rival and quite different theories, two in particular, are being widely and actively discussed.

One difficulty in the way of a complete theory of terrestrial magnetism is that so many observations have been made in the hundreds of years of systematic study of this subject that there is an embarrassingly large number of facts to be explained. Another difficulty is that it is rather hard to prove a particular theory to be correct, because we cannot yet get far enough inside the earth to see what is going on.

Terrestrial magnetism really consists in several connected problems. We need to explain the main magnetic field, sometimes called the primary field. We should account for its polarity; that is, why does the north pole of a compass point north rather than south? Why does the earth's magnetic field coincide approximately but not exactly with its axis of rotation? The north magnetic pole, for example, at present lies somewhat above the latitude of 70 degrees in the islands to the north of continental Canada. What causes the gradual drift of the earth's field? The magnetic poles, for example, wander slowly in the Northern and Southern Hemispheres in the general neighborhood of the geographical poles. There are also questions that have to do with the magnetism of other bodies. The sun has been thought to have a general magnetic field, also tipped a little with respect to its axis of rotation. Recently this field seems to have disappeared, and there is even some doubt about its existence, though there is no doubt that strong magnetic fields exist in and about the restricted areas occupied by sunspots. In the last few years the astronomer Horace W. Babcock, of the Mount Wilson and Palomar Observatories, has made the fascinating discovery that some stars have magnetic fields, quite strong ones, which change their strength by large amounts in the course of a few days or so; some even reverse their polarity. Does this curious, unexplained magnetic behavior in the sun and stars have anything in common with the earth's magnetism? If so, what?

WE SHALL restrict ourselves here almost entirely to a discussion of the main problem, the primary magnetic field of the earth, since its explanation would probably go far toward clearing up a number of the associated problems.

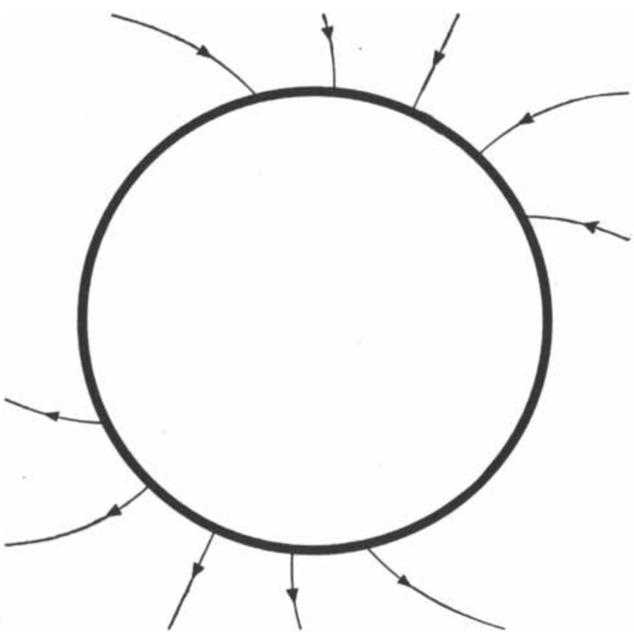
It was William Gilbert, natural philosopher and physician to Queen Elizabeth, who first pointed out, at the end of the 16th century, that the earth resembles a huge magnet. Two centuries later the famous German physicist and mathematician Carl F. Gauss established that terrestrial magnetism arises chiefly within the earth and not from outside it. Gauss, whose name, like Gilbert's, has been given to one of the units of magnetism, derived a mathematical expression for the strength and shape of the earth's field which fitted the observed values rather closely. His calculations showed that a magnetic field produced by any external agency would have a very different shape from that of the earth's actual field. We know, therefore, that there is no need to look to the sun or to electric currents circulating in our atmosphere or to anything happening elsewhere in the universe as the direct cause of the earth's main field (although the sun and atmospheric currents do affect the small daily fluctuations that occur in the field). We must look inside the earth itself.

Now we might explain the observed facts fairly well by the simple theory that the earth's field is caused by a magnet thousands of miles long embedded in the planet. But nobody seriously believes such a magnet to be present. Apart from the problem of who could have put it there, seismologists tell us that much of the earth's deep interior is probably liquid; furthermore the temperature at depth in the earth is probably far above that at which ferromagnetic materials lose their magnetic properties. This last argument also seems to rule out any likelihood that the whole sphere of the earth is permanently magnetized.

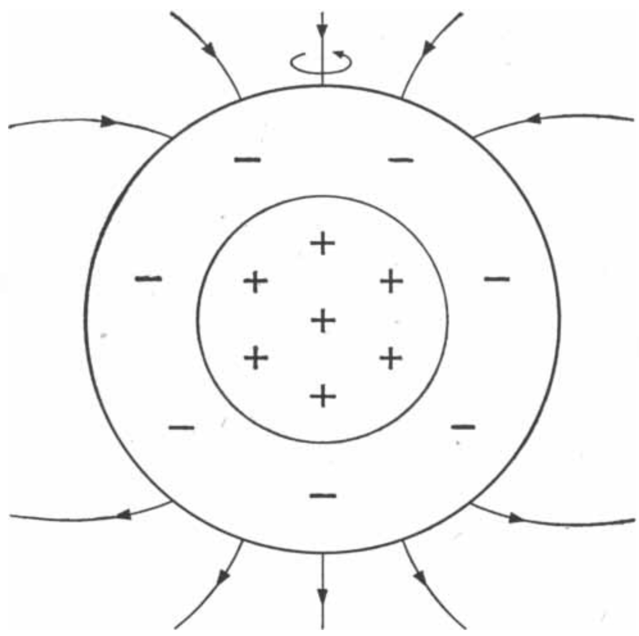
COULD the magnetic field be due to a permanent magnetization of the cool outermost shell of the earth? This, too, is not very likely, since to account for the strength of the field the shell would have to consist of highly magnetized material that is rarely found to any extent in nature, even in the few places where large deposits of the mineral magnetite exist. Moreover, if this hypothesis were correct, one would expect to find the magnetic field over the oceans systematically different from that on the thicker-crusted continents. Such differences are not found. There are also other arguments against the theory of a permanently magnetized shell.

Let us turn, therefore, to other sources of magnetism. Magnetic fields can be produced, of course, by electric currents. André Marie Ampère, who over 100 years ago studied the magnetism produced by electric currents in wires, was the first to suggest that microscopic electric currents, now known to be derived from the motions of electrons in atoms, might be the cause of all magnetism. Some modern physicists have suggested that this may not be entirely true: for example, the British mathematical physicist P. A. M. Dirac has predicted that small isolated magnetic poles can exist under certain unusual conditions—but Dirac's poles have not yet been found. In any case, theories have been proposed which attribute the earth's magnetism to electric currents in its interior.

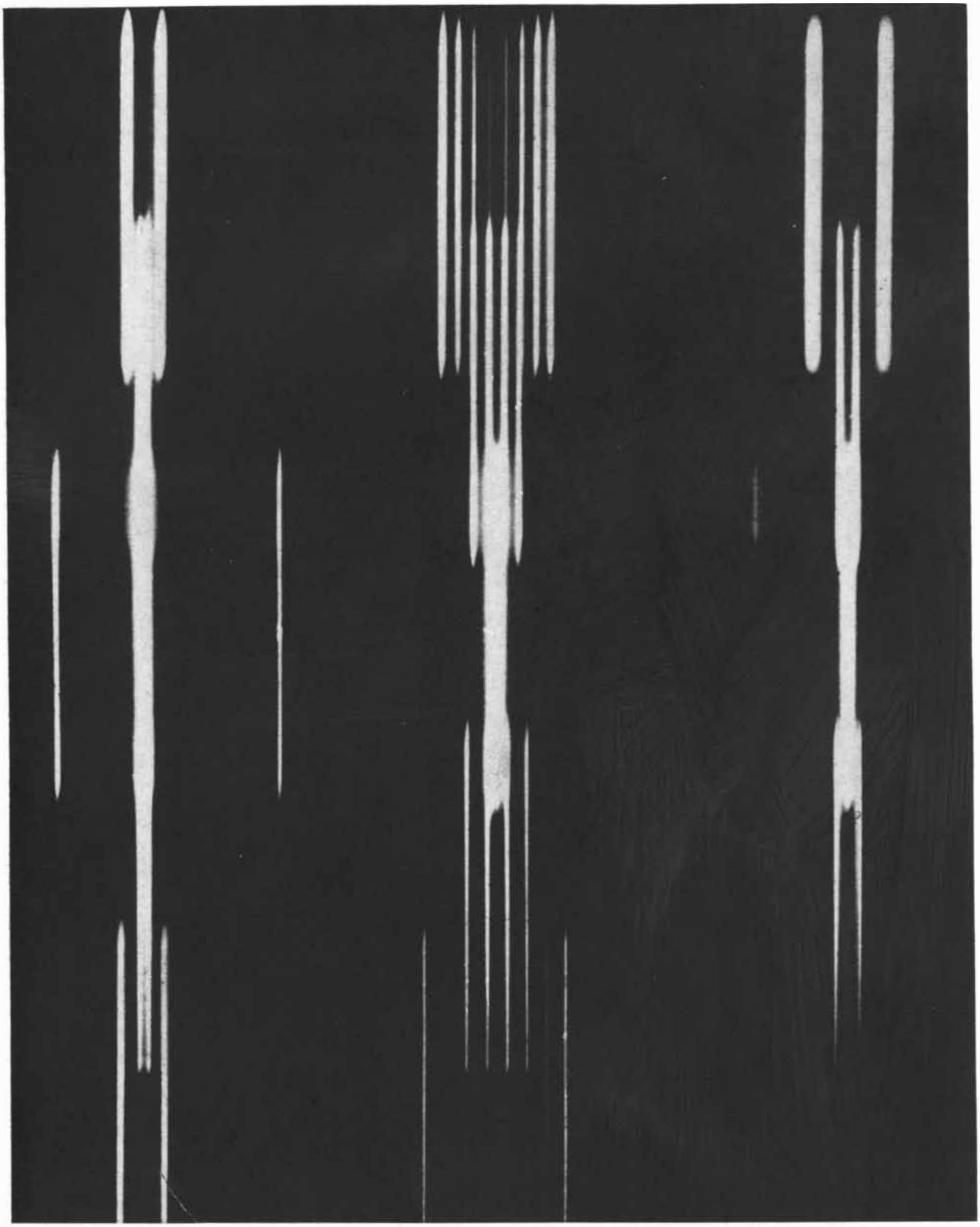
Electric currents are known to flow on occasion in the rocks of the earth's surface and in the oceans. One of the electric-current theories suggests that some unknown event produced immense currents in the earth earlier in its history, and that these currents persist to the present day at a steadily and slowly decreasing rate. This theory is not attractive, partly because it seems unsatisfactory to ascribe the original currents to an unknown cause, but even more because, on the basis of the estimated rate of decay of such currents, the theory implies that the original currents had fantastic magnitudes, even if they arose relatively recently in the earth's history. Another idea is that there are static electric charges fixed in the earth's interior. If the central parts of the earth were charged positively and the outer parts negatively, the daily rotation of the earth would produce a magnetic field of the right shape and size. But so vast a charge separation is needed, and the associated voltages are so tremendous, that this



MAGNETIZED SHELL just below the earth's surface would account for its magnetic field. The shell would have to be perhaps 50 miles thick. The hypothesis is weak because it requires large amounts of a highly magnetic material that has seldom been found in nature.



SEPARATED CHARGES within an electrically neutral earth might also explain its magnetic field. The positive charge would have to be distributed toward the center of the earth and the negative charge nearer the surface. The separation of charge is too large to be likely.



THE ZEEMAN EFFECT is the principal means of detecting the magnetic fields of the sun and the stars. It consists in the splitting of spectral lines. The single lines across the middle of this spectrogram are from a single source of light. The two sets of split lines above them are from the same source of light in a strong magnetic field. The three sets of lines at the top are produced by light that is polarized at right angles to the light producing the lines below them. The split lines below the middle of the spectrogram correspond to those above except that they are produced by a stronger magnetic field and thus exhibit a greater splitting. The spectrogram was made in the Spectroscopy Laboratory of the Massachusetts Institute of Technology.

theory is not popular. Some relativists have suggested that a charge separation of the necessary magnitude might be produced in the earth's interior by an electric field associated with the earth's gravitational field. The electric field in the deep interior of the earth would have to be of the order of at least 100 million volts per centimeter—a field so immense that if a shaft could be drilled to open up only a few feet deep down, nuclear physicists would have a voltage that could accelerate protons, electrons and other particles to higher energies than the most fabulous synchro-cyclotron or cyclo-synchrotron ever designed. The existence of such a colossal electric field is generally thought to be very unlikely.

NEVERTHELESS, the idea of a connection of some sort between gravitation and electromagnetism has intrigued people for many years, and it has been revived in one of the current theories of the earth's magnetism. Michael Faraday looked for a connection between gravitation and electromagnetism a century ago. His own careful electro-gravitational experiments, and others that have been made since, have had negative results. Faraday did, however, find a connection between magnetism and light, and 29 years after his death the distinguished Dutch physicist Peter Zeeman discovered the Zeeman effect, which is an effect produced by magnetism on the spectra of atoms and molecules. It is the Zeeman effect that enables astronomers to find the magnetic field of certain stars. When a radiating source of light, such as a flame or the glowing gas of a star, is in a magnetic field, the spectral lines produced by passing the light through a prism tend to split into two or more lines of slightly different frequencies. The larger the magnetic field, the wider is the split, *i.e.*, the greater is the difference of frequency between the original single line and its "magnetized" components. Hence the Zeeman effect can show not only that a magnetic field is present, but how strong it is. Furthermore, the magnetized light is polarized, and the manner of its polarization can indicate the polarity of the star's magnetic field.

Of the modern theories of the earth's magnetic field, probably the two most interesting and most widely discussed are those proposed by the British physicist P. M. S. Blackett and by the geophysicists Walter M. Elsasser and Edward C. Bullard, of the U. S. and England, respectively. Let us now examine these theories.

Blackett supposes that a rotating body produces a magnetic field simply by virtue of its rotation. This idea is not new, as Blackett himself has been the first to point out. He has, however, revived a considerable interest in it, and has added some plausible arguments in its favor. There is a certain equation which was once proposed to describe the magnetic field that might be associated with an electrically uncharged mass moving in a straight line. We now know that this equation is incorrect, not only because the magnetic fields it predicts have never been observed, but also because it does not check properly with physical theory. Blackett, however, suggested in 1947 that this equation, though not valid for bodies moving in a straight line, might be true for bodies that rotate. In support of this idea he called attention to an apparent fixed ratio between the rotation and the magnetism of the only astronomical bodies whose magnetic fields had at that time been measured—the earth, the sun and a peculiar star designated 78 Virginis. The ratio of the magnetic moment to the angular momentum was nearly the same for all three of these bodies. Babcock independently also noticed and mentioned this. Blackett reminded us that this situation could be described by another equation, a beautifully simple one that has never been derived from first principles but is a kind of intuitive guess. This latter equation looks so nice and simple, and seemed in 1947 to check so well with the observations, that many have thought it might be true.

Since the beginning of 1947, however, a number of things have happened. One is that the sun seems to have lost its general magnetic field; at least nobody has lately been able to find more than a faint, uncertain trace of it. Another is that Babcock, continuing his exciting work on the magnetism of stars, has now found several stars with varying magnetic fields, in some of which the magnetic field actually changes its polarity. This would presumably imply, under Blackett's theory, that the stars alter their rate of rotation. Now it is very hard to comprehend how a star could frequently and repeatedly change its rate of rotation, to say nothing of reversing its rotation altogether.

There are other difficulties as well. The extremely dense white dwarf stars might reasonably be expected to show large magnetic fields, but so far none has been found. Again, if the earth's main magnetic field is due simply to its daily rotation, why does not the annual movement of the earth and other planets about the sun produce a general magnetic field throughout the solar system, centered near the sun? On Blackett's hypothesis a field of this kind would apparently exist and be easily observable, yet it is not found. Furthermore, it seems odd that a mass should produce a magnetic field only when it rotates, in view of the fact that an electric charge creates such a field either by rotating or by moving in a straight line.

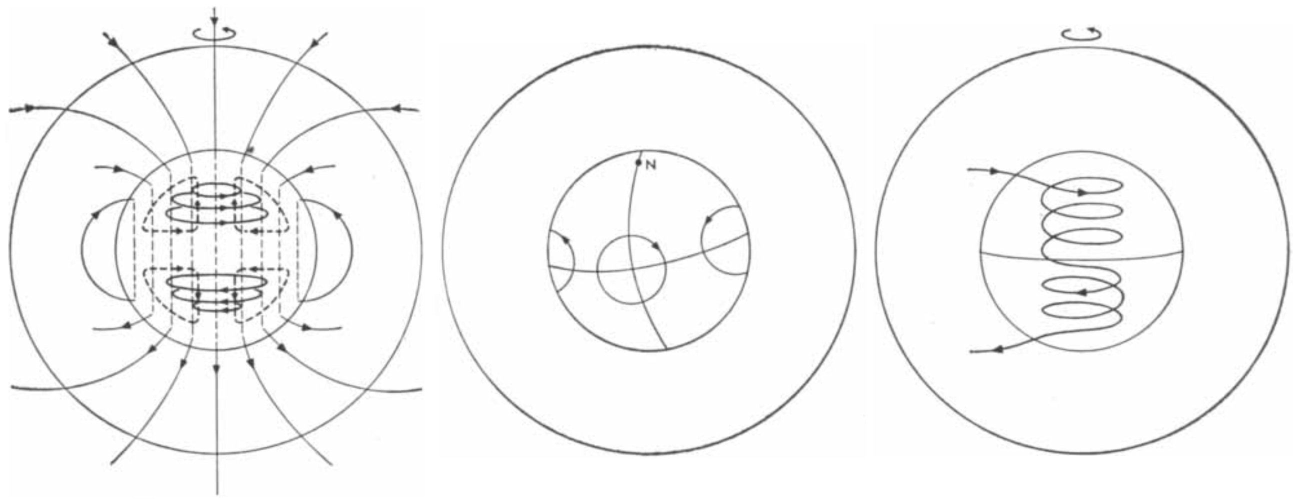
Nevertheless, odd things sometimes do occur in nature, and Blackett's idea is a very interesting one. He has proposed answers to a number of the objections. If his theory proves to be true, it will be a great discovery. Yet there will still remain the problem of explaining why the earth's north and south magnetic poles do not line up exactly with the axis of the earth's rotation, why the poles slowly drift over the course of decades, and why the shape of the field is found to be rather complex in detail.

ACCORDING to the Elsasser-Bullard theory, the earth's main field is caused by electric currents in the liquid of the earth's core. The Elsasser-Bullard idea is that the radioactive content of the core supplies sufficient heat to produce motion, or convection currents, in the liquid of the core. Bullard has shown that the necessary radioactive heat is roughly of the same order of magnitude as that known to be generated in meteorites, which are sometimes thought to come from a broken planet.

Convection currents will cause the inner part of the core to rotate at a faster rate than the outer part, much as water rotating slowly in a washbasin after the plug has been pulled out speeds up its rotation as it approaches the central outlet, in accordance with the law of conservation of angular momentum. For the purpose of the Elsasser-Bullard theory only an extremely small difference is needed between the rates of rotation of the inner and outer parts of the core. Such a differential of rotation can be shown to give rise to electric currents, provided that a magnetic field like the earth's is already present. These electric currents, Elsasser and Bullard reason, cause and maintain the earth's field.

Now this may seem at first sight to be an unpromising method of attack—to postulate that the required electric currents arise from the very magnetic field we are trying to explain. But there is no real difficulty, for the mechanism is much like that of a self-exciting dynamo: a small initial magnetic field builds up until it reaches an equilibrium value. The situation is not unlike that of an electrical oscillator, which is not oscillating beforehand but when switched on immediately develops spontaneous oscillations that increase rapidly to an equilibrium value and maintain themselves with the aid of energy supplied from batteries. In the case of this theory of the earth's field, the energy comes from radioactivity instead of batteries. There are, of course, no oscillations, since the earth's field does not alternate, but the "building up" principle is similar.

The Elsasser-Bullard theory is attractive: it seems able to account for more of the observed facts than any other. Bullard has shown that eddies in the convection currents near the surface of the core can explain the drifting of the earth's field. Compared with most geo-



ELSASSER-BULLARD THEORY of the earth's magnetism requires a small difference between the rates of rotation of the inner and outer parts of the earth's core. In the presence of the earth's magnetic field (*vertical dotted lines in the drawing at left*) the differential rate of rotation creates an electromotive force that drives electric currents in the core (*dotted quadrants*). These currents in turn create a toroidal magnetic field (*concentric circles*). This mechanism would also give rise to other magnetic fields (*drawing in middle*). A single line of force due to all these magnetic fields would have the shape shown in the drawing at the right.

logical processes this drift is very rapid: for instance, mountain building does not produce appreciable effects for many thousands or even millions of years, whereas there is a considerable variation in the magnetic field in a few decades. Hence it seems reasonable to attribute it to motions in the liquid of the core. The theory also suggests an explanation of the fact that the axis of the earth's field does not coincide with the planet's axis of rotation: unsymmetrical eddies in the core may be responsible.

According to the Elsasser-Bullard theory the convection currents generate other magnetic fields besides the main one, but many of these are restricted to the core and are unobservable by us on the earth's surface. One of these fields in the core, thought to be many times greater than the main field we observe, is called the toroidal field, because the theory indicates that its lines of force are continuous circles concentric with the earth's axis. Something like this toroidal field may be responsible for the strong solar magnetic fields of opposite polarity that occur with pairs of sunspots. It has been suggested that sunspots may mark the place where a patch of the sun's toroidal field comes to its surface and breaks into the open, so to speak. But the phenomenon of sunspots is too complicated to be entirely explained in this simple way.

THE Elsasser-Bullard theory in its present form does not explain everything. It does not indicate why stars have alternating magnetic fields. It does not tell us why the earth has its observed polarity, except to indicate that there is a 50-50 chance of its polarity being the way we find it. But the theory seems to do pretty well as far as it goes, and it is perhaps the most likely explanation that has yet been suggested.

How are we going to find out what theory is correct? Can we test the theories at all? It is not easy. However, there are a number of tests that may, and probably will, be applied in the next few years.

One test, recently started, is to measure the magnetic field at the bottom of deep mines. If the origin of the earth's field is in its core, as Elsasser and Bullard believe, both the vertical and horizontal components of the field should increase as one approaches the core; whereas if Blackett's theory that the whole earth is contributing to the field is correct, the horizontal component (though not the vertical) should decrease as one descends within the earth. The trouble is that the deepest mines go down only a tiny fraction of the distance to the earth's center, and distortions of the main field from small amounts of ferromagnetic materials in local rocks may interfere with the measurements. So far there has been no clear answer from this test, but a trend should begin to appear when a larger number of measurements have been made.

Another test that has been suggested is to fly an airplane with a magnetometer across a deep canyon or a mountain range running in an east-west direction. The Grand Canyon has been suggested as a good place for this test. If Blackett is right, the magnetometer, flown in a north-south direction at a steady altitude, should record small changes in the magnetic field due to the difference in mass beneath it as it crosses a canyon or range. As in the case of measurements in mines, however, variations of the magnetic content of the local rocks may be large enough to make the test inconclusive. Another suggestion is to measure the magnetic field in the deep oceans, since water is less massive than rock. This again would probably not be as useful as one would at first suppose, since small electric currents in the oceans create magnetic fields which are large enough to be troublesome.

ANOTHER test of Blackett's theory would be to whirl a mass in the laboratory to see if it created a magnetic field. This experiment may be rather difficult, as Blackett's theory indicates that a large mass would have to be rotated at high speed in order to produce a tiny field, but perhaps it will not be long before somebody provides the ingenuity, patience, money and time necessary to try it. The result would be of great interest.

Another test, not feasible at present but perhaps not completely out of the question for the future, would be to measure the magnetic field that may exist on the moon. It cannot be measured by the Zeeman effect, since the moon shines only by reflected light, and its field, if any, is probably far too small to be detected by this method anyway. The way to make the test would be to get to the moon itself, or near enough to measure its possible magnetic field with a magnetometer.

For the present, and perhaps for some little time in the future, the cause of the earth's magnetic field must remain uncertain. It is a fascinating and challenging problem.

A. E. Benfield is assistant professor of applied physics at Harvard University.

For study of submicroscopic structure by X-ray Diffraction, Kodak offers 6 films

Choice of the best film for a specific problem depends upon the relative importance of film speed, contrast, and graininess—as well as the quality of the radiation. The table shows the characteristics of six Kodak Films suitable for direct x-ray exposure in diffraction work.

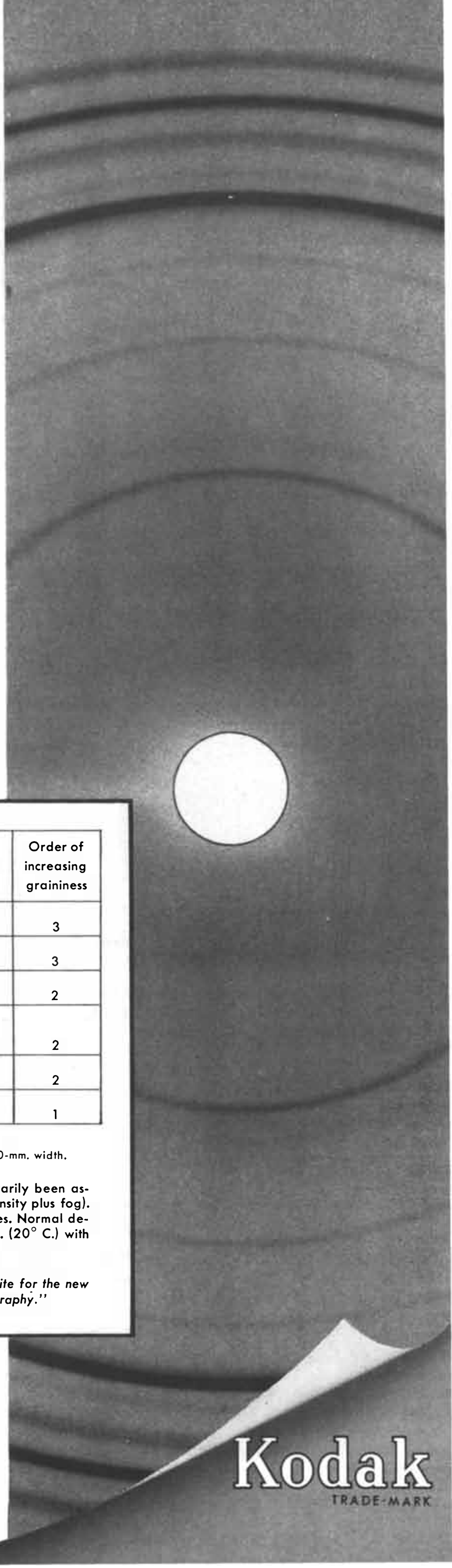
EASTMAN KODAK COMPANY
X-RAY DIVISION
Rochester 4, N. Y.

Kodak Films for X-ray Diffraction	Relative speed K radiation			Contrast	Order of increasing graininess
	Cr	Cu	Mo		
Kodak Industrial X-ray Film, Type K	150	130	110	high	3
Kodak No-Screen X-ray Film	100	100	100	low	3
Kodak Industrial X-ray Film, Type F	85	60	40	low	2
Kodak Single Coated X-ray Film—Blue Sensitive	80	45	25	low	2
Kodak Photoflure Film—Blue Sensitive*	80	45	25	low	2
Kodak Industrial X-ray Film, Type A	22	17	14	high	1

*Kodak Photoflure Film—Blue Sensitive is available only in 100-foot rolls of 70-mm. width.

For each radiation quality, Kodak No-Screen X-ray Film has arbitrarily been assigned the speed value of 100 (at a density of 0.3 above base density plus fog). It is not valid to compare film speeds for different radiation qualities. Normal development is 5 minutes in Kodak Rapid X-ray Developer at 68° F. (20° C.) with 5 seconds of agitation each minute.

For a notebook-size version of this chart and further information, write for the new free booklet, "Kodak Materials and Accessories for Industrial Radiography."



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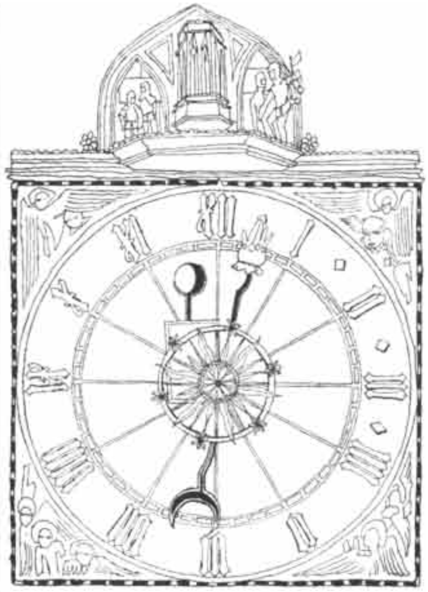

Science Foundation

THE National Science Foundation, the first governmental agency in the U. S. nation's history for the general support of work in the basic sciences, has at long last been established. As enacted by Congress and signed by the President last month, the legislation creating the Foundation represents many compromises, but it has the general approval of scientists. It sets up an institution with large powers "for the promotion of basic research and education in the sciences." And the Foundation's aid to science is to be given in a form that should have the effect of strengthening the nation's universities and permitting a maximum of independence to scientists.

Under the law the Foundation will not itself operate laboratories. All of its support will be distributed as grants or loans to individuals and organizations, including other government agencies, for research projects, and as scholarships and fellowships for scientific study. The Foundation is also specifically instructed to "appraise the impact of research" on the general welfare of the U. S., to evaluate the research programs of other Federal agencies, to "foster the interchange of scientific information among scientists in the U. S. and foreign countries," to establish special commissions to survey and recommend over-all programs in specific fields of science, to maintain a national roster of scientific and technical personnel, and to initiate and support specific projects in military research whenever it is requested to do so by the Secretary of Defense.

This last provision is disliked by many scientists; they would have preferred to free the Foundation from any connection with secret or military work and leave this work to the military and the Atomic Energy Commission. Because of the Foundation's probable involvement in such work, several security provisions were written into the Foundation Act: 1) Foundation contractors who do research for the Defense Department will be subject to that Department's security restrictions; 2) those who do secret work for the Foundation, and employees of the Foundation itself who have access to restricted data, will be subject to investigation by the Federal Bureau of Investigation and security rules to be laid down by the Foundation; 3) those who work in the field of nuclear energy and have access to restricted information will be subject to the AEC's security rules. (The Foundation can support no work in nuclear energy without the consent of the AEC.) The Act also has a general security provision requiring all candidates for scholarships and fellowships to take an oath of loyalty to the U. S. and to file an affidavit that they do not belong to or support any organization for the overthrow of the U. S. Government. A House amendment that would have required FBI investigation and approval of all employees of the Foundation was eliminated from the Act by the House and Senate conferees.

The Foundation's powers lie primarily in a board of 24 members, to be appointed by the President with the advice and consent of the Senate. The members, serving terms of six years, are to be persons "eminent in the fields of the basic sciences, medical science, engineering, agriculture, education or public affairs." The President is instructed to give due consideration to nominations made by the National Academy of Sciences, associations of universities and "other scientific or educational organizations." The President is also to appoint the Foundation's director, with the consent of the Senate. The director, serving a six-year term and receiving $15,000 a year, will be the chief executive officer, but the decisions in all important matters, including the award of grants and fellowships, are to be made by the board. Although the board is authorized to appoint an executive committee of its members, it is not permitted to delegate final decisions to them. Since the unsalaried board will be able to meet only infrequently, it is believed that the Act will eventually have to be amended to provide a less unwieldy arrangement. Board members will receive $25 per day and travel expenses for meetings.

The Act suggests that the Foundation set up four divisions: 1) medical research; 2) mathematical, physical and engineering sciences; 3) biological sciences, and 4) scientific personnel and education. The board is also authorized to form other divisions, and it is not ex-

THE CITIZEN

cluded from supporting research and education in social sciences.

For its first year, which will doubtless be devoted largely to organization, the Foundation will have an appropriation of $500,000. The Act limits its funds thereafter to $15 million a year. It may also receive transfers of research funds from other Federal agencies for grants.

After passage of the Act the Federation of American Scientists urged that the new Foundation immediately sponsor a "thorough study of postwar scientific activity in the U. S." as the basis for its activities.

AEC Reorientation

THE hydrogen bomb project and other military plans have caused substantial changes in the U. S. atomic energy program during the past two months. Sumner T. Pike, acting AEC chairman, observed in a public address that "we are doing some reshuffling of the projects and the personnel in the whole atomic energy program in order to bring the utmost weight to bear on the specific weapons development work which the President has recently directed us to pursue." In a series of guarded subsequent announcements, the AEC indicated the nature of some of these revisions. The most noteworthy announced change was the laying aside of the intermediate breeder reactor project, which many engineers consider to be a keystone in the experimental program for development of atomic power for industrial purposes.

The Commission first announced that it had "temporarily deferred" construction of this reactor, being designed by the General Electric Company Knolls Laboratory, in order to obtain "firmer cost estimates" and permit the Knolls Laboratory to turn to work on "the expanded atomic energy production program." Two weeks later the Commission disclosed that the Knolls Laboratory was shifting to the construction of an intermediate reactor for the Navy. The revised project will not test the breeding principle but will be devoted to the single purpose of developing a nuclear power plant using intermediate-speed neutrons for a ship's engine. Thus the AEC now has two naval reactor projects; the Westinghouse Electric Corporation is soon to build a prototype of a ship reactor using slow neutrons at the AEC reactor testing ground in Idaho. A House committee last month approved a request by the Navy for funds to construct a submarine to be powered by such a reactor.

The AEC further announced that a

new $7-million particle accelerator for secret research will be built at a Naval Air Station in the San Francisco Bay area. The project will be carried out jointly by a subsidiary of the Standard Oil Company of California and the Radiation Laboratory of the University of California.

More Particles

THE list of atomic particles steadily lengthens. The discovery of three new ones, raising the number so far observed to 14, was reported at a meeting of the American Physical Society in Washington, D. C., last month. One of the new particles, created in an accelerator, is a double neutron of extremely short life. The other two are rare cosmic-ray particles, one of which may be larger than a proton.

The double neutron was made in an electrostatic generator at the Los Alamos Scientific Laboratory by bombarding tritons (nuclei of hydrogen 3) with other tritons at high energies. The resulting fusion of two tritons resulted in an alpha particle (nucleus of helium 4) and a double neutron, which split in much less than a billionth of a billionth of a second into two ordinary neutrons.

The two cosmic-ray particles were found by a group headed by Carl D. Anderson, discoverer of the positron, at the California Institute of Technology. The same particles had been reported in 1947 by G. D. Rochester and C. C. Butler of the University of Manchester, but they had not been observed again until Anderson's group detected them several months ago in a specially rigged Wilson cloud chamber. It took 11,000 photographs, of which 8,000 were taken at 10,500 feet on White Mountain, to obtain 30 pictures of one particle and four pictures of the other. The first is an uncharged particle; its mass has not been determined, but it is believed to range either from 500 to 1,000 times the mass of an electron or from 2,200 to 2,500 electron masses. The other new particle is a charged fragment of still-unknown mass.

The list of atomic particles now stands: electron, positron, proton, neutron, double neutron, neutrino, photon, five kinds of mesons and the two new cosmic-ray particles, as yet unnamed.

At the Washington meeting of the American Physical Society a group from the University of California presented definite proof of the existence of a medium-weight neutral meson that had been considered doubtful. They found that its mass is 270 to 300 times that of an electron.

Seven Factors of Personality

THE University of Chicago psychologist L. L. Thurstone, author of the famous factorial analysis method by which he resolved intelligence into seven primary mental abilities, has applied the same analysis to personality and identified seven major factors in human temperament. He reported his findings at the recent meeting of the National Academy of Sciences in Washington. The seven factors that account for people's temperamental differences, he said, are:

1. General activity or drive. A person whose personality is high in this factor is always "on the go," walks fast, drives fast and talks fast.

2. Interest in athletics, or masculinity. Persons high in this factor like to be out of doors and to work with tools.

3. Impulsiveness. People who get high scores on this factor are happy-go-lucky, act on the spur of the moment, make decisions quickly and like competition.

4. Dominance. Those who score high on this factor think of themselves as leaders and enjoy promoting new projects, presiding at meetings and persuading others.

5. Emotional stability. Those with high scores are characteristically cheerful. "They can relax in a noisy room, and they remain calm in a crisis. They don't fret about the daily chores, and they are not irritated if they are interrupted when they are concentrating. They awake rapidly after sleep."

6. Sociability. High scorers on this factor get along well with other people, are sympathetic, cooperative and agreeable, and are usually tolerant of a great variety of foods.

7. Reflectiveness. People who score high on this like to deal with theoretical rather than practical problems, are usually quiet, like to work alone, and enjoy work that requires accuracy and fine detail.

Thurstone has devised an objective test of 20 questions for each of these factors.

Aureomycin for Pigs

THE golden antibiotic aureomycin is more effective than vitamins in accelerating the growth of animals; it can speed up the growth of chicks, pigs and turkeys by as much as 50 per cent. This surprising discovery was announced at the recent national meeting of the American Chemical Society in Philadelphia by E. L. R. Stokstad and T. H. Jukes of Lederle Laboratories.

The discovery was an accidental byproduct of the Laboratories' research on vitamin B-12, an animal protein factor that has come into wide use in the feeding of hogs and chickens. B-12 is a fermentation product. Aureomycin is obtained from a mold by fermentation. Recently the Lederle investigators noticed that the mold residue of aureomycin contained commercial quantities of B-12. They then found that this mixture was more effective in stimulating growth than B-12 alone. Further tests showed that the introduction of only .0004 of an ounce of aureomycin in a pound of feed increased the average rate of an animals' growth by about 10 to 15 per cent.

Why aureomycin has this effect is not known. Stokstad and Jukes suggested that it may aid growth by attacking detrimental microorganisms in the intestinal tract that may rob the intestine of some unknown vitamin or produce a toxic compound.

Bottle Tits

FOR some time British milkmen have been puzzled and annoyed by a growing practice among British birds: they have formed the habit of prying open the tops of milk bottles left on doorsteps and drinking the milk. The chief offenders are various varieties of tits, notably the great tit (*Parus major*), the blue tit (*P. caeruleus*) and the coal tit (*P. ater*). The tits began this stealing of milk as far back as 1921, and by now sparrows, blackbirds, starlings, robins and several other species have caught the habit.

In a recent issue of *Nature* an investigator named T. H. Hawkins reported that he and others had looked into the matter and were more puzzled than ever. How did the birds find out that there was food inside milk bottles? How did they learn to open the bottles? Did they learn from one another or did each bird make the discovery independently?

After investigating some 400 recorded cases of this avian pillage Hawkins is inclined to think that it is a case of independent intelligence. He points out that British tits seldom migrate more than a few miles from their breeding place, so they could hardly have passed on their skill to the predators in widely separated parts of England, Wales, Scotland and Ireland. He finds that the same bird often uses different tactics on different milk bottles. "When the milk bottle is closed by a cap of metal foil, the bird usually first punctures the cap by hammering with its beak and then tears off the metal in thin strips. Cardboard caps may be treated in a variety of ways. The whole top may be removed, or only the press-in center, or the cardboard may be torn off layer by layer until it is thin enough for a small hole to be made in it."

In areas where different grades of milk are distinguished by different colored caps, the tits generally show a marked preference for one particular type. "The bottles are usually attacked within a few minutes of being left at the door," says Hawkins. "There are some reports of parties of tits following the milkman's cart down the street and removing tops from bottles in the cart while the milkman is delivering milk to the houses."

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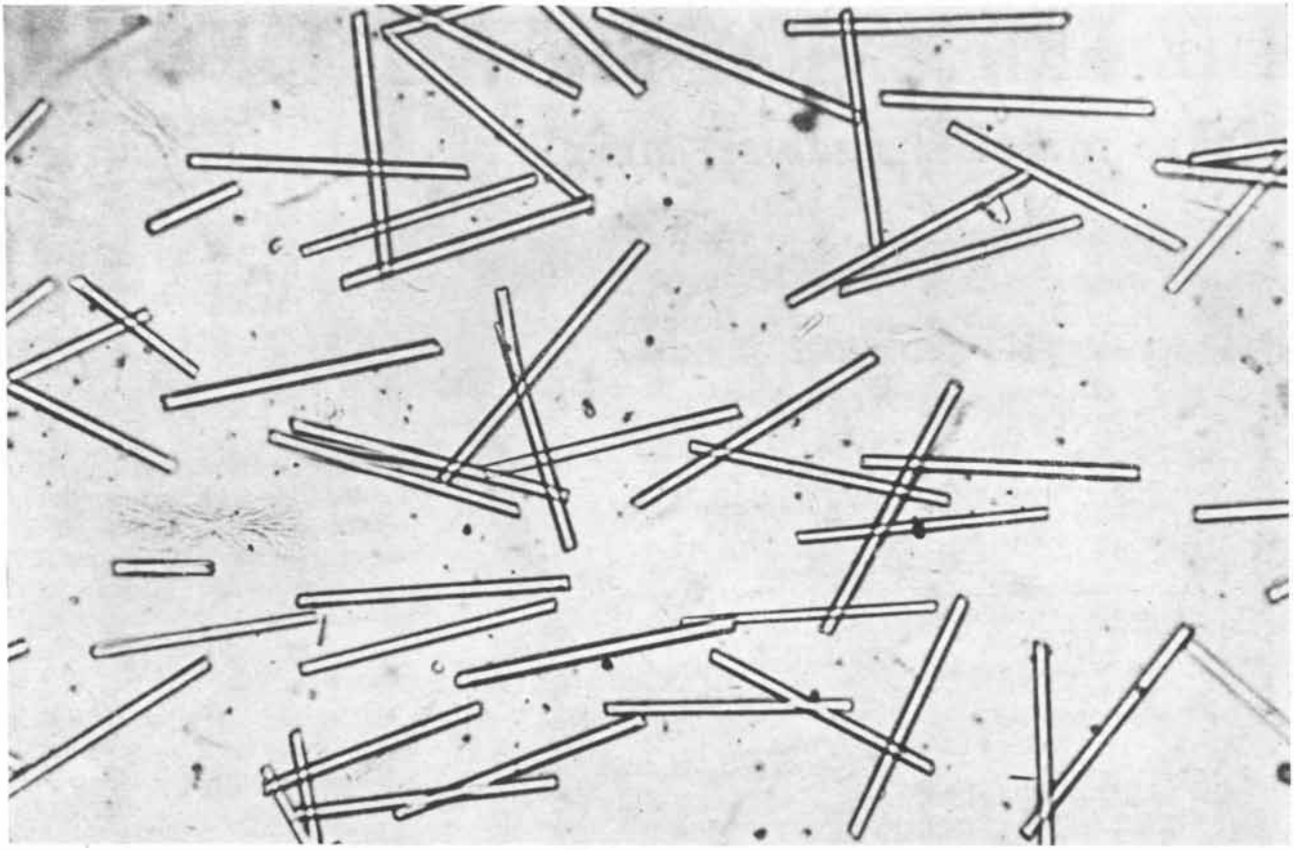
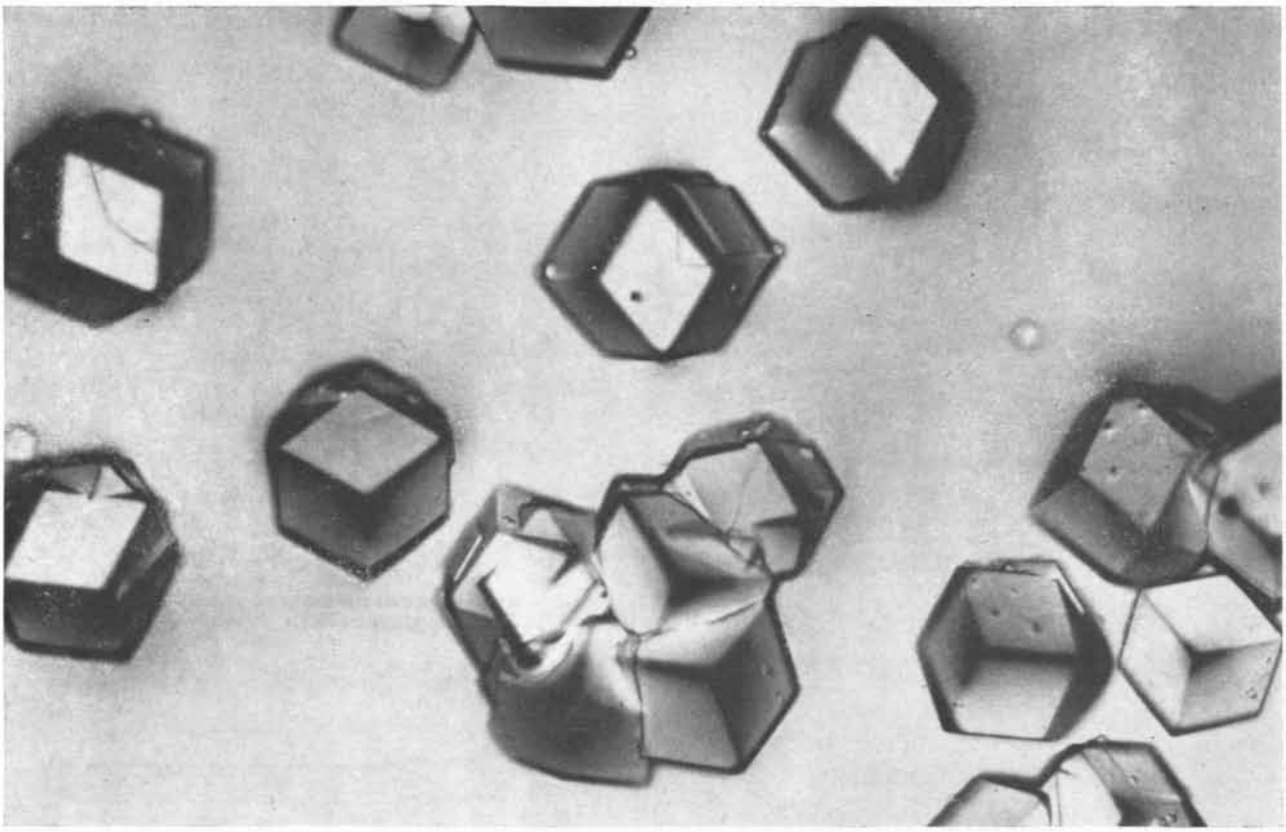


THE ENZYME PHOSPHORYLASE, like other enzymes, is a protein. These phosphorylase crystals, magnified 270 times, were isolated by Arda Alden Green and Gerty T. Cori of Washington University at St. Louis.



THE BUSHY STUNT VIRUS, like other viruses, is also a protein. These bushy stunt virus crystals, magnified 336 times, were isolated by Wendell M. Stanley, then of the Rockefeller Institute for Medical Research.

PROTEINS

The large molecules characterized by nitrogen are synonymous with life. Their structure and function are fundamental problems of chemistry

by Joseph S. Fruton

There is present in plants and in animals a substance which . . . is without doubt the most important of all the known substances in living matter, and, without it, life would be impossible on our planet. This material has been named Protein.

SO WROTE Gerard Johannes Mulder, a Dutch agricultural chemist, in 1838. It was in his scientific papers that the word "protein," from the Greek *proteios,* meaning of the first rank, made its first public appearance. The word had been suggested to him by the great Swedish chemist Jöns Jacob Berzelius (who also introduced to chemistry "catalysis," "polymer" and other important terms). Mulder and his great German contemporary Justus von Liebig thought that protein was a single substance—a basic structural unit existing in the same form in materials as diverse as egg white and blood fibrin. This was soon shown to be an error; the number and variety of proteins was found to be legion. But Mulder has certainly been proved correct in his emphasis on the importance of proteins to life.

The proteins are one of the three principal organic constituents of living matter (the fats and carbohydrates are the others), but in the importance and diversity of their biological functions they stand alone. They represent nearly one half of the body's dry matter. (About 70 per cent of the body is water.) Of the total body protein, more than a third is found in the muscles: the protein myosin forms the fibers that are the fundamental contractile elements in muscular movement. The bones and cartilage account for another 20 per cent; here the protein collagen contributes to the structural stability of the skeleton. And the skin has about 10 per cent of the body protein, the skin protein keratin serving to protect the interior tissues against attack from the external environment.

Perhaps the most important of the proteins are the enzymes. These substances are present in only minute amounts in comparison with myosin, collagen or keratin, but they are indispensable for the promotion and direction of the body's myriad chemical reactions. Thus the digestion of foodstuffs in the stomach and the intestine depends on the continuous activity of protein enzymes such as pepsin or trypsin. It is the synchronized action of a series of enzymic proteins that enables the body cells to use oxygen to oxidize the carbon and hydrogen in food and thereby provide the major portion of the chemical energy required for vital functions. This energy is used not only for muscular movement but also to counteract the wear and tear of living tissues by the continuous regeneration of body constituents, including the proteins, under the specific directive influence of a host of other enzymes.

The hormones also are proteins. These remarkable products of the secretory activity of the endocrine organs are carried by the blood in infinitesimal amounts to the tissues, where they play a decisive role in the regulation of the pace and direction of metabolism. Still other proteins are the antibodies of the blood, which defend the organism against viruses, which are themselves proteins, and the harmful substances produced by disease-causing bacteria. Finally the genes, the basic units of heredity, are believed to contain a particular type of protein called nucleoproteins.

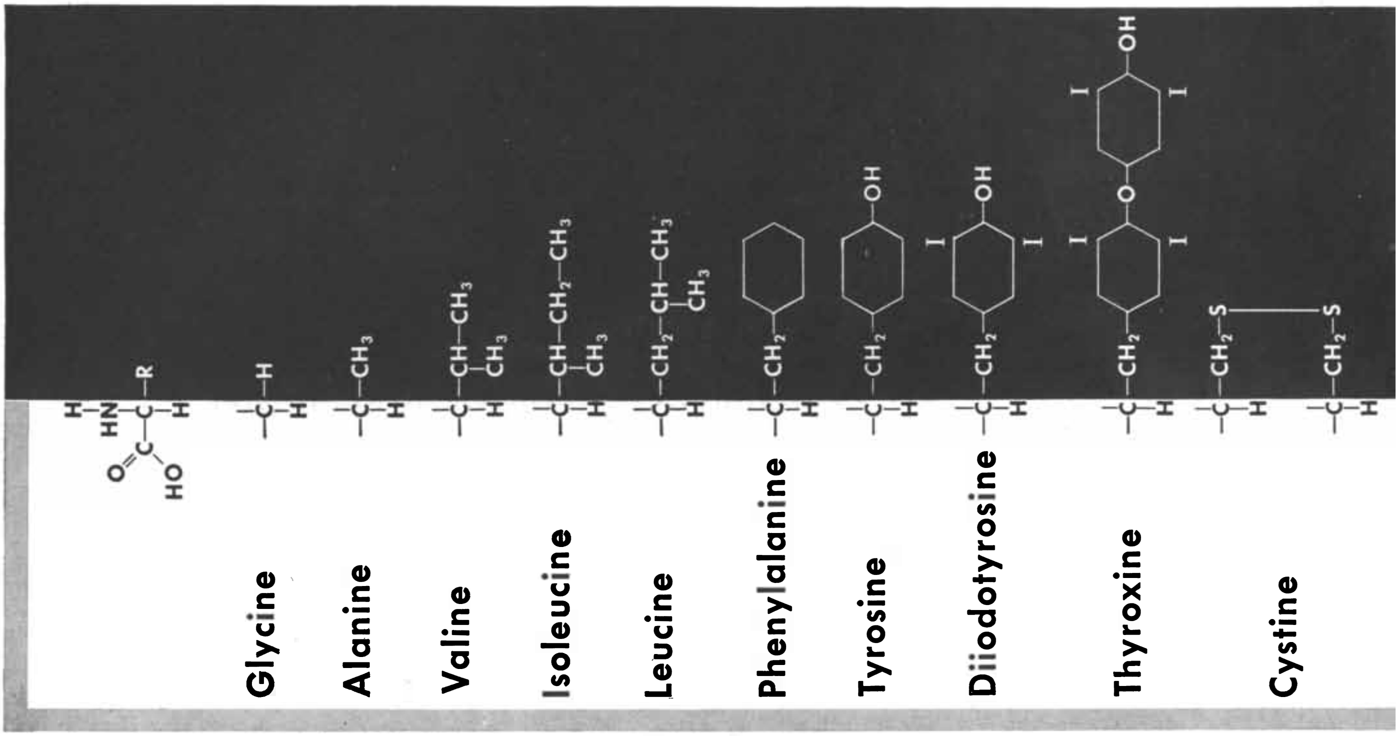
Where there is such diversity of function, there must be a corresponding diversity of chemical structure. The number of identified proteins is extremely large, and growing rapidly. To learn what proteins are present in living systems, to examine their chemical structure, to explain their biological functions in terms of their structure—these are among the most fundamental problems of modern biochemistry. When the answers to them have been found, we shall have a much more precise definition of what has been termed "the physical basis of life."

The Problem

To study the chemical structure of a particular protein it is necessary to destroy the cellular organization characteristic of life and to extract the protein with a suitable solvent, such as a dilute salt solution. This procedure inevitably brings into solution many of the other proteins present in the cell, and the task of separating the desired protein from the unwanted materials becomes a test of the experimenter's skill and, very frequently, of his good fortune. Proteins are extremely fragile chemical structures. This imposes serious restrictions upon the kind of laboratory procedures the chemist may use in separating them from one another. Delicate techniques for separating proteins have, however, been worked out during the past 25 years in fundamental researches by a number of great biochemists, especially Sven P. L. Sörensen of Denmark, Otto Warburg of Germany, and John H. Northrop, Moses Kunitz, Edwin J. Cohn and Carl F. Cori of the U. S.

By careful control of factors such as salt concentration, alcohol concentration, acidity and temperature, fairly selective precipitation of a given protein may be achieved; today it is often possible to isolate a single protein from the dozens or even hundreds present in a tissue extract. Many individual proteins have been obtained in the form of crystals which may be recrystallized at will, thus leading to further purification. Although crystallinity *per se* is not a satisfactory criterion of a protein's purity, the availability of crystalline proteins has for the first time given to the biochemist reproducible material for the study of the chemical nature of these substances.

All proteins are made principally of carbon, hydrogen, oxygen, and nitrogen. It is the nitrogen, representing from 12



THE AMINO ACIDS are the molecular constituents of proteins. Shown in this chart are all 22 of the amino acids that have been obtained by breaking down proteins (*see diagram on page 38*). At the far left is the

to 19 per cent of the molecule, that is the special mark of a protein. Most proteins also contain small amounts of sulfur, and many have some phosphorus. Over a century ago Mulder, noting these very small proportions of sulfur and phosphorus in his crude protein preparations, concluded that the protein molecule must be huge, since each molecule had to contain at least one atom of these elements. Proteins, in other words, are "macromolecules." Not until modern methods of measuring their molecular weights were developed, however, was it possible to determine just how large they are.

The most reliable and convenient method is to whirl them in an ultra high speed centrifuge, a technique devised by the Swedish physical chemist, The Svedberg. The proteins are spun in a centrifuge at speeds up to 70,000 revolutions per minute, which develops a centrifugal force as much as 400,000 times that of gravity. In such a field the large protein molecules move outward from the center of rotation with selective speeds: the larger they are, the faster their motion. An ingenious optical apparatus measures the rate of this molecular sedimentation, and the molecular weight can then be calculated.

Their Size

Now these measurements show that the smallest known protein is about 13,000 times as heavy as a hydrogen atom, *i.e.*, its molecular weight is about 13,000. The largest known proteins have molecular weights of the order of 10 million. To determine the structure of molecules of such sizes is obviously quite a formidable problem. One can get some idea of how formidable it is by comparing a protein with a nonprotein organic molecule. A particularly complex example of the latter is one of the penicillins, which has a molecular weight of 334 and the formula $C_{16}H_{18}O_4N_2S$. This molecule is simplicity itself in comparison with the typical milk protein lactoglobulin, whose molecular weight is about 42,000 and whose approximate formula is $C_{1864}H_{3012}O_{576}N_{468}S_{21}$.

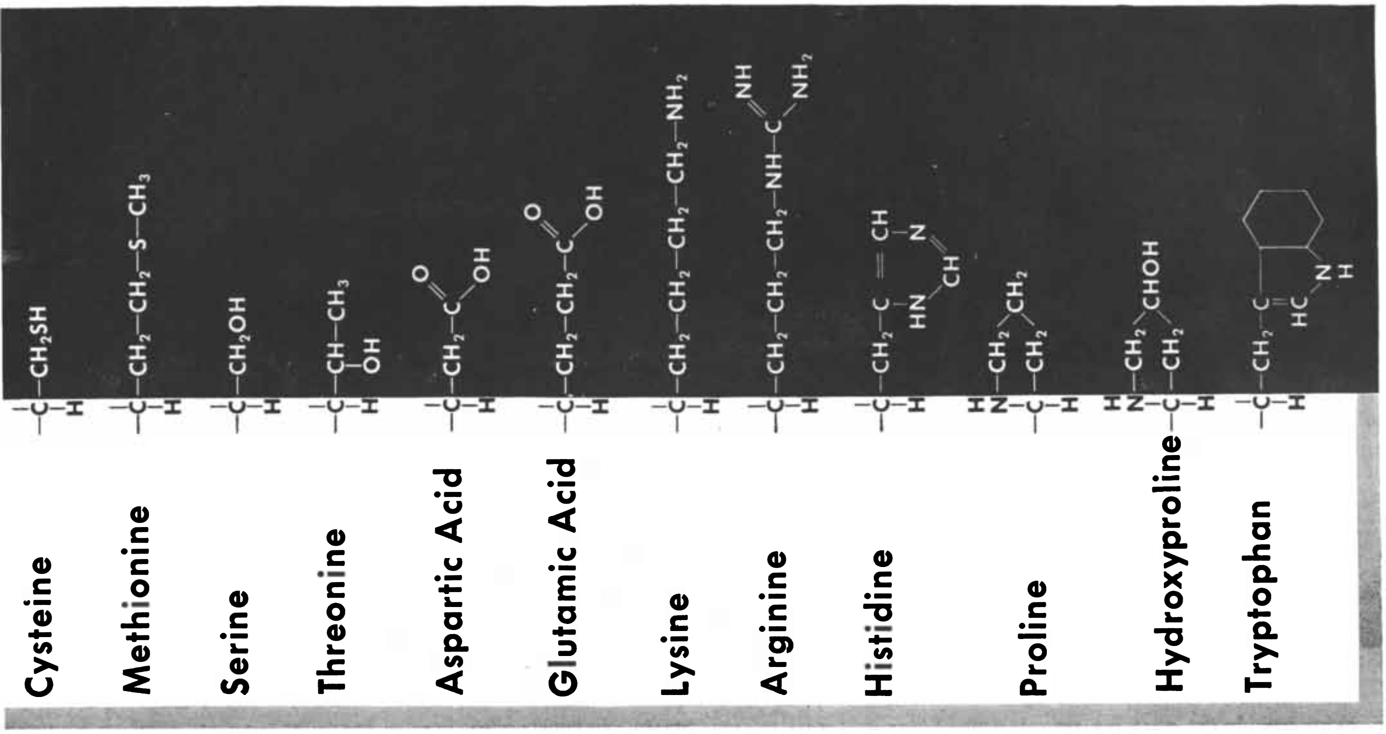
The structure of the penicillin molecule was worked out only after years of joint labor by the great chemists of the U. S. and England. The usual method of attacking such a task in organic chemistry is (1) to establish the proportions of the various elements in it, (2) to develop a working hypothesis about the arrangement of these atoms by a process of trial and error, and finally (3) to test the hypothesis by trying to synthesize the molecule from known substances by known chemical reactions. By this classical procedure organic chemists within the past 100 years have found the formulas of about 500,000 organic compounds, including many that are made by living organisms. But in a protein the number of atoms is so large that it has not been possible to establish its molecular structure by this method.

What the protein chemist can do at present is to cleave the protein molecule into the smaller molecules of which it is composed—the amino acids. The protein is cleaved by treatment with acids or alkalis; because water enters into the reaction, the process is called hydrolysis. When the protein has been broken down into its amino acids, the chemist can then obtain some clues to its composition, because the atomic structures of the amino acids themselves have all been determined by the classical methods of organic chemistry.

The amino acids formed by hydrolysis of a protein have certain structural features in common: each has an acidic carboxyl group (COOH) and a basic amino group (NH_2) or imino group (NH). Both the acidic and basic groups are attached to the same carbon atom, the so-called alpha-carbon. Since a carbon atom has four chemical bonds, this same alpha-carbon has two other units linked to it. One of these is invariably a hydrogen atom. What distinguishes the amino acids from one another is the fourth group attached to the alpha-carbon. This group, the so-called side chain, differs in each amino acid.

Isolating Amino Acids

The simplest amino acid, glycine, was isolated in 1820 by the French chemist Henri Braconnot. He obtained it by acid hydrolysis of gelatin. The list of known amino acids from proteins has now grown to 22. It is not likely that many new ones will be added to it. Every protein amino acid except glycine can exist in two geometrical forms, one the mirror image of the other; by convention



basic chemical structure common to all amino acids. In the shaded area are the characteristic structures of the various amino acids. The amino acids are here arranged in the order of their similarities in structure.

these are designated the "L" and "D" forms. Only the "L" type of the amino acids is obtained by the hydrolysis of proteins.

During the past 80 years an intensive effort has been devoted to the development of experimental methods for the accurate quantitative determination of the relative amounts of the various amino acids formed by hydrolysis of a protein. All the great names associated with the recent history of protein research have been linked with ingenious techniques designed to solve this problem. Among them are those of the German chemists Albrecht Kossel and Emil Fischer, Thomas Burr Osborne of the Connecticut Agricultural Experiment Station, and Max Bergmann and Donald D. Van Slyke of the Rockefeller Institute for Medical Research.

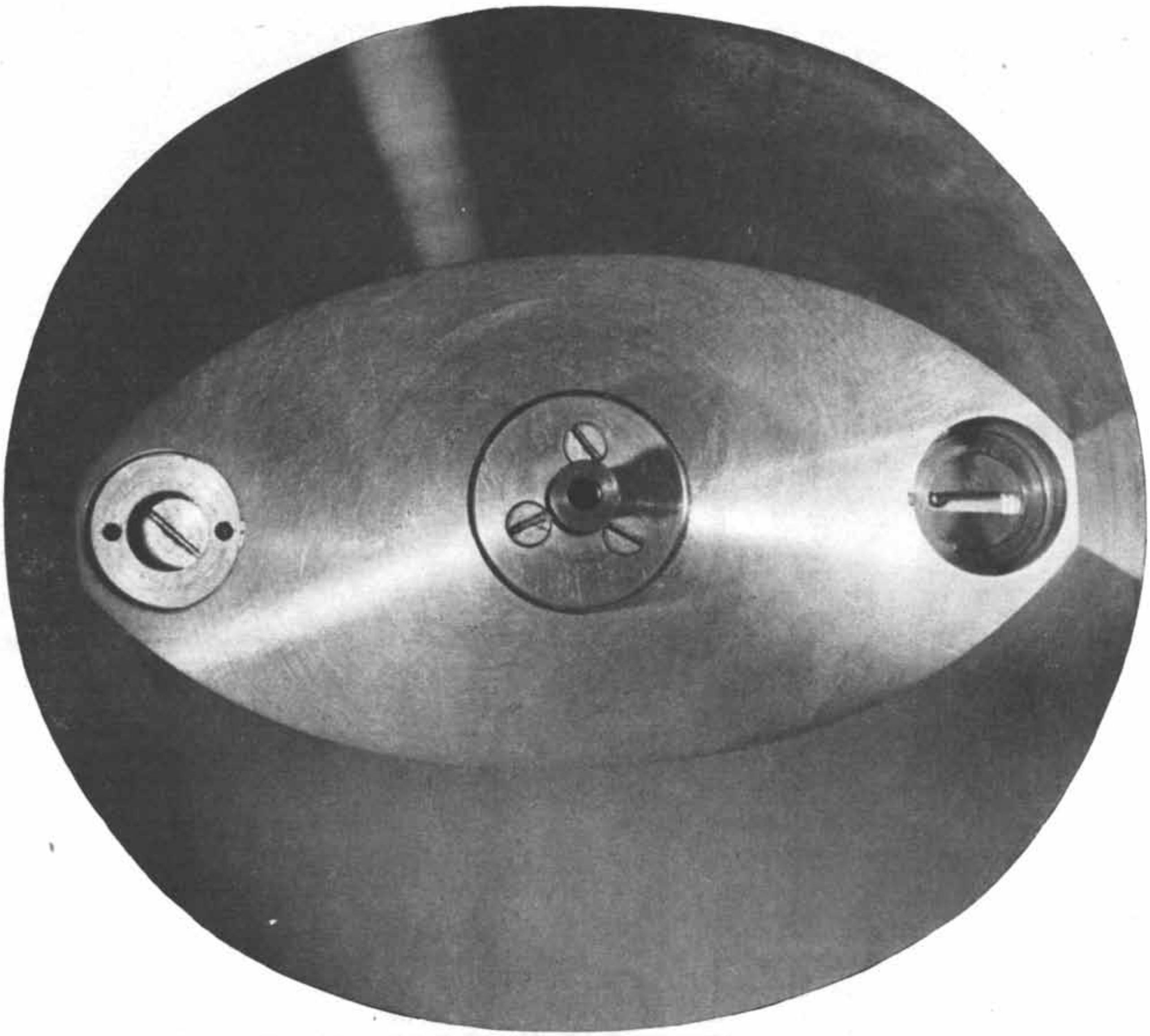
Because the various amino acids are structurally similar in all respects except the nature of the side-chain group, the problem has been to find chemical processes that will select and isolate them on the basis of this rather subtle mark of identification. Until about a decade ago the main effort was concentrated on a search for specific chemical reagents which in each case would precipitate completely a single amino acid from the complex mixture produced by the hydrolysis of a protein. A few amino acids were actually determined by this method, but eventually it became clear that it was hopeless to try to separate all the amino acids in this way.

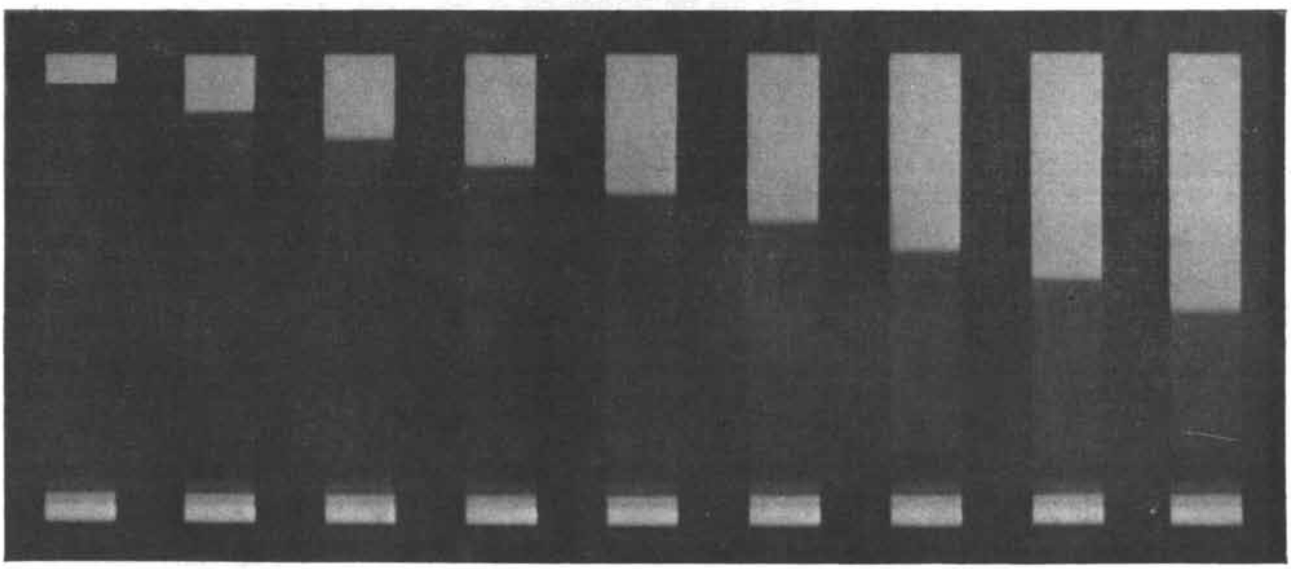
Several years ago Erwin Brand of Columbia University, by dint of much labor and the use of a number of different techniques, finally accomplished the first complete analysis of a protein into its constituent amino acids. There was still needed, however, a single reliable analytical method. In the past few years this goal has been achieved, and it is now possible to say that the problem of protein analysis has been solved, at least in principle.

The most valuable contribution to the solution was the development of new chromatographic techniques for the separation of amino acids. Chromatography itself was invented by the Russian botanist Michael Tswett in 1906. It got its name from the fact that it was first used to separate pigments. Tswett was interested in isolating the chlorophyll pigments of green leaves. He conceived the idea that they might be separated quickly by taking advantage of their differing rates of adsorption by an adsorbing material. As he himself described it, "if a petroleum ether solution of chlorophyll is filtered through a column of an adsorbent (I use mainly calcium carbonate which is stamped firmly into a narrow glass tube), then the pigments . . . are resolved from top to bottom into various colored zones, since the more strongly absorbed pigments displace the more weakly absorbed ones and force them farther downwards. This separation becomes practically complete if, after the pigment solution has flowed through, one passes a stream of pure solvent through the adsorbent column. Like light rays in the spectrum, so the different components of a pigment mixture are resolved on the calcium carbonate column . . . and can be estimated on it qualitatively and quantitatively. Such a preparation I term a chromatogram and the corresponding method, the chromatographic method."

Tswett realized that "the adsorption phenomena described are not restricted to the chlorophyll pigments, and one must assume that all kinds of colored and colorless chemical compounds are subject to the same laws." It was many years before this brilliant intuition of Tswett was appreciated. Since 1930 chromatographic techniques have been developed to separate colorless as well as colored chemical compounds. It was the English chemists A. J. P. Martin and R. L. M. Synge who found a way to apply the technique to the separation of amino acids. They introduced the use of a starch column as the adsorbent. From this idea William H. Stein and Stanford Moore of the Rockefeller Institute for Medical Research later worked out a beautiful method for the precise quantitative analysis of all the amino acids formed when a protein is hydrolyzed.

In their method a carefully prepared starch column in a tall glass tube is treated with an organic solvent such as butyl alcohol. To this column then is added the amino-acid mixture that is to be analyzed, this mixture also being diluted with the same solvent. After this, more of the solvent is passed through the column. The individual amino acids





THE ULTRACENTRIFUGE is used to determine the molecular weight of proteins. At the top is a rotor from the ultracentrifuge at the Rockefeller Institute. At the bottom is a series of photographs made by E. G. Pickels, now of the Specialized Instruments Corporation, showing the sedimentation of a protein in an ultracentrifuge.

move down the column, each at a different rate that depends largely on the nature of its side chain. Under favorable circumstances, these differences in rate may be so great that each of the amino acids emerges from the column separately. Thus it is possible to follow accurately the successive appearance of the separate amino acids and to determine the amount of each.

So far only a few proteins have been studied by this method, but the results attained are sufficient to indicate its great importance in protein chemistry. Nevertheless, it has not by any means solved the problem of protein structure. What this advance has accomplished is to bring the proteins to the historical stage reached by the simpler organic molecules a century ago, when it became possible to calculate the relative proportions of the atoms constituting an organic compound. From this, organic chemists were able to go on to discover the arrangement of the atoms in an organic molecule. In the same way protein chemists are now in a position to proceed with greater confidence to consider the spatial arrangement of amino acids in a protein molecule.

How Amino Acids Are Linked

The next question concerns the nature of the linkages between the individual amino acids. The most widely accepted hypothesis is one proposed independently by Emil Fischer and the German biochemist Franz Hofmeister in 1902. They suggested that the amino group attached to the alpha-carbon of one amino acid is joined to the carboxyl group attached to the alpha-carbon of another. This union is accompanied by the elimination of the elements of water from the molecules that unite. It is this bond that is broken when the elements of water are introduced in acid hydrolysis. The bond is called a "peptide linkage," and the Fischer-Hofmeister hypothesis is known as the peptide theory.

The theory has been supported by so much experimental evidence that its essential truth seems highly probable. Support for the theory came from work on artificially synthesized peptides, *i.e.*, groups of amino acids linked together by peptide bonds. In this Fischer was the pioneer; he pointed out that "if one wishes to attain clear results in this difficult field, one must first discover a method which will permit the experimenter to join the various amino acids to one another in a stepwise manner and with well-defined intermediary products." Much research has been done during the past half-century, and is still continuing, to develop methods for the laboratory synthesis of peptides. One of the greatest achievements came in 1932 with the invention of the "carbobenzoxy" method by a distinguished pupil of Fischer, Max Bergmann, who was then director of the Kaiser Wilhelm Institute for Leather Research in Dresden and later came to the Rockefeller Institute for Medical Research.

In living systems proteins are hydrolyzed by enzymes such as pepsin, trypsin and chymotrypsin. These catalysts act to speed up the hydrolytic reactions, thus making it possible for them to take place at the ordinary temperatures and under the normal acidity conditions of the organism. According to the peptide theory, these enzymes cause the hydrolysis of peptide bonds. If this theory is correct, then the same enzymes should hydrolyze simple peptides synthesized in the laboratory. For a long time protein chemists made intensive but vain efforts to create synthetic compounds that could be hydrolyzed by the enzymes, and their failure was interpreted by some as evidence against the peptide theory. In 1937, however, the author, working in Bergmann's laboratory at the Rockefeller Institute and using the carbobenzoxy method of peptide synthesis, succeeded in forming synthetic compounds which were specifically hydrolyzed at their peptide bonds by these enzymes. This finding strongly supported the Fischer-Hofmeister theory.

The Peptides

An additional support for the peptide theory is the finding that when the hydrolysis of protein is interrupted before the protein is entirely converted to amino acids, peptides can occasionally be isolated. The isolation of peptides obviously is not easy, for we have here the same difficulty of separating the components of a complex mixture that we encounter in the case of amino acids. The problem is, if anything, even more complicated, because the number of different peptides into which a protein may be split is considerably larger than the number of possible amino acids, and the amount of each peptide is very small. The new methods of chromatography appear well suited to the fractionation of peptides, and many investigators are now using them. Another valuable new approach to the problem has recently been provided by Lyman C. Craig of the Rockefeller Institute. He has developed a separation method based on the same general principles as are the familiar laboratory procedures for the extraction of a chemical substance from one solvent, such as water, by another solvent, such as ether. With this method Craig has demonstrated that preparations of several of the antibacterial agents, such as gramicidin, which were thought to be pure peptides, actually are mixtures of several distinct but closely related peptides. It is to be expected that this promising technique and the chromatographic method will form the main experimental lines of attack in the investigation of peptides obtained from proteins.

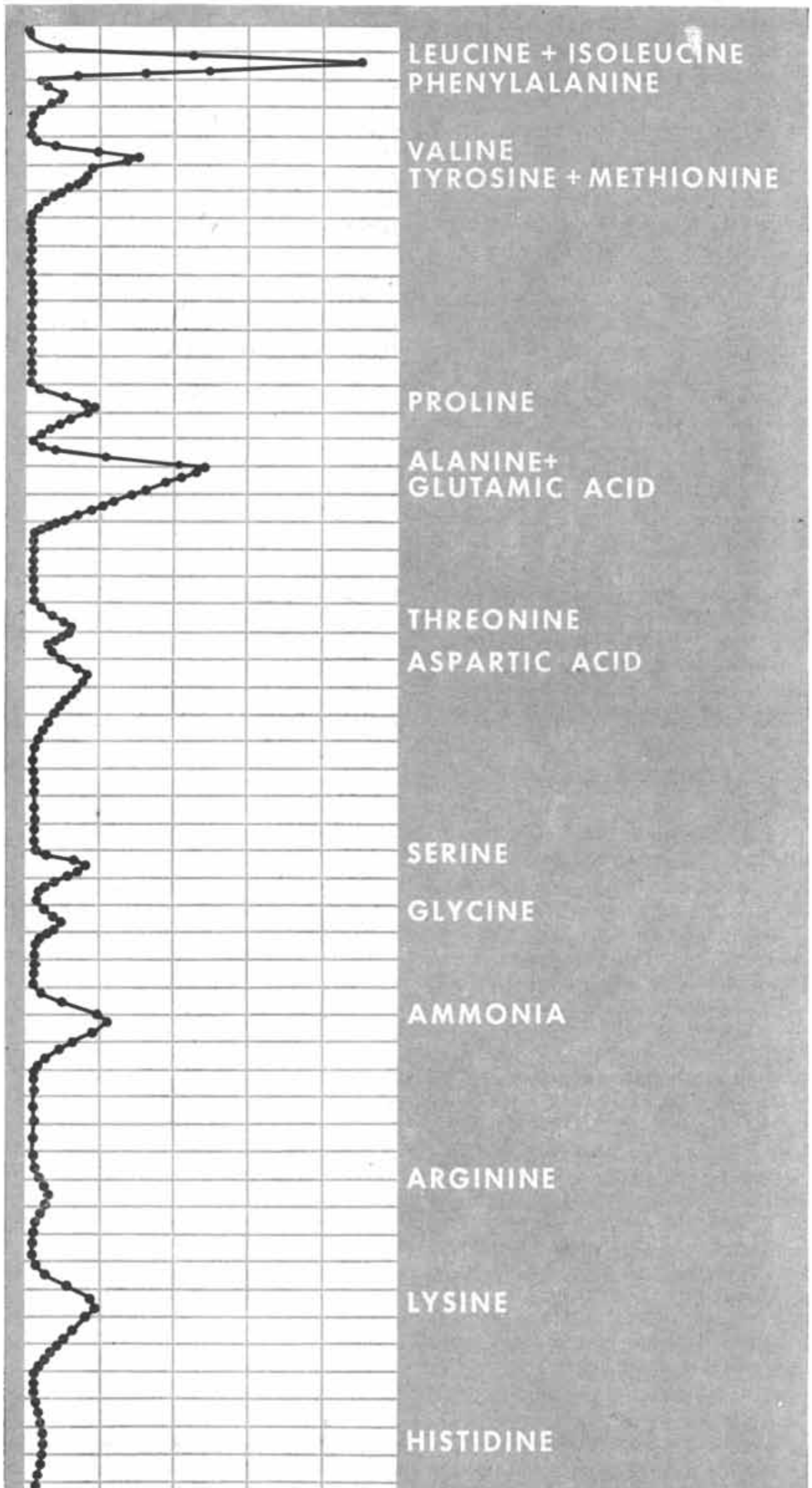
The brilliant work now being done by the British chemist Frederick Sanger at Cambridge University provides further grounds for optimism. Sanger is studying the structure of the important protein hormone insulin. He has subjected insulin to the action of the reagent dinitrofluorobenzene, a substance that combines readily with the alpha-amino groups at the ends of insulin's peptide chains. The result of this combination is a compound called dinitrophenylinsulin (DNP-insulin). All the end alpha-amino groups in the compound are occupied by dinitrophenyl (DNP) groups. When the protein is subjected to hydrolysis by strong acid, all the peptide bonds are cleaved, but the linkages between the DNP group and the alpha-amino groups of the end amino acids are essentially unaffected. In other words, each end amino acid remains linked to a DNP group. Since the DNP group confers upon any compound in which it is present a distinctive yellow color, the DNP-amino acids can readily be separated by means of chromatography, and their structure can be determined.

By this method of analysis Sanger has shown that the basic structural unit of insulin is composed of four peptide chains, of which two have glycine and two have phenylalanine as the end amino acids. He has also offered strong evidence for the idea that the four peptide chains are held together by bridges consisting of two sulfur atoms; when these disulfide bridges are broken by a relatively mild chemical treatment, the peptide chains are separated from one another. The next step, which is now occupying Sanger's attention, is to determine the sequence of the amino acids in each of these four chains. For this purpose the four DNP-peptides are subjected to partial, rather than complete, acid hydrolysis of the peptide bonds. The result is a series of yellow DNP-peptides that can be separated by chromatography. If the elucidation of the structure of these peptides, now under way, is successful, the next step will be to attempt to construct a picture of the insulin molecule from the nature of the fragments.

Portrait of a Protein

The studies discussed thus far suggest that the protein molecule is a threadlike structure of several hundred amino acids, linked to one another through peptide bonds and strung out to form a chain (or several chains joined by disulfide bridges) of considerable length. There is good evidence that this description actually applies to insoluble proteins such as keratin or silk fibroin and to a few soluble ones, notably the myosin of muscle and the fibrinogen of blood.

But most of the known proteins are not threadlike or fibrous. The enzymes,



CHROMATOGRAPHY reveals amino acid content of decomposed protein beta-lactoglobulin. Vertical coordinate: amount of solvent passed through chromatographic tube; horizontal, concentration of amino acid in solvent.

the protein hormones and all the blood proteins except fibrinogen are globular. They are soluble in water or salt solutions, but this characteristic solubility may readily be lost or decreased by subjecting the proteins to relatively small increases in temperature (up to 140 degrees Fahrenheit) or to mild acidity. This alteration in solubility is referred to as "denaturation." When the shape of such altered proteins is studied, it is found that they now approximate more closely the fibrous proteins. The denaturation of an enzyme or of a hormone usually deprives it of its characteristic biological activity. In some cases, if the exposure of the protein to the unfavorable conditions is not prolonged unduly, its denaturation can be reversed by restoring normal conditions. The protein then regains its characteristic solubility and its biological activity simultaneously.

It is obvious, therefore, that protein denaturation is associated with the conversion of a globular molecule to a rather fibrous one, and that this transformation is accompanied by the loss of some of the important biological properties of the protein. A natural deduction from these facts is that the peptide chains in the globular protein are coiled in a very specific way and that this characteristic folding is made possible by specific bonds between parts of the peptide chains. We can also make a deduction about the relative strength of these bonds. They must be much easier to rupture than ordinary peptide bonds, because the conditions required for denaturation are quite mild compared with those necessary for the cleavage of peptide bonds.

The nature of these special bonds has been the subject of much stimulating speculation. Among the several theories is one offered in 1936 by Alfred E. Mirsky of the Rockefeller Institute for Medical Research and Linus Pauling of the California Institute of Technology. They suggested that a major factor in conferring upon the extended peptide chain of a protein its characteristic folding is the presence of "hydrogen bonds." This hypothesis has been successful in accounting for many of the known differences in the properties of "native" and denatured proteins. According to the theory, there are a multitude of bonds formed by the "sharing" of a hydrogen atom of an amino group with an oxygen atom of a carboxyl group. Taken individually these hydrogen bonds are weak, but in a protein molecule with several hundred amino-nitrogen atoms and a correspondingly large number of carboxyl-oxygen atoms, these weak bonds reinforce one another so that a stable structure results.

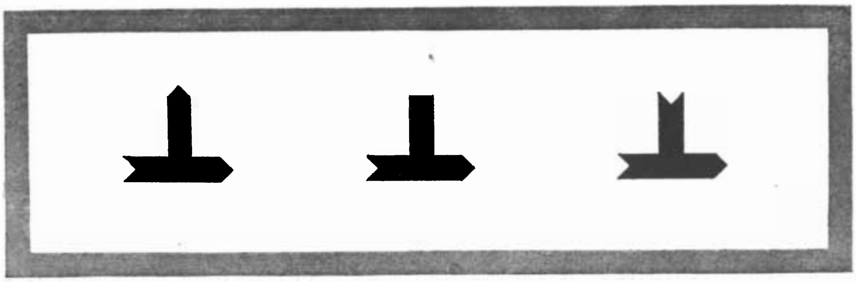
To the concept of the protein molecule as a long polypeptide chain or chains composed of many amino acids must therefore be added the idea that in each kind of protein the parts of the peptide chain have a characteristic internal arrangement which is responsible for that molecule's particular chemical and biological properties. Consequently the problem of protein structure involves not only the already formidable task of establishing the arrangement of the amino acids in the peptide chain, but even more difficult questions as to the nature and position of the bonds that are broken during denaturation.

Although the artificial creation of a protein molecule still lies beyond the powers of the chemist, it is no problem at all for the living organism. The living cell, whether of an amoeba or of a mammalian liver, performs the task of protein synthesis with rapidity and precision. Many organisms can use proteins foreign to their make-up, break them down to the component amino acids or peptides, and use the fragments to create their own characteristic proteins. Moreover, the proteins of a living organism are not laid down and kept intact throughout its life; rather there is a ceaseless breakdown and resynthesis of body proteins. In a sense, therefore, the problem of life is the problem of how living systems make proteins and how they constantly counteract the tendency toward protein degradation. Thus the study of the mechanisms by which cells synthesize proteins is perhaps the most challenging task of biochemistry.

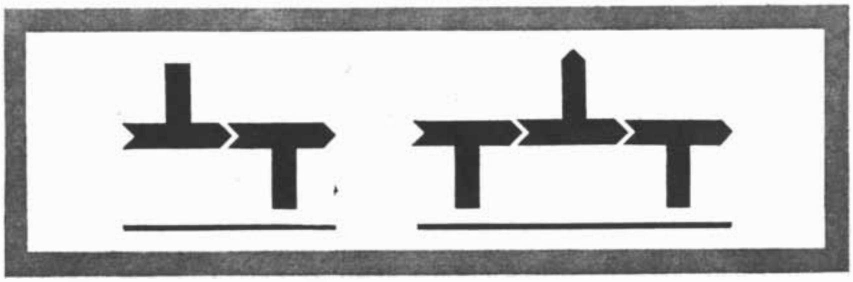
The Making of a Bond

A logical starting point for this investigation is the comparatively simple question of how living systems put two amino acids together to form a peptide bond. Many laboratories in this country are actively engaged in the exploration of this question. Although no clear-cut answer can yet be given, there are several hints as to its possible solution.

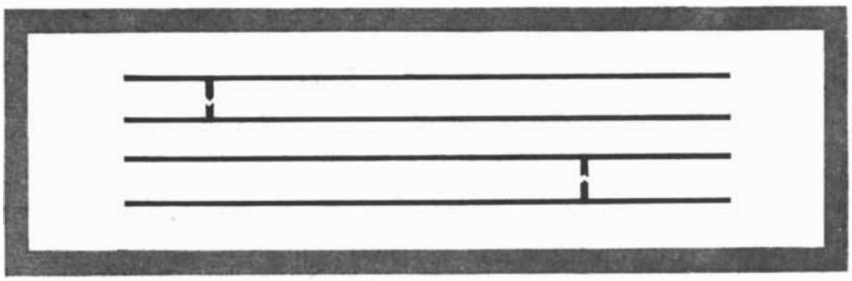
Among the views that have been entertained is the theory that in living cells the formation of peptide bonds is effected by the same enzymes that cause the breakdown of the peptide bonds after death. The principal support for this hypothesis has come from the demonstration that protein-splitting enzymes can indeed link two amino acids together to form a peptide bond. But this process will occur only under certain specific conditions. The most important of these is the necessity of counteracting the natural tendency of the protein-splitting enzymes to effect the hydrolysis of peptide bonds. A simple experimental procedure for achieving this reversal of hydrolysis is to choose a reaction which will result in formation of an insoluble peptide that comes out of solution as fast as it is formed. By taking advantage of this fact, it is possible to show without question that protein-splitting enzymes



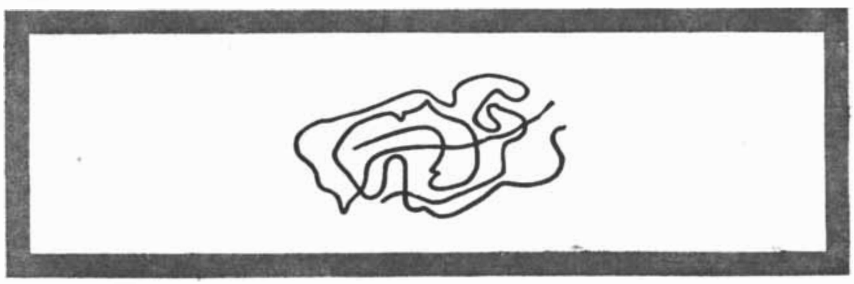
AMINO ACIDS are symbolized with acidic (*pointed*), neutral (*flat*) and basic (*notched*) ends. They are thus acidic (*left*), neutral (*center*) or basic.



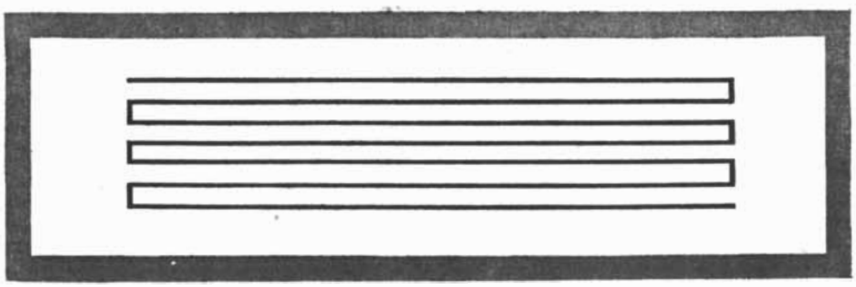
PEPTIDES are chains of amino acids joined acidic end to basic. Line below each peptide is a symbol for a longer chain of amino acids (*see below*).



FIBROUS PROTEIN is constructed of polypeptide chains (*parallel lines*). Some of the chains are joined by linkages between amino acid side chains.



DENATURED GLOBULAR PROTEIN is a disorganized skein of polypeptide chains. The structure of the protein in its native state is thus destroyed.



NATIVE GLOBULAR PROTEIN is made up of organized polypeptide chains. The organization, here shown in two dimensions, occupies three.

can catalyze the synthesis of peptide bonds.

The attractive feature of the theory is the fact that these enzymes exhibit a striking specificity of action on peptide linkages. In the case of the protein-splitting enzymes, the specificity of enzyme action depends largely on the nature of the amino acids that participate in the formation of the peptide bond. What is more, these enzymes act only at peptide linkages that involve amino acids of the L-type, which we noted earlier to be characteristic of the protein constituents. For example, one enzyme may catalyze peptide synthesis only when the amino acid that contributes the alpha-carboxyl group for formation of a peptide is L-tyrosine or L-phenylalanine. Replacement of either of these two amino acids by any other amino acid, as far as tests made so far show, prevents action by the enzyme. Indeed, biochemists know of no other group of biocatalysts that compares with the protein-splitting enzymes in their selective action on peptide bonds. By virtue of this sharp specificity, therefore, these enzymes are well fitted to direct, precisely and reproducibly, the complex sequence of successive peptide syntheses required for the formation of a protein.

To observe their synthetic action, however, it is necessary to remove the product from the reaction. In other words, work must be put into the system to counteract the natural tendency of the enzyme to hydrolyze the product after it is synthesized. It follows that if enzymes do actually perform peptide synthesis in cells, this process must be coupled to another reaction that provides the necessary chemical energy. There is excellent reason for believing that the chemical energy comes from the breakdown of foodstuffs such as glucose by oxidation or fermentation, but it has not been possible as yet to demonstrate that the breakdown of glucose is linked directly with peptide-bond synthesis in cells.

Possible Sources of Energy

Much attention has been paid in recent years to the suggestion of Fritz Lipmann of the Massachusetts General Hospital that peptide bond synthesis involves the intermediate formation of amino-acid derivatives of phosphoric acid. The source of these phosphoric-acid intermediates, according to Lipmann's theory, is a "high energy" phosphate carrier such as adenosinetriphosphate. The latter substance has been shown to play a decisive role in the exchanges of chemical energy that occur during the metabolic breakdown of sugars. Work in several laboratories during recent years has provided experimental evidence that phosphate-containing intermediates may indeed be involved in the biological formation of certain amides, such as hippuric acid or glutamine. These amides are closely related structurally to the peptides; they differ from the latter only in that the CO-NH bond links an amino acid to a non-amino acid group. The intervention of adenosinetriphosphate in the synthesis of the amide bond of glutamine, first demonstrated by the late John F. Speck of the University of Chicago, is of especial interest because this glutamic acid derivative is widely distributed in the tissues and fluids of animals and plants.

Although the experimental data offered in support of the Lipmann theory are impressive, they do not yet present a picture that would account satisfactorily for the specificity of peptide-bond formation. Each of the two theories discussed above thus contributes to a different, but equally essential, facet of the problem; it may well be that the two theories are complementary, rather than mutually exclusive. Such a view is supported by work begun in Bergmann's laboratory in 1937 and continued by the author at Yale University. These experiments have shown that protein-splitting enzymes will catalyze the hydrolysis and synthesis of peptide bonds. They have also shown that the same enzymes will cause reactions in which one of the two components contributing to a peptide bond may be replaced by another, without the need for the introduction of appreciable chemical energy but with the same specificity exhibited in synthesis and hydrolysis.

If these results should prove to have general significance, it would mean that an amide containing an amino acid derivative linked to ammonia (*e.g.*, glutamine) could exchange the ammonia for an amino acid or even a peptide. The energy for this process would come from the synthesis of glutamine, which, as Speck has shown, may involve a phosphate-containing intermediate. The specificity of the enzyme that catalyzes the exchange of the amide-nitrogen for the alpha-amino nitrogen of an amino acid or peptide would then determine the nature and sequence of the amino acids linked by peptide bonds in the final product. As a further consequence of this hypothesis, it would follow that a simple peptide composed of two or three amino acids would be transformed, in the presence of a suitable enzyme, into a longer chain by the replacement of one of the amino acids by a peptide. Energy would be required for the formation of the simple initial peptide, perhaps via a phosphate-containing intermediate, but the further course of peptide synthesis would be under the directive control of the highly specific enzymes that act at peptide bonds.

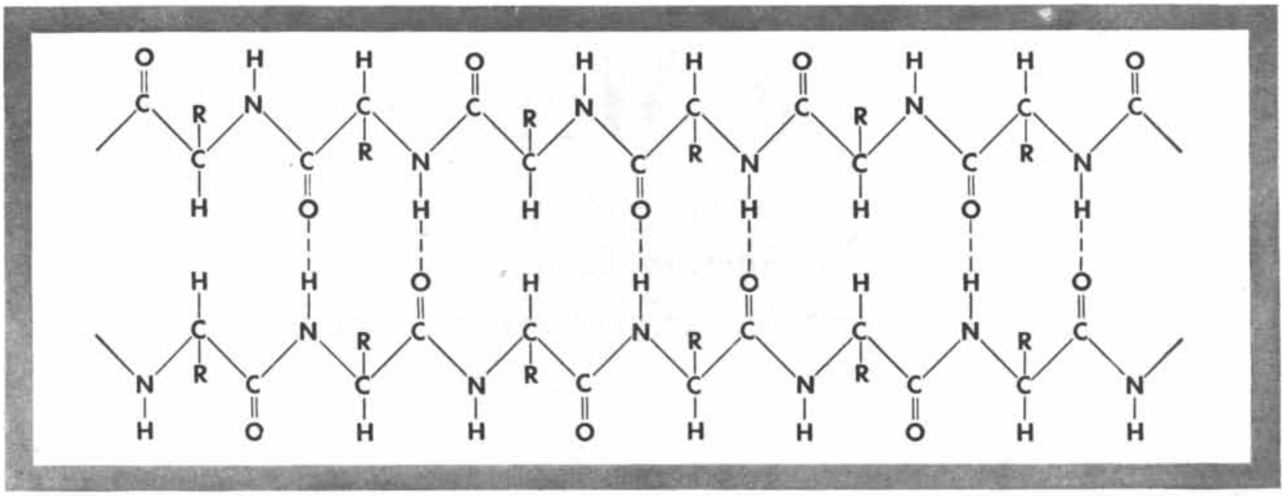
Another avenue of approach to the problem of how peptide bonds are formed is to seek out biological systems that exhibit unusual requirements for certain peptides, as compared with their demand for the individual amino acids of which these peptides are composed. If a bacterial cell, for example, uses a peptide for growth more efficiently than it does the amino acids, that would suggest that the rate of synthesis of the peptide controls the rate of utilization of the amino acids for protein formation. This approach is being explored in studies of the bacterial metabolism of peptides at Yale University by Sofia Simmonds in collaboration with the author. They may be expected to provide valuable biological material for the unequivocal testing of the various hypotheses relating to the mechanism of peptide-bond formation.

Nature's Noblest Structure

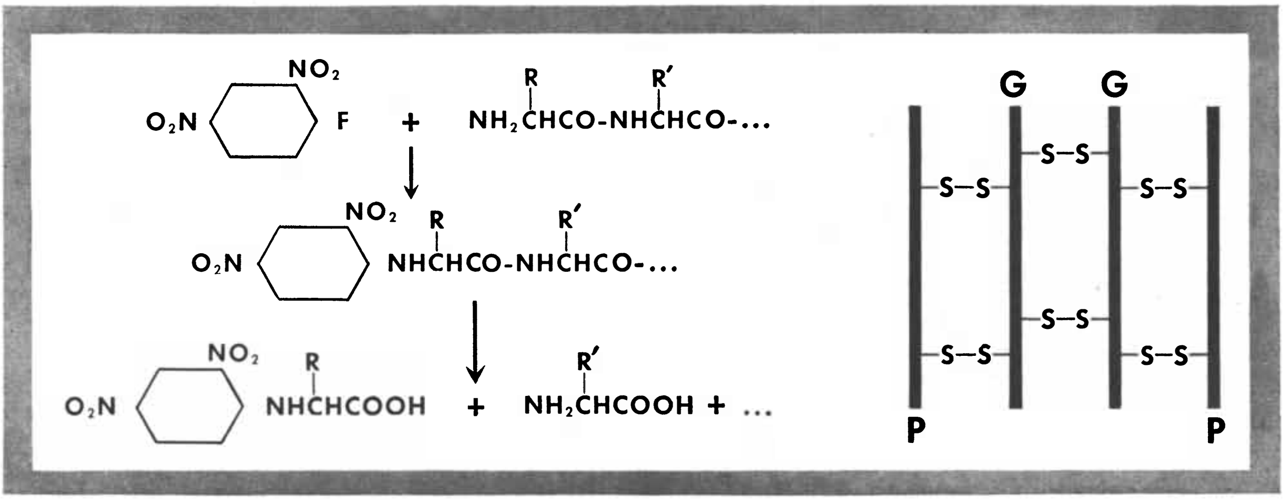
From all this it must be abundantly evident that the decisive discoveries in the study of the biological synthesis of proteins still lie in the future. Whatever the answer concerning the enzymatic mechanism of peptide-bond formation turns out to be, clearly it will provide only a part of the picture of the total process. What, for example, is the nature of the forces that confer upon the biologically interesting proteins, such as the enzymes and hormones, their characteristic physical, chemical and physiological properties? A denatured insulin molecule, though rendered inactive as a hormone, presumably still contains the same amino acids as the active molecule, and the peptide linkages that join these amino acids apparently have not been broken measurably. How, then, is the peptide chain molded in the living cell so as to form an active hormone with its specific attributes? Are we dealing here with an intricate mechanism whereby a model of the finished product is available as a matrix upon which the fragments are assembled?

These questions cannot be answered as yet, but it is well to remember that biochemistry is a relative newcomer among the scientific disciplines. Its growth has been meteoric, and it is exerting a decisive influence on the future development of all aspects of biology and their applications to medicine and agriculture. In the last analysis all the problems of biology meet in the unsolved problems concerning the structure and the mode of action of proteins. In groping for new experimental avenues into this great unknown, the protein chemist is thus probing into the basic questions of life. Whether he succeeds or not, he cannot help being filled with a sense of awe and humility in the face of what has justly been called the noblest piece of architecture produced by Nature—the protein molecule.

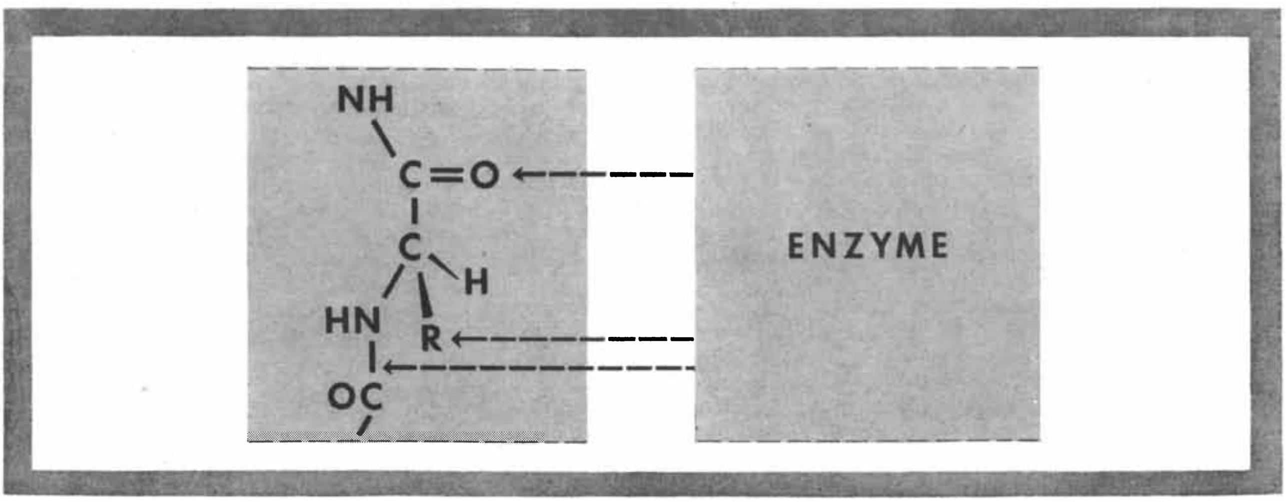
Joseph S. Fruton is professor of biochemistry at Yale University.



HYDROGEN BONDS between parallel polypeptide chains have been postulated as one of the forces holding together a highly organized native protein molecule. Here the hydrogen bonds are indicated by dotted lines. In the hydrogen bond a hydrogen atom is shared by amino acids in each of the parallel polypeptide chains.



END GROUPS of insulin were identified by allowing them to combine with reagent (*upper left*). When insulin was broken down, end groups were still attached to reagent. Such work showed that insulin has four peptide chains joined by disulfide bonds (-S-S- *at right*). Two chains end in glycine (G) and two in phenylalanine (P).



POSSIBLE ACTION of a protein-splitting enzyme is illustrated in this drawing. The enzyme molecule comes in contact with certain parts (*arrows*) of the protein molecule (*left*) in such a way as to make the sensitive peptide bond (*between* C *and* NH *at upper left*) more reactive. Only a segment of the protein molecule is shown.

The Great Meteor of 1947

Little has been told of the small asteroid that three years ago crashed into a Siberian forest. A brief account of one of the most impressive natural events witnessed by man

by Otto Struve

FEBRUARY 12, 1947, was a cloudless day in the Siberian village of Novopokrovka, a few hundred miles from the port of Vladivostok. The pale rays of the winter sun shone upon the land and into the windows of the village schoolhouse, where they fell upon a group of children absorbed in their morning lessons. Suddenly the class was startled by a brilliant flash like a bolt of lightning from the sky. With admirable presence of mind the teacher picked up an English textbook from a desk and recorded in it the time: "10^h35^m." The children hurried out of doors; in the sky overhead they saw only a long dark streak. The strange track hung in the sky for many hours, and when darkness fell it glowed like a streamer of the northern lights, against a background of sky that was itself unusually luminous.

Hundreds of other people in the same area who happened to be out of doors got a direct look at the phenomenon. Against the blue of the sky they saw a ball of light as brilliant as the sun and about the size of the full moon. It traveled swiftly across the sky toward the south, shedding showers of sparks and carrying in its immediate wake a brightly colored streak which quickly turned into a thick black trail. Within four or five seconds the object had disappeared in the general direction of the Sikhota-alin Mountains of Eastern Siberia.

News of this exciting event soon arrived in Moscow and came to the attention of the Academy of Sciences. In the belief that a large meteor had fallen in Siberia, an expedition of astronomers and geologists led by Basil Fessenkov, one of the ablest astrophysicists of the Soviet Union, set out immediately to look for traces of the object and to investigate the region where it had fallen.

On the rocky slopes of the Sikhota-alin Mountains the explorers found a series of more than 100 holes, some of them 30 to 40 feet deep and as wide as 75 feet at the top, scattered over an area of one square mile. The rocks of the slope had been completely shattered and the trees felled. Most of the trees had fallen radially from the direction of the center of each crater. Some had clearly been uprooted and thrown several miles high in the air before they fell.

Over an area of several square miles around the craters the ground was strewn with pieces of meteoric iron, ranging from chunks several hundred pounds in weight to tiny specks barely visible with a magnifying glass. The investigators described what they had seen as evidence of a veritable "rain of iron," the like of which had never before been recorded.

In the immediate vicinity of some of the smallest craters many trees were found standing, but their tops had been cut off by the flying iron. Standing in the center of a crater, the scientists could sight along the broken trunks of the trees and determine accurately the angle at which the meteor had approached the ground. The path of its flight was an arc from north to south; it had come in at first at an angle almost 60 degrees from the vertical, then had been retarded by the obstruction of the air and finally had struck at an angle of only about 38 degrees from the vertical.

IN a forest 50 miles from this spot the scientists found a woodcutter who had noticed a strange effect when the meteor passed by: the trees had suddenly begun to cast a second shadow other than that of the sun—a shadow that changed position swiftly in a peculiar turning motion, as though cast by a brilliant source of light in rapid flight. A hundred or more miles farther away people were found who had also remarked the unusual sight of a bright star in broad daylight—a white-yellow dot of light against the clear blue of the sky.

From the snow-covered ground on which the meteor had fallen distant witnesses had seen rising a gigantic brownish pillar, doubtless composed of rocks, dirt and steam from the melting snow. The column, which must have reached a height of about 20 miles, remained visible until after sunset. Gradually a dark "dust" had settled upon freshly fallen snow.

This object that collided with the earth on February 12, 1947, and left its scar on the countryside was a relatively small asteroid, or minor planet. The thousands of people who saw its fall were eyewitnesses to one of the rare occasions when the earth has collided with another member of the solar system. These collisions have all been comparatively minor, to be sure, but on an earthly scale they can be breathtakingly destructive.

The first impact of the meteor must have been terrific, judging from the shattering of the rocks in the craters. The largest craters were produced by masses 30 tons in weight—about six feet in diameter. The entire meteor, before it entered the earth's atmosphere and broke into millions of pieces, must have weighed a thousand tons and had a diameter of some 30 feet. Witnesses who described it as "about the size of the full moon" were estimating the size of the cluster of pieces, which shone as one. Its volume was probably comparable to that of a rather large room. After it broke up, each piece, flying through the air at a speed many times that of sound, carried in front of it a shock wave of compressed air that did not have time to move aside from the projectile. It was these waves, not the meteorites themselves, that produced the devastation.

As each shock wave reached the ground immediately ahead of its meteoric piece, it formed an elastic cushion, so that the pieces of iron did not actually hit the ground but were reflected—in the manner of a billiard ball when it hits the rubber cushion at the edge of the table. The reflected fragments, rebounding upward and southward from the crater at an angle of about 52 degrees from the ground, flew with such force that they shot clear through the trunks of trees.

BEFORE this large mass of iron entered our atmosphere, it hurtled through empty space among the planets. Because it encountered no friction in space, it remained relatively cold. Heat from the direct rays of the sun, falling upon one side of it, would warm it only to about room temperature and therefore it would be visible only by reflected light. When it was a million miles or so away from the earth, well out of the earth's shadow and hence illuminated by sunlight, it could have been observed with a moderately large telescope as a faint, starlike object; on a photographic plate it would have appeared as a star of about the 15th astronomical magnitude.

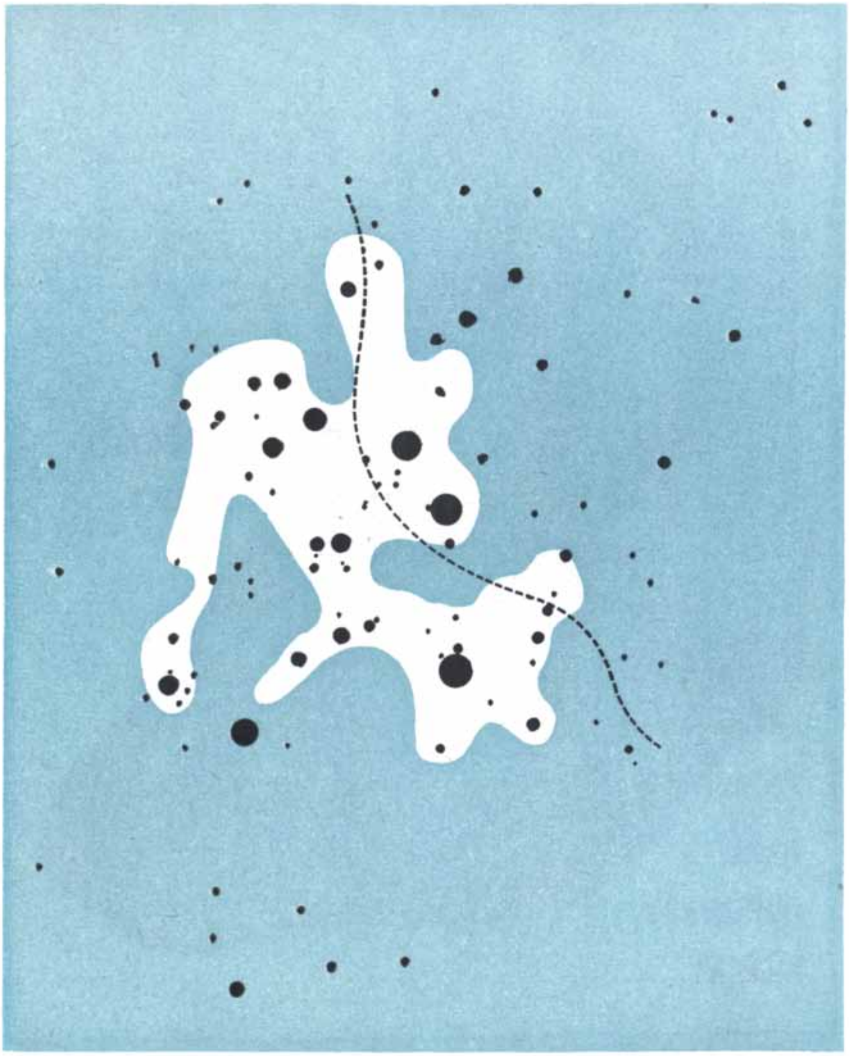
After the meteor entered the earth's atmosphere, friction with the air rapidly heated its surface layers to a high temperature. From its reported brightness and its white-yellow color the peak temperature is estimated to have been 5,000 degrees Centigrade. By the time the meteoric mass struck the earth its fragments had lost the larger part of their momentum, and their temperature had been reduced to a few hundred degrees above the cold of interplanetary space.

Several thousand of these asteroids, the largest of which are a few miles in diameter and the smallest between 10 and 100 feet, have been discovered and are accurately recorded. It is believed that they represent the debris left from the explosion of what was originally a major planet revolving between the orbits of Mars and Jupiter, although we have no knowledge of the cause of the explosion. It may have been a collision with a much larger body than that of the Siberian meteorite. At any rate, the explosion must have been on such a tremendous scale that most of the matter within the planet disintegrated into space and only a small fraction remained in the form of asteroids.

THE ASTEROID that struck in Siberia in 1947 is not by any means the largest that has hit the earth. There exists in our own country the imprint of a vastly more destructive collision which occurred in prehistoric times—the meteor crater in Arizona, between the towns of Winslow and Flagstaff. This is a single huge hole in the ground, about a mile across and several hundred feet in depth. For a distance of several miles from the crater the ground is strewn with countless pieces of meteoric iron, the largest of which weigh hundreds of pounds, while the smallest are probably in the form of microscopic dust. No large meteoritic mass has been discovered thus far within the crater itself, but its bottom is filled to a great depth with shattered rock containing small metallic particles. The Arizona crater is one of the strangest formations on the surface of the earth. It is quite certain that the giant meteorite whose shock wave resulted in its creation must have been an object of far greater energy than the one observed three years ago in Siberia.

Otto Struve is professor of astronomy at the University of California.

LOCATION OF CRATERS is indicated by the star northeast of the Siberian port of Vladivostok. The meteorite fell in the Sikhota-alin Mountains.

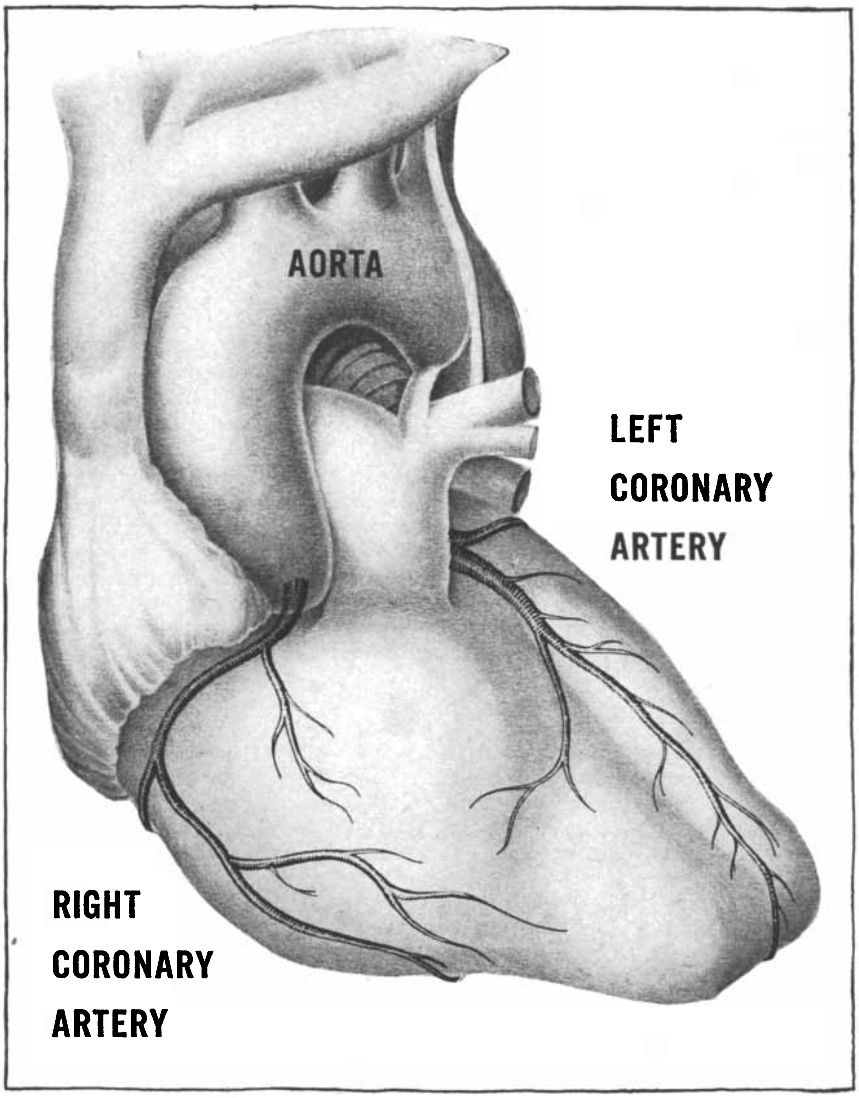


AREA OF DESTRUCTION in forest (*white*) was approximately 1,500 feet across. Some craters (*black*) were 75 feet across. Dotted line is a stream.

CORONARY THROMBOSIS

One of the principal causes of sudden death, it is the culmination of slow processes in coronary artery disease

by Paul D. White



THE CORONARY ARTERIES, which spring from the aorta, supply the hard-working muscles of the heart with fresh blood. The left coronary artery subdivides into two main trunks, each as big as the right coronary.

THE PHENOMENON of the sudden death of apparently healthy human beings has been one of the great mysteries of the ages. For thousands of years such a dramatic event was considered an act of the gods, especially of Zeus or Jove, Wotan or Jehovah. Even as recently as the winter of 1705 to 1706 the occurrence of an unusual number of sudden deaths among prominent persons in Rome was ascribed by many to God's displeasure with the city. Pope Clement XI and his remarkably able physician Lancisi challenged this belief, and by repeated post-mortem examinations proved during the following winter that every sudden death could be explained by natural causes. In fact the first and, so far as I know, the only scientific book on sudden death was Lancisi's *De Subitaneis Mortibus,* published in Rome in 1707 and dedicated to the Pope.

The first clue to what has now come to be recognized as the leading cause of sudden death had appeared in print even before Lancisi's book. In 1700 Theophile Bonet, a leader of French medicine, published in the second edition of his *Sepulchretum* the case of a fat poet who died within a few minutes after showing symptoms of trouble in his chest. A post-mortem examination disclosed a very marked narrowing of his coronary arteries, the vessels that supply the heart muscle with blood. The bore of the vessels had narrowed to such a degree that not even the point of a needle could be inserted in them, whereas normally the main coronary arteries can admit a good-sized knitting needle.

This narrowing or partial occlusion of the coronary arteries is of fundamental importance in the causation of thrombosis, that is, of a blood-clot formation in a vessel. Indeed, thrombosis is merely one of the complications of coronary artery disease, and more persons die suddenly of the disease itself without thrombosis than of an actual thrombosis. Hence a brief review of our current knowledge of coronary artery disease is a necessary background for understanding that great hazard of middle age: coronary thrombosis.

The coronary arteries bring oxygen and nutriment to the most important muscle in the body, the heart muscle or myocardium. The heart, a powerful and remarkably efficient muscle, contracts an average of 72 times a minute day and night and in the average human adult pumps 4,000 gallons of blood in 24 hours. For this it requires an especially efficient blood supply. The blood is brought to the heart muscle through two coronary arteries, which come off the main arterial trunk, the aorta. The left artery quickly subdivides into two main trunks, each as large as the right coronary trunk. These three trunks course in grooves over the outside of the heart. They give off many branches, and these in turn send twigs down into all parts of the heart muscle. The branches and twigs are connected by many minute blood vessels, forming a vast network which plays an important role in maintaining an adequate coronary circulation in later life.

TWO other observations may be added about the coronary arteries. First, they are more subject to change in position than other arteries of the body, and the constant kinking and stretching of the elastic tissue and muscle in their walls may be an important factor of wear and tear. Second, they are supplied with nerves, and very probably are subject to narrowing and widening through nervous influences, though not very much is actually known about this in the human heart as yet.

Now let us consider disease of the coronary arteries. Such lesions may or may not have serious consequences; that is, they do not necessarily result in actual heart disease, and even if they do it may be reversible. Although there are several different kinds of coronary artery disease, I shall discuss only one here, since it is responsible for at least 99 per cent of all cases. That kind is what we used to call arteriosclerosis but now prefer to call atherosclerosis, because the latter designation indicates the evolution of the process. Atheroma (from the Greek word for pudding) means a soft swelling. Atherosclerosis begins with a soft swelling of the inner lining of the artery and proceeds in the course of months or years to hardening or sclerosis. The soft swelling consists essentially of the deposition of globules of the fatty substance cholesterol just under the thin layer of cells forming the inner surface of the blood vessels. This is followed by a reaction which forms fibrous tissue in masses and layers in the artery wall. Small cholesterol fat particles, or small collections of this fatty infiltration, can be disposed of by being transported through the wall to the *vasa vasorum*, the little blood vessels in the outer part of the walls. But larger collections of larger droplets accumulating rapidly cannot be so readily absorbed. They develop into masses of fatty crystals and globules that finally change to calcified plaques with accompanying fibrous scars. These bulge into the arterial passages and cause varying degrees of obstruction to the flow of blood.

This process doubtless takes years to develop serious consequences. Important lesions of this nature may begin, say, at 30 but not become manifest by symptoms or signs until the age of 50. From my own observations the average age at which coronary heart disease first shows itself is about 52. It is always in a diseased, badly narrowed, atherosclerotic coronary artery that a thrombus, or clot, rather suddenly forms one day to present the clinical picture which we call coronary thrombosis.

Three other observations should be made about coronary atherosclerosis. In the first place, the process involves one particular spot more often than any other. This spot is located on the anterior descending trunk of the left coronary artery about half an inch below the point where it branches off. Secondly, and of the utmost importance, there is the fortunate, life-saving fact that as the obstruction of the coronary blood supply due to atherosclerosis slowly evolves, a collateral circulation develops to compensate for this. As a result of the constantly increasing head of pressure of obstructed blood, hammering away day and night, the tiny junctional vessels between the coronary arterial trunks become enlarged to permit blood to pass more freely. Thirdly, this compensatory development may entirely prevent injury to the heart muscle, even though there is extensive atherosclerosis.

Every person who lives long enough develops at least a little coronary artery atherosclerosis. But why some individuals acquire such a high degree of it in youth or middle age that their hearts are seriously affected remains a mystery. The fact that the disease cripples or kills so many of our leading citizens at the height of their careers has at last in recent years prompted the medical profession to challenge the spirit of fatalism that long prevailed about these "acts of God." Important researches—clinical, biochemical, metabolic and anthropological—have been started on this problem. We have learned something about the cause of extensive coronary atherosclerosis, but we have barely scratched the surface. This disease, more common than cancer, is the most serious in the U. S. today. It needs intensive research.

ONE thing we do know about coronary heart disease is that it is much more common in men than in women in youth and middle age. In two different series of 100 cases each of persons under 40 with this disease, we found the ratios of males to females respectively 96 to 4 and 97 to 3. An anthropological study of the second series showed that the majority were of the mesomorphic (thick and muscular) build. These young coronary patients as a rule had a higher cholesterol content in the blood and a lower basal metabolic rate than controls of the same age. This is probably due to some unknown metabolic or endocrine factor.

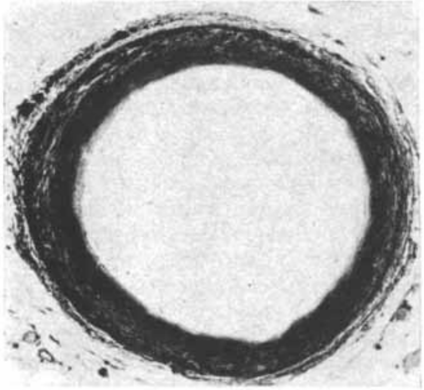
One symptom, and only one, is thoroughly characteristic of coronary heart disease. This symptom is the condition known as angina pectoris, which literally means a strangling in the chest. The oppression is generally located under the breastbone, and it often radiates into an arm, usually the left. Induced chiefly by effort, the anginal pain ordinarily lasts only a minute or two; it may be relieved by rest or by the administration of nitroglycerin. The discomfort is explained as an ache in the heart muscle caused by its working too hard for the amount of its blood supply; a similar ache can be induced in the muscles of the forearm by repeated bending of the wrist when a tourniquet around the upper arm cuts off their blood supply.

An electrocardiogram may also yield evidence of coronary heart disease, but sometimes the electrocardiogram may be normal except during an attack of angina pectoris. In doubtful cases a physician may deliberately induce angina by exercise in order to look for changes in the heart's electrical record. Such tests are rarely needed, however, if the patient tells his story well or his history reveals old trouble.

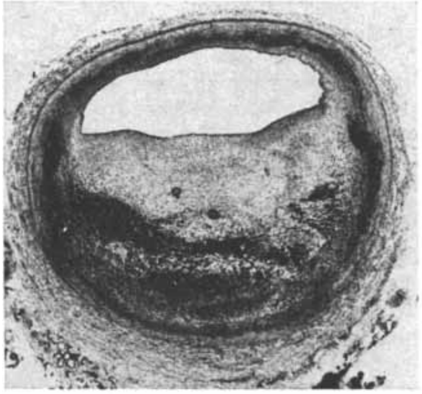
How does a restriction of the coronary circulation itself bring on sudden death? I have already mentioned that deaths from coronary disease actually occur more often without thrombosis than with it. In a series of 2,030 cases of sudden and unexpected death, reported by Milton Helpern, Chief Medical Examiner of New York City, the most common cause of death (30 per cent of the cases) was coronary atherosclerosis of high degree. Almost three quarters of these showed no thrombosis.

There is evidence that the mechanism that produces death in the latter cases is often the fatal disorder of the heart rhythm called ventricular fibrillation. Normally the ventricles, the major pumping chambers of the heart, beat regularly in rhythmic response to the stimulus from the heart's pacemaker: the sino-auricular node, situated in the right auricle. If the muscle of either ventricle is irritated by nervous stimulation or some local fault, an extra heartbeat may be set off by the irritated spot. This premature beat or extrasystole is by itself of no importance; it is a common occurrence even in an otherwise normal heart. But if the ventricular muscle is exceptionally irritable, an irritation may induce paroxysmal racing of the heart, and when there are many irritable or otherwise abnormal foci in the ventricular muscle, the heart may try to beat in a very incoordinated way from numerous points simultaneously. The result is a sudden complete failure of the heart to act as a pump; instead it becomes a squirming mass of muscle, and death comes quickly. Very rarely can the human heart recover from ventricular fibrillation, either spontaneously or as the result of treatment with electrical shocks designed to restore its rhythm.

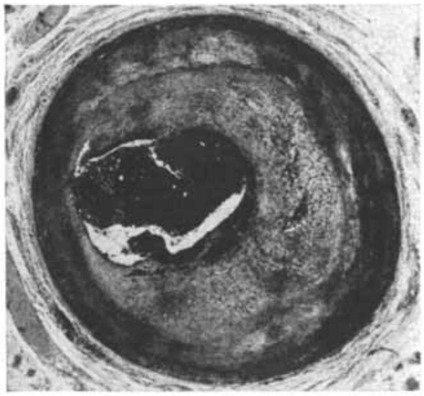
AFTER all these remarks the reader must have become aware that the phenomenon described by the title of this article, though well publicized as



NORMAL coronary artery has a cross section of a dark muscular layer and a thin inner lining called the intima.



DISEASED coronary has a greatly thickened intima. Passage is sufficiently narrowed to cause angina pectoris.



THROMBOSED artery is plugged with a blood clot. Photographs courtesy Dr. Timothy Leary of Boston.

the prime malady of the middle-aged American business and professional man of today, is but an incident, though a very important one, in the evolution of the process of coronary heart disease. The stage is all set before the thrombus is laid down in the diseased artery.

Just how the blood is triggered to clot is not yet fully clear. Most often, perhaps, a thrombus begins to form on a roughened bit of the inner lining of the artery, or at a very much narrowed place in the vessel. Within minutes or hours the thrombus grows large enough to block the blood flow and to cause the various symptoms and signs that follow. This basic mechanism may sometimes be supplemented by others: a calcified plaque or a small clot attached to the artery wall may break off and pass along the bloodstream to block a narrow place further on; clots may form from a hemorrhage of the small blood vessels in the outer part of the diseased artery wall; a "cholesterol abscess" may rupture. Some persons may have a tendency to thrombosis because their blood clots at an abnormally rapid rate.

An attack of acute coronary thrombosis usually develops as a sudden severe illness, with pain which is exactly like angina pectoris but persists for hours and is not relieved by nitroglycerin. As a rule it is so severe that it is necessary to administer an opiate. Death may come—in minutes, hours or days—through a variety of immediate causes: a state of collapse, vascular shock, ventricular fibrillation or (uncommonly) the choking of the heart's action by blood pouring into the sac about the heart from the ruptured heart wall. In about 80 per cent of all cases, however, the patient survives the immediate attack, and the heart usually heals to allow life for at least some years.

As a rule the attack leaves a permanent scar in the heart muscle. Aside from the temporary irritation and shock caused by the lack of oxygen and accumulation of waste products, the blocking of the coronary bloodstream damages the tissue. Heart muscle, like any other tissue in the body, dies when deprived of its blood supply, and the portion of the myocardium that is cut off from its normal blood supply by the plugging of the thrombosed artery becomes an infarct—a term applied to tissue anywhere in the body that dies and is replaced by a scar when its circulation is cut off. Fortunately we have more muscle in our hearts than we need for ordinary activity, and so we can get along with an acute infarct or an old scar in the heart, or indeed three or four old scars, if they are not very large. Myocardial infarcts may range in size from that of a small marble to that of half a tennis ball, and in shape from a thin flat area to a thick mass like a truncated cone or pyramid. Naturally the smaller the infarct the better for the patient, but he may survive a very large one; he may even live comfortably for years with a rather badly scarred heart.

It is encouraging to bear in mind also that the blocking of a coronary artery by a thrombus does not always necessarily damage the heart. If, as often happens, the interconnecting channels in the coronary arterial system have developed an adequate collateral circulation to compensate for the atherosclerotic obstruction, the blood flow can bypass the obstructed artery to nourish the threatened heart muscle. Patient waiting and common-sense measures over the period of disability may be rewarded by the slow development of an adequate collateral blood supply.

WHAT are the measures of treatment? When first formed, the acute myocardial infarct, acting like an abscess though it is actually sterile, gives rise to a low-grade fever for a few days and an increase of white blood cells. It also produces a rise of the blood-sedimentation rate and certain abnormalities of the electrocardiogram. In a week or so the dead muscle cells are cleared away and a scar begins to form in their place. Complete rest is necessary for about three or four weeks in order to prevent a blowout through the temporarily weakened heart wall or an unnecessary degree of dilatation of the heart with permanent enlargement. When the scar is well set, the patient can usually start a program of gradually increasing activity, and within three or four months many patients can resume their usual occupations. During the several weeks of the acute illness, nursing care is of chief importance. Two medicines have proved useful: 1) quinidine sulfate, which helps to prevent ventricular fibrillation, and 2) dicumarol, the anti-coagulant or anti-clotting agent, which reduces the danger of the blocking of circulation by emboli, or traveling clots. Such clots may form in the leg veins and travel to the lungs, or form in the left heart chambers, particularly over the region of the infarct itself, and migrate to the peripheral arteries. Sometimes circumstances may also demand other measures of treatment: for example, oxygen for certain acute emergencies and digitalis if the heart muscle fails. But it is nature that heals the infarct, as it heals a broken bone or develops the collateral coronary circulation.

Coronary heart disease, with its company of angina pectoris, acute coronary thrombosis and myocardial infarction, may continue to kill and to cripple for generations to come. Actually it is not an altogether unmitigated evil: if it ended our lives only when we reached an advanced age, we should not object to the quick and merciful death of heart disease for all men. What we do need to do, however, is to study intensively the disease as it affects men and women in youth and middle age, in order to apply effective measures of prevention, if we can. Here is an outstanding challenge to the medical profession, and indeed to all others to aid us in this important task.

Paul D. White is clinical professor of medicine at Harvard Medical School.

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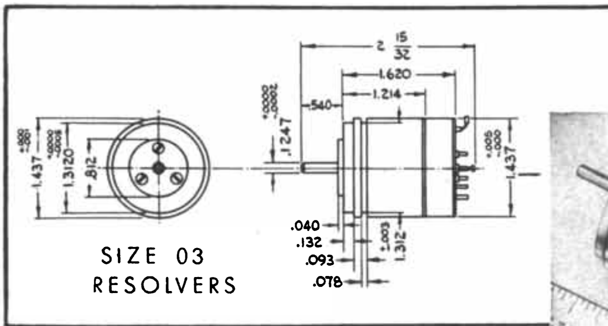

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SIZE	TYPE	DRAWING NUMBER	FREQ.	INPUTS	OUTPUTS	TRANSFORMATION RATIO (S/P)	PHASE SHIFT	INERTIA (oz. in²)	MAX. STATIC TORQUE (oz. in.)	WEIGHT (lbs.)	MAX. ANGULAR ERROR	MAX. AXIS MISALIGNMENT	REQUIRED TO ATTAIN TABULATED ACCURACIES: INPUT VOLTAGE	TEMPERATURE	AMPLIFIER DWG. NO.	AMPLIFIER WEIGHT (lbs.)
03	03JJ400	786832	400 ± 0.5	2	2	1.000 ± .0025	0° 0' ± 3.5'	0.05	0.5	.35	0.12% E_s†	± 7.0'	0.5 to 16.0	15° to 70° C	789640	1.2
03	03KK400	786833	400 ± 0.5	2	1	1.000 ± .0025	0° 0' ± 3.5'	0.05	0.5	.35	0.12% E_s†	± 7.0'	0.5 to 16.0	15° to 70° C	789640	1.2
03	03LL400	786834	400 ± 0.5	1	2	1.000 ± .0025	0° 0' ± 3.5'	0.05	0.5	.35	0.12% E*	± 7.0'	0.5 to 16.0	15° to 70° C	789640	1.2 Note #1
03	03MM400	786835	400 ± 0.5	1	1	1.000 ± .0025	0° 0' ± 3.5'	0.05	0.5	.35	0.12% E*	± 7.0'	0.5 to 16.0	15° to 70° C	789640	1.2 Note #1
03	03NN400	786836	400 ± 0.5	2	2	.955 ± .015	4° 30' ± 30'	0.05	0.5	.35	0.12% E_s†	± 7.0'	0.5 to 16.0	25° C	Not Required	
03	03PP400	786837	400 ± 0.5	2	1	.955 ± .015	4° 30' ± 30'	0.05	0.5	.35	0.12% E_s†	± 7.0'	0.5 to 16.0	25° C	Not Required	
03	03QQ400	786838	400 ± 0.5	1	2	.955 ± .015	4° 30' ± 30'	0.05	0.5	.35	0.12% E*	± 7.0'	0.5 to 16.0	25° C	Not Required	
03	03RR400	786839	400 ± 0.5	1	1	.955 ± .015	4° 30' ± 30'	0.05	0.5	.35	0.12% E*	± 7.0'	0.5 to 16.0	25° C	Not Required	

Deviations shown are maximum — Average deviation is much less. Quadratures and harmonics each never exceed 0.1% of the sum of the input voltages. Characteristics shown are attainable with indicated required auxiliary equipment and good engineering practices for precision circuits. Note #1. One amplifier may be used with two resolvers of this type.

***E = Input**
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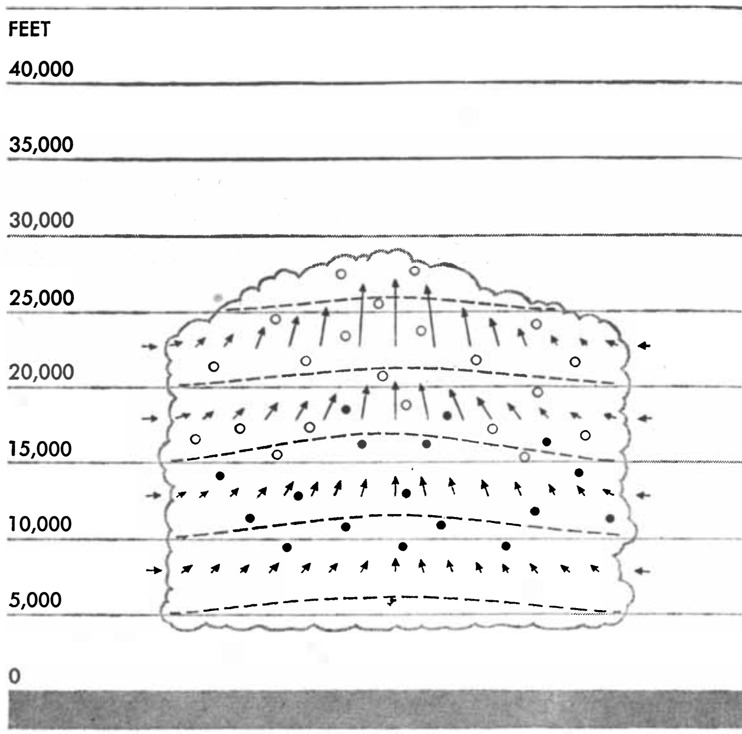
QUALITY ARMA INSTRUMENT PRECISION

Life of a Thunderstorm

The structure of the violent atmospheric phenomenon has long been unclear. Now it is known to incorporate "cells"

by Roscoe R. Braham, Jr.



THREE STAGES in the life of a thunderstorm cell are shown in these three drawings. At the far left is a scale of height. At the far right is a scale of temperature cor-

IN THE SUMMER of 1946 a small group of Northrup Black Widow (P-61) night fighters, flown by some of the Air Force's most expert instrument pilots, began a series of hazardous flights through thunderstorms over Florida. The planes carried various instruments for recording and measuring wind currents, temperatures, moisture and other conditions in the turbulent storm clouds. They were tracked from the ground by radar, and the clouds themselves were also examined by radar and other devices at a number of ground stations. The planes took off day after day into the most violent storms, systematically exploring the thunderclouds at various levels.

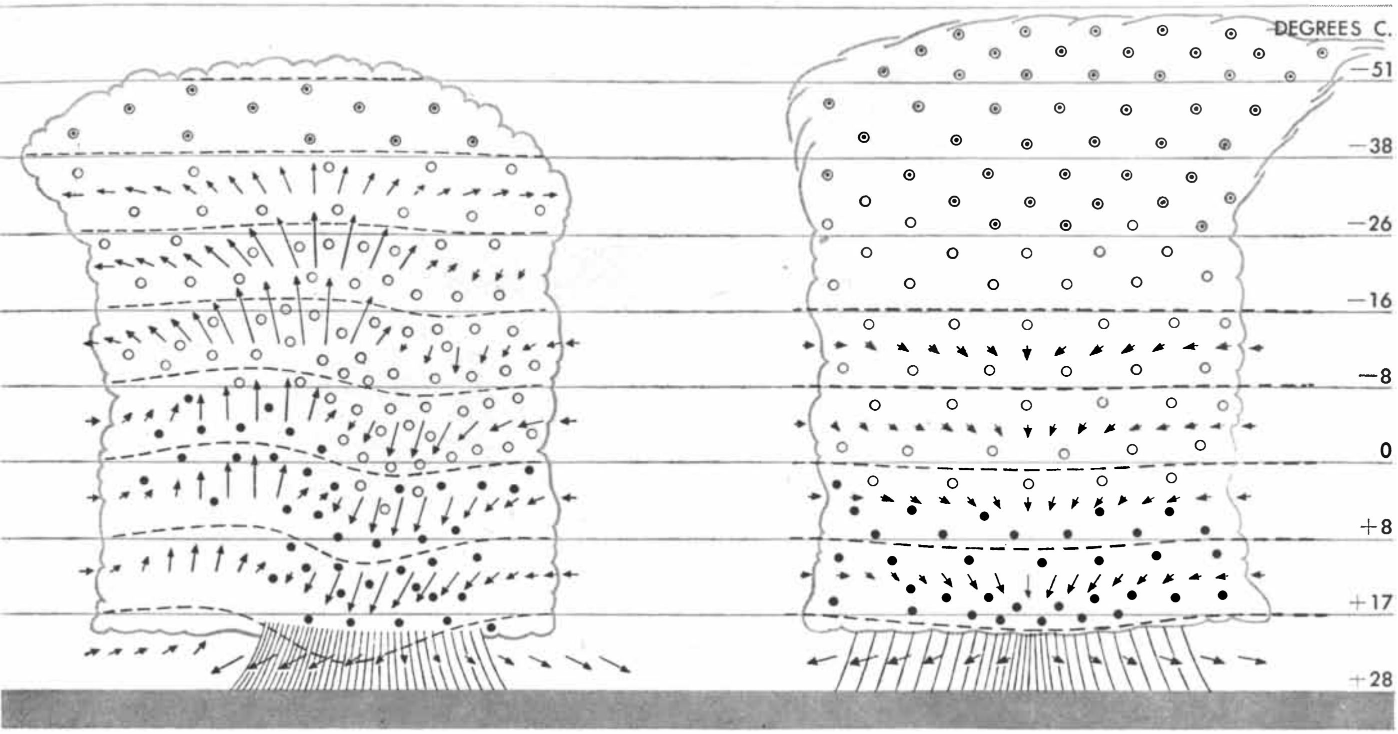
This project, started in Florida and continued in Ohio through the summer of 1947, was the first large-scale, comprehensive study of the actual anatomy and dynamics of the thunderstorm. There had been many theories about the nature of thunderstorms, and even laboratory models of their structure, but very few precise observations of the phenomenon itself. What is the origin of this violent event in the atmosphere? What goes on inside the storm? How does it build up its huge energies and its spectacular display of lightning, wind, hail and torrential rain? What can be learned about thunderstorms that will reduce their hazard to aviation? To find the answers to these questions the investigation, known as the Thunderstorm Project, was undertaken jointly by the U. S. Weather Bureau, the Air Force, the Navy and the National Advisory Committee for Aeronautics, under the direction of Horace R. Byers, chairman of the University of Chicago department of meteorology.

The pilots made a total of 1,363 flights—without accident—through thunderstorms in varying stages of development and at levels from 5,000 to 25,000 feet. Radiosonde balloons also were used to track the wind currents in the storm clouds. From the great amount of data collected have come many important findings. A thunderstorm is in effect a large heat engine. It has strong updrafts and downdrafts thermally driven by differences in air temperature. In the development of the downdrafts, which usher in the mature, violent stages of the storm, the fall of raindrops plays a key part. It was found that a thunderstorm is not a single unit, as used to be thought, but generally develops several distinct "cells," each of which has a life cycle of its own. The life cycle of a thunderstorm cell divides naturally into three stages: the cumulus, mature and dissipating stages.

DURING the first stage the cell grows from a small cumulus cloud to a towering cumulo-nimbus, the well-known herald of the approach of a thunderstorm. In this stage, which may take no more than 10 minutes to develop, an individual cell may grow to three miles in diameter and 15,000 feet or more in height. It forms a tall, cylindrical column. The air within the cell, being warmer than that outside the cloud, rises with accelerating rapidity; in the upper part of the cell the updrafts often attain a speed of more than 35 miles per hour. An airplane flying through a cell late in its cumulus stage finds the air turbulent and bumpy. On the ground about the only change during this phase is a slight drop in pressure beneath the cloud and a resulting slight inward flow of air toward the base of the cell from the surroundings. If a light prevailing wind on the downstream side of the developing storm happens to be blowing counter to this inflowing air, the currents may block each other; the result is the well-known "calm before the storm."

Until recently it was thought that most of the air drawn into a cumulus cloud entered through the cloud base, but H. Stommel of the Woods Hole Oceanographic Institution showed in 1947, and the Thunderstorm Project confirmed, that a substantial part of the air is drawn in through the sides of the cloud—a process called "entraining." This mixing of colder air from the environment with the air inside the cloud is to play a part in the later evolution of the storm, as we shall see.

In the early cumulus stage there is very little lightning, little or no hail, and only a small amount of liquid water inside the cell. But as the updraft rises to the cold higher altitudes, more and more water vapor condenses and forms raindrops. By the time the cell has grown to a height of 20,000 to 25,000 feet the amount of rain within the cloud is sub-



responding to height. The arrows in all three drawings indicate the flow of air. The dotted lines running across the drawings indicate the displacement of temperature zones within the cell. The black dots are rain; the circles, snow; the circles with a dot in the center, ice crystals. The vertical lines beneath mature cells are rain.

stantial, and above the freezing level heavy snow is present. It becomes more difficult for the updraft to carry along the increased amount of rain and snow, and part of the rain begins to fall through the cloud toward the ground. Now comes a crucial event in the storm's development. The rain falling through the updraft, which has been made thermally less stable by the entrainment of environment air, drags along part of the air of the updrafts and initiates a downdraft in the cell. This event marks the beginning of the second phase of its life cycle: the mature stage.

A WARM updraft and a cold downdraft are now flowing past each other in the lower levels of the cell, with the updraft sloping over the top of the downdraft higher up. The downdraft gradually increases in horizontal extent and in speed until it has expanded entirely across the base of the cell. It pours out of the base of the cloud and spreads out over the ground to form a dome of cold air about 2,000 to 3,000 feet thick. The action of the cold dome generally is considerably greater on the leading edge of the traveling storm; often it is almost entirely absent from the trailing edge. The spreading air from the cold dome causes the sharp fall in temperature and sudden increase in the speed of the wind which are the best-known surface characteristics of a thunderstorm.

In the mature stage, which lasts from 15 to 30 minutes, the updrafts in the cell may reach a speed of 70 miles per hour at the top of the cloud, and downdrafts range up to 50 miles per hour. There is heavy rain in the lower levels and snow above the freezing level; if the updrafts and downdrafts are exceptionally severe, hail may fall. This is also the stage of frequent lightning and heavy turbulence.

While this is happening in one cell, other cells in the same cloud may be, and usually are, in different stages of development. Beneath the base of the cloud each cell is visible as a separate rain area extending from the cloud. Between the cells are regions of stratus-like cloud containing a minimum of updrafts, downdrafts, turbulence and precipitation. These relatively calm gaps between the active cores of the cells may be as much as several thousand feet wide. Thus their discovery suggests a practical solution to the problem of flying through thunderstorms. While such breaks between the cells cannot be located reliably with present equipment, there is considerable promise that further developments in radar will make their detection possible.

The surface weather under a thunderstorm usually reflects clearly the cellular structure of the storm. From a point in the path of a storm the first condition noted is usually an almost breathless calm. Suddenly one of the cells reaches the mature stage and rain begins to fall. With it comes the cold downdraft. The rain falling from the storm is visible when it is still a mile or two away from the observer. Presently the wind increases markedly in speed and becomes very gusty as the edge of the outflowing air arrives. As the cell moves overhead the observer may notice several other cells off to the sides, each of which can be detected by its individual rain center. The cells may by-pass the observer entirely, bringing a sweep of cold, gusty winds but no rain to his immediate vicinity—a fact which underlines the point that the individual cells in a thunderstorm are relatively small. The thunderstorm as a whole sometimes covers more than 200 square miles, but a cell is seldom more than three miles wide.

THE THIRD, or dissipating, stage of a thunderstorm cell begins when the downdraft has spread completely across the base of the cell. This cuts off the supply of air entering the base of the updraft; as a result the supply of rain, formed from condensation in the updraft, is also depleted. The downdraft decreases in speed. Turbulence inside the cell declines. The downpour moderates to a light steady rain which may linger for several minutes.

During this final stage the cell probably reaches its greatest height. The strong updraft of the mature stage sometimes carries the cloud top to phenomenal heights: the average height of a summer thundercloud in Ohio was 37,000 feet, and some were observed to extend over 50,000 feet—the dividing line between the troposphere and the stratosphere.

The thermodynamics of the thunder-

TOWERING CUMULO-NIMBUS CLOUD is the first stage in the growth of the thunderstorm cell. Such clouds may expand to three miles in diameter and more than 15,000 feet in height within the space of only 10 minutes.

storm heat engine rests on the facts (1) that the early stage of the storm is dominated by updrafts warmer than the surrounding environment and (2) that at some point this relationship is reversed, so that air in the cloud becomes colder than the surroundings. Although a complete discussion of the physical processes by which the drafts become warmer or colder than the environment is beyond the scope of this article, we can note one or two of the important features.

The temperature of the warm air that starts the updraft is somewhat reduced, as the cell develops, by the entraining of cooler air from the environment. But calculations show that the entrainment factor is not sufficient to account for the observed reduction of speed of the updrafts and their ultimate reversal. It is evident that drag forces must play a part. Of the several possible drag forces, the one that can be estimated is that generated by condensing and falling raindrops.

As is commonly known, raindrops fall only a few feet before reaching terminal speed, *i.e.*, the speed at which the force of gravity tending to make the drops fall faster is just balanced by frictional forces holding them back. This means, of course, that the total drag exerted by the falling drops on the air through which they fall is just equal to the weight of the drops. In a thunderstorm the rain is frequently very heavy, and the drag force exerted by the raindrops is considerable. In fact, after the updraft has been in existence for several minutes, it may contain a sufficient amount of liquid water to overbalance the force of the updraft and thereby cause part of the air to be forced downward. Once the air is started downward by the weight of the rain, it quickly becomes colder than the environment, by virtue of the fact that the rate of change of temperature for a moist, descending parcel of air is smaller than the rate of change of temperature of the environment through which it passes. Obviously after the downdraft air becomes colder than the environment it will fall of its own accord; it thus becomes the cold downdraft core of the rain area. When the rain and downdraft core reach the ground, the cell passes into the mature stage. Considering the drag effects of the rain, it is also easy to see how the downdraft expands at the expense of the updraft and how, after the updraft is cut off, the air in the cell begins to come into thermal equilibrium with the environment and the cell passes into the dissipating stage.

THE information obtained in the Thunderstorm Project should be of considerable value to aviation. One of the worst hazards of a thunderstorm is the great air turbulence. The levels of greatest turbulence have now been carefully mapped. It turns out that the roughest air is in the region between 15,000 and 25,000 feet, and that for maximum safety a plane that must fly through a thunderstorm should fly at heights somewhat below 10,000 feet. Ultimately with appropriate radar a pilot should be able to thread his way safely through a storm by flying between the cells.

Roscoe R. Braham, Jr., was official in charge and senior analyst of the Thunderstorm Project.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

• The non-technical public seems to have a general impression that the problem of the constructive use of the disintegrating atom has arisen only since Hiroshima. The fact is, however, that man-made radio-active isotopes were being used in research and medicine before the first atomic pile was built. Revere, for example, in 1941 sponsored a scientific investigation of the corrosion process known as dezincification, using tracer elements created in a cyclotron. The purpose was to discover why it is that the addition of a minute amount of an extra element makes copper-zinc alloy condenser tubes much more resistant to corrosion. We knew that certain elements had that effect, but before we could take full advantage of them, it was necessary to know how the result was brought about. Then it would be possible to abandon the rule of thumb, and prescribe accurate percentages of a chosen inhibitor. Measurement is part of science.

Dezincification is a process that takes place in uninhibited condenser tubes, materially shortening their life. The alloy seems to dissolve away from small local areas, and the zinc is carried off, while the copper is redeposited as a porous plug. It is an electro-chemical phenomenon, chiefly, though sometimes there is evidence that a mechanical factor, such as scale, may play a part in initiating the attack.

Since cyclotrons are not conventional equipment in an industrial laboratory such as Revere's, we engaged a prominent technical college to undertake the work. Its cyclotron produced the tracer elements or radio-active isotopes of the inhibitors. These were dissolved, and the radio-activity measured. A plate of the copper-zinc alloy was immersed in the solution, and from time to time the amount of radio-active material deposited upon it was measured. The nature of the deposited film was determined by the electron-diffraction method. This was in effect an accelerated test for dezincification and its inhibition, and was repeated many times with solutions of varying concentration. In the end it produced not only a clear picture of the process, but accurate measurements of it.

Research into the fundamentals of materials, using radio-active tracers, thus is not new. Many scientifically minded companies besides Revere have employed the method, and since the atomic piles have made such elements available in larger quantities at less expense, they are being used quite generally. No matter what you make, nor from whom you buy your materials, it is quite possible that somewhere in the background some abstruse scientific investigation has been done or is now going on, employing the atom as a guide to better products.

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GAS FROM THE MINE

An experiment now being conducted in the South will measure the practicality of harvesting the energy of coal by burning it underground instead of mining it

by Leonard Engel

IN *Technics and Civilization,* a provocative study of the evolution of the modern Western world, Lewis Mumford pens a harsh indictment of coal as a destroyer of environment and of humane values. Coal diggings, he points out, have no equal in the destruction of countryside and befouling of streams. Coal furnaces shroud our cities in corrupting banks of acrid smoke. Coal mining remains one of the most dangerous of occupations: more than 37,000 miners were killed or injured last year in the U. S. alone.

Yet without coal modern civilization would not have developed and could not continue to exist. Coal represents more than 95 per cent of our available mineral fuel. Somehow, a few engineers have insisted, the ingenuity of 20th-century technology should be equal to the problem of siphoning out the energy of the earth's coal without the dangers and blights that now attend it. There is a fairly promising method for doing this which for some years has been the subject of experiments in the U.S.S.R. and is now being explored on a considerable scale in the U. S., England, Belgium, France, French Morocco and Italy. The idea is simply to burn the coal underground in its native seams to produce a gas that can be drawn off and used as fuel—an operation technically known as underground gasification.

The scheme is so simple that it seems odd that no serious attempt to test it was made until recent years. It was first proposed as long ago as 1868 by Sir William Siemens, the inventor of the open hearth steel furnace. Sir William, a German who became a British subject, conceived underground gasification as a means of salvaging coal residues left in worked-out mines. He suggested that abandoned shafts be sealed and the slack coal remaining in them be set afire to generate fuel gas. Twenty years later the Russian chemist D. I. Mendeleyev proposed that the idea be applied to virgin coal seams. Mendeleyev's proposal was repeated in 1912 by the Scottish chemist Sir William Ramsay on the occasion of an international smoke abatement exhibition in London. "Just as deposits of salt are worked not by mining salt but by pumping in water and recovering brine," he urged, "so it would be ideal, instead of mining coal, to have retorts in the bowels of the earth for the production of gas." Preparations were made to try his plan, but the First World War put a stop to the attempt.

Actually an unintentional demonstration of underground gasification had already occurred in Scandinavia. In 1908 an uncontrollable fire broke out in a coal mine on Spitsbergen. Some resourceful Norwegian engineers piped gas from the burning mine to the nearest mining town. Seven years later the geophysical explorer Hans Lundberg on a visit to the island found the coal seam still burning and still providing a steady flow of gas.

The first systematic experiments in underground gasification were started in the U.S.S.R. in 1930. It was Nikolai Lenin who was chiefly responsible for them. Attracted to the idea by Ramsay's widely publicized 1912 speech, the Russian revolutionist at once wrote several articles about underground gasification in *Pravda,* then an obscure underground journal. Shortly after he came to power in the Russian Revolution, he initiated some preliminary research on the scheme. He saw it as a short cut to electrification and Soviet industrial power. His successors carried on with his plan after his death in 1924. By the beginning of World War II the U.S.S.R. had several underground gasification installations in operation, producing water gas and synthesis gas. The current Soviet five-year plan calls for a daily output of 100 million cubic feet of gas by the end of this year. This is roughly nine per cent of the current U. S. production of manufactured gas. Very little information on the techniques or results of the Soviet venture is available, however, in this country.

The long interval between Sir William Siemens' suggestion and the first experiments was due in part to the fact that full field tests of the process are very expensive. In the U. S. interest in underground gasification was finally awakened some three years ago by a special combination of circumstances. One of them was that the Alabama Power Company, one of the principal coal operators in the South, saw it as an opportunity to get more fuel out of its coal fields. The coal deposits that have made the Birmingham region the "Pittsburgh of the South" are generally thin and expensive to work. In some fields the limit of workability is fast being approached. Milton H. Fies, the manager of the company's coal operations, began to study the possibilities of underground gasification. The other circumstance was that at about the same time the U. S. Bureau of Mines was launching an extensive investigation of the possibility of producing liquid fuels from coal, because of the impending shortage of petroleum. Since the principal barrier to the commercial conversion of coal to synthetic liquid fuels by the Fischer-Tropsch process, which uses synthesis gas, is the cost of coal mining and gas manufacture, the Bureau of Mines also became interested in underground gasification. A successful method of obtaining gas directly from coal seams, it was thought, might reduce the cost of synthesis gas by 80 per cent and thereby make synthetic liquid fuels as cheap as fuels from petroleum.

As a result of their simultaneous, mutual interest, the Alabama Power Company and the Bureau of Mines undertook a joint investigation of underground gasification. After an encouraging preliminary test in a small underground peninsula of coal, they launched a large-scale project last year in an extensive coal deposit at Gorgas, Ala., 45 miles west of Birmingham. The company provided a 100,000-ton seam of coal and the Bureau of Mines decided to invest about $1 million in Government funds and equipment. Mining engineers of both parties, under Fies and James L. Elder of the Bureau of Mines, designed the installation.

Essentially the process of making gas in a coal seam is the same as that long used for converting coal into certain fuel gases in chemical plants. The procedures involve the heating or chemical treatment of coal or coke in special retorts. In underground gasification the earth itself is the retort. A section of a coal seam is fired and kept burning under carefully controlled conditions, and the resulting gas is drawn off through a system of pipes. In practice, however, the procedure presents some formidable difficulties. The earth is not a retort built to a designer's specifications, nor is it necessarily supplied with coal of ideal characteristics.

Coal burns readily underground, as the history of mine disasters abundantly proves. Basically the procedure for underground gasification is to bore an inlet to the coal seam through which to pump in air for combustion and to draw off the gas thus made through an outlet pipe. The chief problem is to control the flow of air so that the coal burns to produce a high quality of gas. This is difficult because the earth is not a uniform, airtight container: leakage of air from the bore into the surrounding rocks and soil and blockages that arise in the bore itself interfere with the air flow, which should be kept at a certain constant pressure.

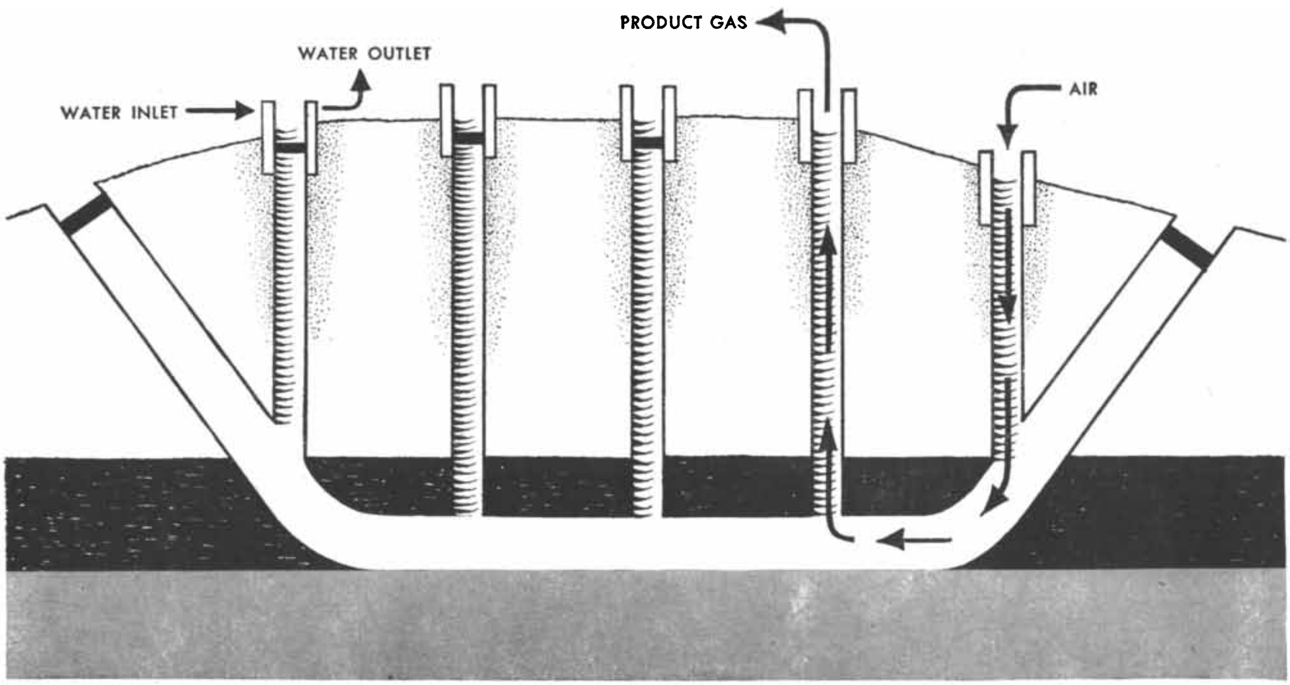
If underground gasification is to be economically feasible, certain conditions must be met: the coal must burn for a distance of at least 50 feet from each air inlet, to avoid the necessity of boring an impracticable number of tunnels; the gas produced must be of a good, uniform quality; virtually all of the coal present must be converted into gas. These are the critical questions that the Gorgas experiment is designed to answer.

The scene of the experiment is a pleasant hill whose green flanks are covered with second-growth trees. The countryside shows none of the scars that mark a conventional coal field, and at the surface there is no obvious sign of the inferno burning below. Along the crest of the hill, flanked on both sides by a few small buildings, runs a large main pipe surmounted by several smaller ones. This main, paralleling the chief axis of the coal seam below, carries the air to vertical pipes, which are sunk from it at intervals to the coal seam 150 feet underground. The vertical mains can serve either as air inlets or as outlets for the product gas. At the surface they have oversized jets for drawing off the gas. (None of the gas produced is now used for fuel; the surplus over what is taken for laboratory analysis is burned at the jets.)

The coal deposit, bituminous in grade, is 42 to 46 inches thick and covers 1,200 acres. The burning region is along a tunnel driven horizontally through the seam from a point on the hillside where the coal crops out on the surface. For the purpose of safety while the early development work was in progress, a second tunnel was driven parallel to the first for a short distance, and connected with it at intervals, to provide ventilation and a secondary means of escape for the tunnelers.

The firing of the seam took place in March, 1949. An engineer dropped several thermite incendiary grenades down borehole I, at the innermost end of the longer tunnel. In a matter of minutes black smoke was pouring from borehole II, at a junction of the two tunnels. The fire slowly traveled along the passage. Combustible gas containing carbon monoxide began coming from borehole II in July, when the fire had heated the seam to 2,000 degrees Fahrenheit.

On the whole the experiment is working out more favorably than had been anticipated. At the time of writing the flame had eaten more than 35 feet into the seam on each side of the tunnel and it appeared that the desired 50-foot radius of burning would easily be attained. It was originally assumed that the borehole linings and the piping would not tolerate a temperature of more than 800 degrees F., but the piping has shown no sign of failure even at much higher temperatures. Thus it seems that it will be possible in future to obtain a great deal of usable energy in the form of heat from the emerging gas even before it is burned as a fuel. The product gas now



FUNDAMENTAL SCHEME of the underground gasification of coal is represented in this simplified drawing. A horizontal shaft, the slope of which is exaggerated here, is drilled into a seam of coal. Vertical pipes are then sunk into the shaft from above. When the coal is ignited, air may be pumped into it and product gas allowed to flow out. During Gorgas experiment tops of pipes were first cooled with water, but this was later found to be unnecessary. Several pipes were sunk into the horizontal shaft to test different pipe materials.

is hot enough as it emerges from the ground to heat boilers or drive a gas turbine. After being used for such a purpose, the cooled gas is still available for use as a combustible fuel.

As expected, the principal problem still to be solved is the control of the flow of air to provide a product gas of adequate quality. The gas produced so far has not had a high heating value. As the coal burns, the rock just above the seam becomes plastic and expands so that it largely fills the space formerly occupied by the burned coal. There was some apprehension that this might interfere with the flow of air to the burning coal face and thereby reduce the temperature below the optimum or choke off the fire entirely. Actually the expansion of the rock had the desirable effect of forcing the air to the burning coal face. But early in the experiment some broken rock caved into the tunnel. The air stream then passed through this porous rock in the center of the tunnel without reaching the burning coal face along the sides. The Gorgas engineers have recently devised an ingenious stratagem that may solve this particular problem. They blow fluidized sand into the broken rock through special boreholes. The sand fills and effectively seals the open spaces in the rock. It is then possible to pump air into the tunnel at higher pressure and force it to the outer edges of the partly obstructed passage. By this means the engineers have achieved an improvement in the heating value of the product gas.

To keep the test conditions as simple and the cost as low as possible, only one type of gas is being generated at Gorgas. This is air-blast producer gas, a low-grade fuel usually burned only under industrial boilers. Producer gas consists principally of carbon monoxide, with carbon dioxide and atmospheric nitrogen as inert diluents. But in principle and in practice underground gasification can just as readily yield richer fuel gases, such as water gas, which consists of carbon monoxide, hydrogen and nitrogen. The Russians are reported to have produced by underground gasification a synthesis gas with a heating value of 200 to 300 British thermal units per cubic foot. In the Gorgas experiment oxygen and steam, as well as air, may be blown into the shaft to produce water gas. The experimenters hope to obtain a gas yielding 75 to 125 B.T.U.'s per cubic foot with an air blast alone.

Whether the underground burning of coal can achieve a high conversion of the coal into gas—a crucial test of the economic feasibility of the process—will not be known, of course, until the fire is extinguished and the underground results of the Gorgas experiment are examined some two years hence. In the earlier preliminary test in a small seam nearby complete gasification of the coal was obtained; only ash and clinkers were left in the space that had been the combustion zone.

Should underground gasification be completely successful, engineers estimate that the method may enable mankind to obtain a somewhat higher percentage of mechanical energy from the earth's coal than conventional mining does. More than this, it would permit the exploitation of vast deposits of coal that are too thin or too poor in quality for recovery by present mining methods. Although the earth's reserves of coal of all grades total several trillion tons—roughly a 3,000-year supply at the present rate of consumption—the coal is not uniformly distributed over the world and much of it is not now economically recoverable. England and some other nations of Europe, for example, have worked out many of their best deposits and are reduced to mining poorer seams. In the U. S. the eastern slope of the Rockies and the Great Plains overlie immense deposits of sub-bituminous and lignite grades of coal that are uneconomic to mine but could be tapped by underground gasification.

Underground gasification might also avoid the undesirable features of the current trend toward the mechanization of coal mining. Because of the rising cost of labor, coal-cutting machines are rapidly being introduced in underground mining, and there has been a huge increase in strip mining—an unparalleled despoiler of the countryside. Opencut mines now account for a fifth of U. S. coal production. Since the capital costs of mechanized underground mining and strip mining are high, the effect is to narrow the range of economically workable coal deposits. Only relatively large, high-grade seams will make the mechanization cost worth while.

The architects of the Gorgas experiment believe that several years of intensive development could make underground gasification an industrial actuality in the U. S. They envision vast installations built around seams containing as much as 100 million tons of coal. Some of the first units may well be set up in the Great Plains states. Electrical power would be generated by the heat of the emerging product gas and by the gas as fuel. And associated with them would be plants for manufacturing synthetic gasoline.

Even if underground gasification is successful, a great deal of coal will still be dug, of course, as raw material for the chemical and metallurgical industries and for other purposes. But coal mining will be reduced to a less noticeable blemish on the civilized scene, and there will be few to mourn it.

Leonard Engel was the author of Smelting Under Pressure and other articles that have appeared in this magazine.

What GENERAL ELECTRIC People Are Saying

V. J. SCHAEFER

Research Laboratory

Cloud Seeding: Part of the benefit which may come from recent cloud-seeding experiments could be the *prevention* of rain or snow. Our investigations show that this could be brought about by intentional overseeding. By seeding supercooled or below-freezing clouds with excessive amounts of dry ice or silver iodide, we can bring about the formation of snow crystals which are unable to grow big enough to fall. By continuously seeding new supercooled regions as the cloud produces them. all—or a large part—of that cloud would either be dissipated or kept from growing into a thunderstorm.

There is even a possibility that, using the overseeding technique on huge areas of supercooled stratus clouds, we may produce snow crystals in such tremendous quantities that they could constitute holding reservoirs of snow crystals in the sky. These might later affect lower supercooled clouds, and in that way initiate widespread effects of a different pattern than would occur under natural conditions.

There is a distinct possibility that dangerous aircraft-icing conditions caused by supercooled clouds might be eliminated or reduced along major airline routes or in the vicinity of airports by converting the clouds to snow crystals. In a similar manner, ground fog, if it is sufficiently supercooled, might be cleared by seeding.

WGY Science Forum,
March 8, 1950

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C. W. CLAPP
STANLEY BERNSTEIN

General Engineering & Consulting Laboratory

Beta-ray Thickness Gage: X-rays have been used successfully in measuring the thickness of steel as it is being rolled in a hot-strip rolling mill. The great success of this method of measurement has stimulated study of the possibilities of using other types of radiation in a similar manner. Of these. beta rays appear to hold the greatest promise at the present time.

Beta rays are electrons emitted spontaneously by certain radioactive materials. Depending on the nature of the source material, these electrons are emitted with maximum energies varying from a few thousand electron-volts up to several million electron-volts. Those electrons emitted with high initial energy are able to pass through an appreciable thickness of solid material. For example, an electron with an initial energy of 1.3 million electron-volts will lose only one half of its energy in passing through a sheet of aluminum .038 inch thick.

In principle, it is therefore possible to measure the thickness of a homogeneous sheet of material by placing a source of beta rays at a fixed position on one side of the sheet and measuring the number or the energy of the beta rays which pass through the sheet and reach a detector at a fixed position on the other side. This principle has already been applied successfully in practice. Such a thickness gage has the important advantage of not requiring physical contact with the sheet being measured. It can therefore be used to measure the thickness of soft, uncured rubber or plastic, of textiles or paper coated with soft, gummy substances, as well as harder materials such as glass, aluminum, steel, etc.

A.I.E.E.,
New York, N. Y.
February 3, 1950

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W. H. ROBINSON, JR.

Lamp Department

Monopoly: There is considerable evidence to indicate that there are few large industrial concerns today which hold monopoly positions. . . . The word monopoly is virtually synonymous with "non-competition." It means, in short, that you control a market, fix the market's prices and policies, determine production and consumption, and so forth.

My company, General Electric, has probably never been more fiercely engaged in competition than it is today. In all spheres of activity we are constantly pressed to get a share of the customer's dollar. Initial advantages that come to the producer of new products never last long. . . .

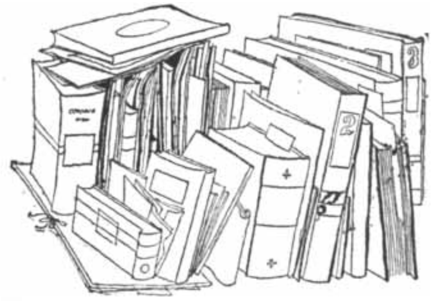
In 1934 the automatic blanket was initially developed by General Electric. Today there are 12 other companies making electric blankets in competition with us. In 1935 we first demonstrated fluorescent lamps. Today they are being manufactured by a number of companies. After years of laboratory development General Electric began in 1935 to produce and sell the Disposall kitchen waste units. Today 14 other companies are in the same field. Seven other manufacturers compete with us for x-ray tube business, following the development by General Electric of the x-ray tube. Today 34 different companies, besides General Electric, are manufacturing household refrigerators with hermetically sealed units, which in 1926 was our own development.

And so the story goes, ad infinitum. Other large companies have found in the automotive, food, oil, rubber, chemical, and steel fields that the degree of natural, unrelenting competition is every whit as keen as we in General Electric have found it to be.

Cleveland Advertising Club,
Cleveland, Ohio,
January 25, 1950

You can put your confidence in—

GENERAL ELECTRIC



BOOKS

A five-volume shelf about a sickness of both individuals and society: prejudice

by Gordon W. Allport

STUDIES IN PREJUDICE. Edited by Max Horkheimer and Samuel H. Flowerman. Harper and Brothers. ($20.00).

The Authoritarian Personality, by T. W. Adorno, Else Frenkel-Brunswik, Daniel J. Levinson and R. Nevitt Sanford ($7.50).

Dynamics of Prejudice: A Psychological and Sociological Study of Veterans, by Bruno Bettelheim and Morris Janowitz ($3.50).

Anti-Semitism and Emotional Disorder: A Psychoanalytic Interpretation, by Nathan W. Ackerman and Marie Jahoda ($2.50).

Rehearsal for Destruction: A Study of Political Anti-Semitism in Imperial Germany, by Paul W. Massing ($4.00).

Prophets of Deceit: A Study of the Techniques of the American Agitator, by Leo Lowenthal and Norbert Guterman ($2.50).

LORD BRYCE once prophesied that a cure will be found for every social ailment except race prejudice. A more recent writer has remarked that it is manifestly easier to smash an atom than a prejudice. There can be no doubt about the predicament of society to which these observers call attention, yet in view of certain recent developments one begins to wonder. After all, the atom has been smashed; conceivably prejudice may be next.

Certainly in no other area of social science is there such an outpouring of research as on this problem. It cascades through the pages of technical journals in sociology and psychology, and gushes forth in monographic publications such as the five impressive volumes reviewed here. What the ultimate impact of all this work will be we cannot tell. It seems likely, however, that in the not-too-distant future its effects will be felt, especially in our educational policies.

What is most impressive about these five volumes as a whole is the extent to which their findings support one another. Such cross-confirmation is heartening, especially in view of the fact that it comes from investigators working independently and using widely divergent methods. In these volumes we find data drawn from psychological tests, attitude scales, public opinion polls; from psychoanalytic protocols of patients, clinical interviews, documentary analysis. The authors have been resourceful in inventing ways of probing prejudice.

It is difficult to define prejudice. Although Bettelheim and Janowitz find that one third of the Chicago veterans they interviewed were outspoken in their hostility to Jews, and that two thirds spoke harshly against Negroes, we can be certain that most of the veterans concerned would insist that their attitudes are based on "facts," on the "well-deserved reputation" of the minority groups in question, and not on prejudice. A logical prerequisite to research on prejudice would seem to be an answer to the question: To what extent are accusations against minority groups true or false? Unfortunately evidence that would resolve this initial issue is hard to come by. The objective study of group differences is plagued by many difficulties. For one thing, some accusations (*e.g.,* "Negroes are lazy") are so vague as to be untestable. For another, we cannot say how often a trait has to be encountered before it can be considered a true group characteristic; for example, what percentage of addiction would justify the statement that "the Irish are alcoholic"? And in the few characteristics in which differences are statistically established, their interpretation is equivocal. Just what do lower verbal test scores for Negroes—and higher for Jews—mean? Do they indicate differences in native ability or in opportunity and incentive?

Although we cannot be certain that there are no *average* group differences in respect to objectionable forms of behavior, we can say positively that prejudice is present whenever a person disparages any group as a whole. No evil trait is the exclusive possession of any one group; nor does every member of a group possess an evil trait. Moreover, the difference within groups is always greater than the difference between groups. We know likewise that many alleged differences are totally nonexistent ("Negro blood is different from white blood"). Finally we know that many accusations are so blatantly contradictory that they cannot all be true ("Jews are beholden to Wall Street" and "to Moscow").

Although these five volumes do not deal directly with the factual study of group differences, they do disclose the prevalence of many palpably false generalizations. Take the case of the Jew. For most people the Jew is merely an ambiguous and formless stimulus; they are ignorant of Jewish customs and of Jewish traits, if any of the latter really exist. Under such circumstances, as Ackerman and Jahoda point out, the Jew may serve as a "living ink-blot" or Rorschach test wherein each person sees what he wants to see: a capitalist or a Communist, a rigid moralist or a libertine, a miser or an ostentatious spender, an aggressor or a coward, an isolate or an intruder. In *The Authoritarian Personality* we learn to what an astonishing degree an anti-Semite may make contradictory accusations.

The Negro is likewise a "living ink-blot." Bettelheim and Janowitz find that especially among the middle- and lower-class veterans they studied there is a tendency to project upon the Negro one's own Id impulses. It is the Negro, instead of the interviewee himself, who seems oversexed, lacking in self-control, lazy, dirty.

But prejudice is more than mere projection. It rests on many factors—among them historical conditions. No one can comprehend the present plight of the Negro in America without taking into account the backgrounds of slavery and the humiliations suffered by the South after the Civil War. Massing, using exclusively the historical method, surveys the steady march of political anti-Semitism in Germany from the time of the Franco-Prussian War to the First World War. Politicians as diverse in stripe as Stoecker (court chaplain to Wilhelm I), Bismarck and Fritsch (a racist forerunner of Hitler) attempted to build party unity out of hatred for the Jewish "enemy." To accelerate and maintain a mass movement from the right the device has been used in Germany time and again, and with catastrophic success by Hitler. The German Social Democratic party was always outspoken against the trick. Its leaders insisted that social ills stemmed from the capitalist system as a whole; but much of the German *Mittelstand* persisted in believing that only the "Jewish" part of capitalism was to blame.

Massing's book warns us that we should not put exclusive reliance on psychological explanations of prejudice and persecution. Hatred of the Jew is often not allowed to remain a private device for gratifying emotional needs. In the hands of political manipulators it shifts from a personal to a mass phenomenon. We know that anti-Semitism flourishes most widely in periods of economic depression, rapid social change, shifting political alignments and general social sickness. Even if prejudice is at bottom a personal state of mind it requires social forces to bring it into a kinetic state.

Yet the social and personal factors are intertwined. Some individuals are bigoted primarily because of an emotional need to be so; others are primarily conformists and adopt prevailing stereotypes as unthinkingly as they adopt their native language. Still others are astute demagogues who know how to exploit these states of mind. It is when the three types join together that violence breaks out. Bettelheim and Janowitz show that persons on the economic downgrade, suffering a severe blow to their self-esteem, are likely to become bitter and prejudiced. When a large group of such people assemble, they are ripe fruit for the agitator, for the "prophet of deceit." It has been estimated that eight to 10 million Americans hang on the words of such prophets. Most of the listeners appear to be joyless individuals over 40 who have failed to comprehend or adjust to the world they live in. They lack political, economic or psychological sophistication. To them all human groupings except their own seem outlandish and menacing.

Lowenthal and Guterman fill their small volume with documentation of the muddied discourse of American agitators. One is struck by the fact that the harangues are clear preparation for violence, if not actually incitement to it. While the target is always primarily the Jew, there is a drunken confusion in naming the scapegoats. In a single breath the agitator vilifies "aliens, Communists, refugees, renegades, socialists, traitors, Godless Bolsheviks, Judaism, nigger-lovers and Eleanor Roosevelt." The Federal administration and our system of political parties come in for prominent attack. The demagogue says in effect, "I know the danger better than you; give me your trust, your obedience, your money, and I'll lead you forth to smash the enemy." Should an economic or psychological crisis strike this country, it seems probable that the prophets of deceit will have a still wider, and perhaps disastrous, appeal.

While these volumes stress the importance of historical and social forces, it is primarily on the "character structure" of the bigot that they focus our attention. It is here that they make their most original contributions. Prejudice, it turns out, may be a systemic disease of the personality.

At the risk of oversimplification I shall venture to summarize the insights that the volumes yield regarding this central psychological problem. The evidence is in many respects still imperfect, yet it is worth our while to mark these emerging generalizations. Most of them meet reasonable tests for statistical significance and find support in two or more independent studies. The deeply prejudiced person seems to show several—sometimes all—of the following characteristics.

In childhood it is likely that he was deprived of a normal sense of love and security—at least he reports today that such deprivation existed early in his life. This sense of rejection may have come from an emotionally broken home or from harsh discipline. Generally the bigot's first social contacts were formed in an atmosphere of power relationships, not of love and trust.

He is haunted by a basic anxiety. This anxiety may arise from the initial insecurity of the home or from rigid moral training. Unable to come to terms with his parents on a friendly and mature basis, the individual goes through life bearing an unresolved protest against their dominance. Even though he may consciously endorse their views and express affection for them, he unconsciously betrays his resentment. Anxiety may also be due to later factors: to the threats that arise from economic insecurity, from physical or intellectual handicaps, from the dread of social ostracism, of war, of atomic bombs, of a depression. Though anxiety is common enough in our day, it seems to be an especially prominent constituent of intolerant personalities.

The bigot's attitudes toward authority are confused. Intolerant veterans, for example, show that they harbor bitter memories of their Army experiences, feeling particularly hostile toward their former officers. They decry their "unfair" treatment at the hands of the Veterans Administration and disparage many of our institutional safeguards of democracy. At the same time they are superpatriotic, nationalistic, militaristic. They feel the need for control, for authority, for definiteness. They are loyal only to groups that for them spell safety.

Human relationships for bigots are categorical; one either belongs or does not belong to the favored group. By and large intolerant people are vigorously loyal to church, school, sorority, to their own ethnic group and nation, for in these they find definiteness, a sense of superiority and safety. Their own groups are the "right" groups; all others are "wrong." Thus the individual relies not on the personal resources of integrity and self-confidence but on his memberships and similar props. This fact helps to explain the bigot's dislike of the democratic mode of living; for his taste it allows too much "slippage" in human relationships. Instead of providing clear-cut constraints, democracy places the responsibility for mature social conduct too heavily upon the individual, in his view.

It follows that intolerant personalities are not well integrated from within. In technical parlance, they have little "ego strength." They lack a trusting philosophy of life, for they are unable to cope with things that seem threatening and "ego alien." They commonly complain of feeling empty, afraid and beyond their depth. Bigots, far more often than tolerant people, see the world as a jungle, as a hazardous place where men are basically evil and dangerous. They are typically more afraid of "swindlers" than are tolerant people. Because of their anxieties they keep important parts of their own personality out of consciousness (especially repressing feelings of hostility toward their parents), and show violent emotion when these repressed regions are inadvertently aroused. Their lives show a lack of strong objective interests, and many of them report fears of going insane.

In the realm of morals their mode of thinking is also categorical. To them "there is always a right way and a wrong way to do anything." This simple two-valued logic dominates their ethical appraisals. Women are "pure" or "bad." They tend to regard sex as a physical matter, divorced from warmth and affection. Moral issues, they feel, must be handled with stern conventionality. Deviants are condemned. A person's conduct is not regarded in the total context of his life, nor from the point of view of psychosocial determinants.

Intolerant people are satisfied with themselves. Asked about the qualities that an "ideal person" would have, they tend to list the same set of traits that they actually believe themselves to possess. By contrast the tolerant individual is more likely to be dissatisfied with his self-recognized shortcomings. This sense of rightness inevitably brings with it a high degree of "extropunitiveness" (the tendency to blame outer circumstance and other people for misfortunes). Luck, bad breaks, lack of "pull" are seen as the reasons for failures in life.

Projection is a consequence of this extropunitiveness. It is of two types. In its simpler form it may only be the tendency to blame others for misfortunes. Jews, labor, Irish Catholic politicians may be perceived as the cause of distress. On the other hand projection may represent a mirroring of the bigot's own unacknowledged sins. Instead of seeing others simply as the external cause of his trouble he may ascribe to them the very sins that bedevil his own nature: lust, greed, laziness, dishonesty. When projection in either sense reaches an excessive degree of rigidity—as it does in militant bigots—we have a condition verging on paranoia.

Finally, and most important, in the bigoted personality intolerance is a generalized trait. A person hostile to Jews is more likely than not to be hostile to Negroes, Catholics, Mexicans, refugees and other "foreigners." There are of course exceptions, but the trend toward the generalization of prejudice is so marked that we cannot escape the conclusion that the problem at bottom is one of "character structure."

In describing this syndrome of intolerance I have leaned most heavily on the 1,000-page volume, *The Authoritarian Personality* (whose importance and originality would not have been diminished at all by cutting it in half). But the evidence comes as well, as I have said, from other volumes in this series and from other contemporary social research.

To only a slight extent is the syndrome related to age, sex, education, religious or political affiliation, income or objective social status. It is not so much the individual's position in the social structure itself that matters but his relative movement upward and downward and his attitude toward it. We cannot therefore accept a simple social theory of prejudice. Social conditions, it is true, activate and intensify bigotry, but unless the personality is ripe these factors have relatively little influence. The heart of the problem of prejudice is personal.

It follows that remedies must be of a sort that will ease the tautness, broaden the trust and enlarge the outlook of developing personalities. In these volumes no therapeutic research is reported. We need now to devise and test methods for changing attitudes in the course of their growth. Naturally the most hopeful place to start is with the child—in the home, church, school and clinic.

Each of the five volumes carries an identical foreword written by Horkheimer and Flowerman, of the Department of Scientific Research of the American Jewish Committee, under whose direction the investigations were carried out. To them and to the authors of the several volumes congratulations are due. They have successfully pushed forward the resistant frontiers of social knowledge with research that is bold, original, and—considering the infant state of social science—of unusually high quality.

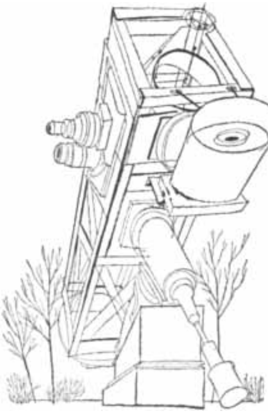
Gordon W. Allport is professor of psychology at Harvard University.

WORLDS IN COLLISION, by Immanuel Velikovsky. The Macmillan Company ($4.50). Scientists consider Velikovsky's laborious theory that 3,500 years ago a great comet temporarily stopped the earth in its rotation to be one of the most astonishing hoaxes ever perpetrated on credulous man. Scientists of the social variety might even find it a study of mass psychology as interesting as the famous Orson Welles "men from Mars" broadcast. The author seems unperturbed by such opinions; the next of his chimeras, *Ages in Chaos,* will appear on schedule.

SCIENCE IS A SACRED COW, by Anthony Standen. E. P. Dutton and Co. ($2.75). What might be a useful and even an amusing idea—namely, to stick pins into the large balloon inflated by scientific pomposity, jargon, pretentiousness, fuzzy ideas, and the cult of "scientificness"—is here perverted in a bumptious, captious and silly book. Standen, who according to the jacket blurb is a chemist now editing a chemical encyclopedia, has little good to say on behalf of any of the sciences except physics and mathematics. He reserves a special hotfoot for the social sciences. Among the more interesting of his conclusions are these: that mathematics is the only science which is "actually true" (it is, of course, in his sense of "true," the only science in which the concept of "truth" is wholly irrelevant); that even an "indifferent theologian is better than a modern scientist"; that the "first purpose of science is to learn about God, and admire Him through His handiwork"; that a U. S. Senator in opposing inclusion of the social sciences in the proposed National Science Foundation uttered a "deep piece of wisdom" when he remarked, "It is a question of keeping selfishness in restraint, that is all." Standen adds that this wisdom differentiates the Senator from any social scientist: "That is why he is in the United States Senate, and they are not." Standen, a commuter, says his book was written on the Long Island Railroad; there is every reason to believe this is true.

CALCULATING INSTRUMENTS AND MACHINES, by Douglas R. Hartree. University of Illinois Press ($4.50). GIANT BRAINS, by Edmund C. Berkeley. John Wiley & Sons, Inc., ($4.00). Each aimed at a different level, these two books are clear, competent introductions to the subject of calculating machines. Hartree, Plummer Professor of Mathematical Physics at Cambridge, summarizes for an audience of trained scientists the history, design and philosophy of analogue and digital machines. Berkeley's book presupposes less special knowledge. He describes the properties of such devices as the "Simple Simon," the Massachusetts Institute of Technology's Differential Analyzer No. 2, Harvard's IBM Automatic Sequence-Controlled Calculator, ENIAC and the Kalin-Burkhart Logical Truth Calculator. Although this is not in any sense an easy book to read, Berkeley writes directly and unpretentiously and the accompanying diagrams are unusually helpful. As both studies plainly indicate, the most up-to-date calculating machine, for all its remarkable prowess, is still in infancy both as to use and design, and is certainly much inferior to most living organisms in its ability to improvise, to make "bright guesses," to leap to conclusions by any intuitive means. In other words, while these machines can substitute for the human brain in certain areas, the possibility of total human obsolescence still lies within human control.

THE AMATEUR



Conducted by Albert G. Ingalls

IF THE FACETS of a pitch lap are arranged symmetrically, a mirror polished on it may show zones. All instructions for making pitch laps therefore specify that the center of the lap must fall in one corner of a facet. But even this method may produce zones, because the channels on either side of the center are equidistant. For that reason J. W. Draper of Warren, Ohio, suggested to Leo J. Scanlon of the Valley View Observatory, Pittsburgh, Pa., that the channels adjacent to the center of the lap be spaced at unequal distances from it, as shown in the left-hand design on the opposite page.

After using this Draper lap layout in teaching mirror making at the Buhl Planetarium, Scanlon praises it highly. He also finds it well worth while to design laps with care on paper and then transfer the design to the pitch by embossing through to the lap.

A refined, delicate, special-purpose lap originally devised by John A. Brashear and used in modified form by George Croston of Aloha, Ore., is shown in the right-hand drawing. It should be made up on a Pyrex or metal backing because it will be cooled under running water, which would crack plate glass. The ripsaw-toothed profile of its long ridges is shown in the drawing. All work done with this lap is against the grain, with the lap on top of the work.

The purpose of this "scraper" lap is the elimination of small imperfections in the last stages of polishing; it should not be used either for normal polishing or for figuring. "It does its special job perfectly," Croston writes, "but is useless for anything else."

He continues: "The Brashear finishing lap is made of pitch that has been hardened with strained rosin. It may be made of rosin alone if the worker can form that brittle material so thin. Strict adherence to the ridge profiles shown is not essential, but their tops must be narrow and parallel. However, a vertical side or a steep slope provides a better wiping action and also tends to hold better the thin application of rouge that does more work than thick.

"To form the lap to the surface that is being worked it should be wetted with soapy water while it is still warm, worked with short strokes parallel to the ridges until it shows perfect contact, and then cooled under the tap before being charged with rouge and used.

"To remove small imperfections such as HCF prints or wiggly lines on a flat, the lap is rubbed across the glass with firm pressure and about one-sixth strokes and with the ridges at right angles to the direction of travel. After 10 strokes the mirror is rotated 90 degrees and the 10 strokes are repeated. This is usually enough to produce a perfect surface. If it does not, wash off all rouge from lap and glass (important) and dip the tips of the ridges of the lap in lukewarm water for a couple of seconds or, better still, use a heat-ray lamp. Very little rubbing and no cold pressing will be needed to make perfect contact. Cold pressing would transfer the irregularities of the mirror to the lap.

"This lap should be used at once after it is formed; otherwise it will slowly flow and then create new defects on the mirror.

"The nearest relative of this lap is shown in John Strong's *Procedures in Experimental Physics,* page 48."

The third lap to be described is the invention of Walter W. Puderbaugh of Richland, Wash. He calls it the sintered pitch lap. Others call it the Puderbaugh lap. Puderbaugh was fed up with pitch, which he says is "just plain hell to form. The more rosin in it the meaner it is—in short, a stubborn mess that will do everything possible to resist taking a charge of rouge." He put some pitch in a household refrigerator, chilled it, brought it out, pulverized it while it was cold between a steel rolling pin and plate glass, and fined it further with a spatula. Next he built the conventional paper dam around the tool. He painted the tool with pitch and beeswax cut with carbon tetrachloride and made tacky. Then he poured in the chilled powdered pitch, leveled it off, painted his mirror thickly with rouge paste and laid it on the lap and tool. He set the whole unit, tool up, in rather warm tap water, waited a while, took the assembly apart, added rouge, and started polishing.

He found that cutting channels in this lap with a wet blade is no trouble, and he believes the lap works faster than the common kind. It cold-presses well.

What is the principle of the sintered lap? Sintering is a method of converting powder into a cohesive mass by heating it to considerably below its melting point, generally after compacting by pressure.

ASTRONOMER

Union between the particles results not from fusion but from surface cohesion. The irregular particles touch one another only at their corners. Elsewhere air spaces remain.

Puderbaugh finds that the main secret of success with the sintered lap is to supply enough heat to produce sintering without melting. Sintered pitch has peculiar characteristics. Some that he kept for months in a refrigerator had not consolidated.

In any case, the Puderbaugh lap is radically different from the fused lap. It was first experimented with more than two years ago, and its fortunes have been watched ever since by this department. It appears to be sound. John M. Holeman of Richland now reports that "more and more local users have tried it and like it very well. They have nothing but good to say for it. Easy to make. Holds figure."

TO ELIMINATE five of Russell Porter's "seven devils" of pitch, Kenneth Falor of Bay City, Mich., simmers pure rosin until the froth and bubbles, which form in large numbers and need close watching, subside. He then adds high-grade no-detergent automobile oil of SAE 30 or 40 to obtain the desired temper. This mixture keeps its temper almost indefinitely despite frequent melting. For his inspiration Falor credits the 200-inch telescope job. He finds advantage in dropping the test samples on metal instead of glass; the metal conducts their heat away much faster than glass and saves much waiting.

IN THE PAST many amateur telescope makers have independently discovered that mirrors may be ground and polished without the conventional handle, and have reported their apostasy with quite unnecessary apology. In a debate on handles *v.* no handles much could be said on both sides. The correct way is the one you like best.

If a handle is preferred, it is likely to receive much use. A good one is thus worth while. Provided it does not cover too much of the mirror, its correct design is again the one you like best. The handle shown in the drawing on page 62, pitched to a 6-inch mirror, is a somewhat aristocratic transparent handle made by Holeman. The shaft was turned from a rod of Lucite. It is screwed to a Lucite disk ⅜-inch thick and 2½ inches in diameter to receive the thrust of the hands.

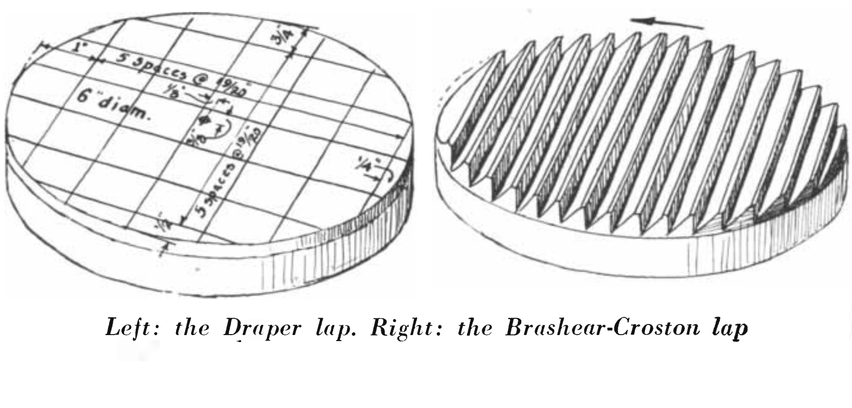
With less trouble a short button may be used as a pickup handle as in the second illustration, redrawn from a little booklet by T. J. Mulligan of 1 Airthwaite, Kendal, Westmorland, England, entitled *Making a Telescope Reflector.* With A. J. S. McMillan of 5 Oakfield Road, Bristol, Somerset, England, Mulligan is attempting to revive the telescope-making hobby in Britain by supplying mirror-making kits there.

The thermal shield shown above the Mulligan handle is devised not by Mulligan but by the editor of this department, and has been used for many years without causing any of the scratches that armchair theorists asserted it would create. It can easily be lifted to inspect the lap through the mirror.

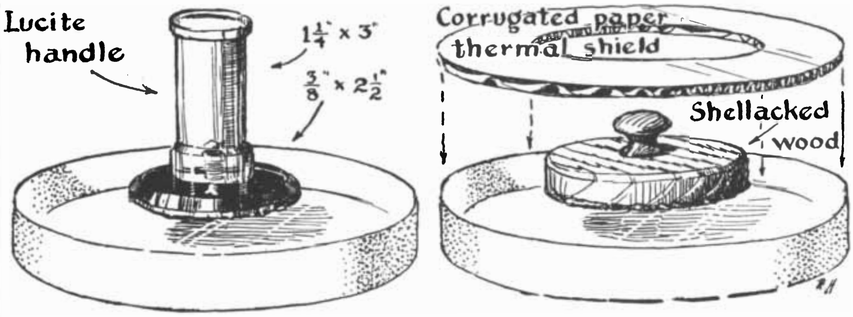
AMATEUR telescope makers have often been disappointed because their mirrors would not pass that part of the diffraction-ring test described in *Amateur Telescope Making* in the final paragraph on page 434. This states that in a perfect mirror the out-of-focus images of a star should be alike at equal distances inside and outside focus. If there are differences the nature of these differences gives useful information about the aberrations.

For some of those who have been unable to obtain this much-desired identity of images F. J. Hargreaves, F.R.A.S., has supplied a happy alibi in *The Journal of the British Astronomical Association,* Volume 59, No. 3. He points out that the metal mounting of the telescope's diagonal support is usually colder than the atmosphere and that it chills the air in its immediate neighborhood. This chilled, dense and therefore more highly refractive air acts as a weak lens. Thus outside of focus the inner ring adjacent to the black central shadow of the diagonal becomes bright, as shown in Hargreaves' second drawing on page 63, and has a hairy or spiky inner fringe.

If there is aberration in the mirror the bright ring is absent on one or the



Left: the Draper lap. Right: the Brashear-Croston lap



Left: Lucite mirror handle. Right: button handle

other side of focus. The "air lens" surrounding the cold metal diagonal support has exactly the same effect, and many mirror makers may have blamed their workmanship because of it.

It remains to be explained why the metal parts of a telescope should be colder than the atmosphere. We would expect this if a telescope had just been brought into the open air from a cold cellar. But even if the telescope starts with its metal parts at exactly air temperature they will be found after a time to have a lower temperature, provided the night is clear. How can we account for this?

In this department in January, 1944, F. N. Hibbard, a U. S. Weather Bureau meteorological physicist and an amateur telescope maker, explained this phenomenon. "It is not generally known, outside the Weather Service," he stated, "that various substances or materials exposed in the open air under a clear night attain temperatures different from that of the surrounding atmosphere. Repeated experiments prolonged for months show that thermometers so exposed consistently register lower-than-air temperatures, differences amounting generally to several degrees and occasionally as much as 8 degrees. They further show that the differences persist for hours at a time. In other words, objects exposed to the clear night sky seldom attain the temperature of the air, but differ from it and from one another. To conceive the process by which two contiguous substances, such as air and metal, can attain and maintain such an anomalous thermal condition for hours together is difficult. It depends, however, principally upon the individual absorption and radiation properties of the substance."

Others have given more than Hibbard's hint of the explanation. All bodies simultaneously radiate and receive heat in amounts depending on their temperatures. The telescope tube radiates to cold interstellar space at a rate so much greater than space radiates to the telescope that the radiation is practically all in the outward direction. This constant radiant heat leak explains why the telescope does not warm up to air temperature—unless clouds cut off the leak, in which event they also cut off the observing.

In his *Meteorology* the late Professor Willis I. Milham, an astronomer-meteorologist, discussed this effect, which hampers meteorologists by causing thermometers to give readings from 1 to 7 or 8 degrees too low on clear nights. Meteorologists reduce this error by placing their thermometers in shelters having diagonal sloping slats like Venetian blinds that admit the air but obstruct radiation to the sky. In an article in *Monthly Weather Review,* a publication of the U. S. Weather Bureau, for July, 1905, Professor Milham described long, painstaking experiments which proved that night after night two matched thermometers only 20 feet apart registered 3, 4 and sometimes more degrees difference. One was exposed to the clear sky; the other was within an unheated, unprotected but radiation-stopping thermometer shelter.

The metal-chilling effect of radiated heat has a direct relation to the selection of materials and forms for telescope tubes. Hibbard and J. C. Vaughan, a Virginia telescope maker, tested telescope tubes of different materials for two years. They found that:

In a solid metal tube the chilled air that constantly drained down next to the metal produced irregular refraction of light and resulted in poor images.

Lining the tube with cork, asbestos or paper improved this performance somewhat.

Holes bored in the upper part of the tube to cause air drainage there admitted cool air that streaked the image.

A solid metal tube with its central two-thirds portion removed and the ends connected only by six lengthwise angle irons did not give the expected beneficial mixing of outside and inside air. Instead, the chilled iron streaked the images. Wrapping the irons with thick black paper improved the images, but at times they were intolerable. By inserting a cardboard lining inside the skeleton tube it was proved that the chilled metal was the cause of this: the streaking vanished and the images became good. This experiment was tried over and over until the conclusion was inescapable that the metal had an entirely different temperature from that of the air, and that this difference persisted hour after hour.

In the entire two years of the tests only a single night afforded first-rate seeing with an open or skeleton tube of metal.

Hibbard and Vaughan's final experiment was to line a solid metal tube with cork a quarter-inch thick and cut a 20-square-inch hole in the tube just above the mirror. This opening, adjustable in area, ventilated and cooled the mirror and gave excellent results, especially if the hole was covered to steady the air inside just before actual observation.

After all these experiments, conducted with the understanding of underlying factors that meteorological physics affords, Hibbard stated that to build any telescope tube of aperture up to 24 inches he would use sheet metal lined with cork, balsa or Douglas fir. "The 24-inch limit," he added, "came from the late J. W. Fecker, who said he had known for many years that skeleton tubes produce troublesome images that decrease as that aperture is approached. At that point the tube effects are hardly noticeable, especially since telescopes that large are placed in domes.

Hargreaves' discovery that the fringed bright ring of his outside-focus image is caused by the refraction of chill dense air next to the metal diagonal support is clearly an example of this phenomenon of cooling by loss of radiant heat. He states that he had been puzzled by the bright ring and its vagaries for 13 years, during which he had tested a great many mirrors in his telescope. He knew that if spherical aberration is present the ring is absent on one side of the focus and that this absence might also indicate a narrow defective zone just outside the area of the shadow of the diagonal. Reviewing the problem carefully he was struck by the fact that "in every case when other tests had shown that a mirror is free from aberration, the inner bright ring had been absent from the image inside focus and abnormally bright outside focus, and never the other way round."

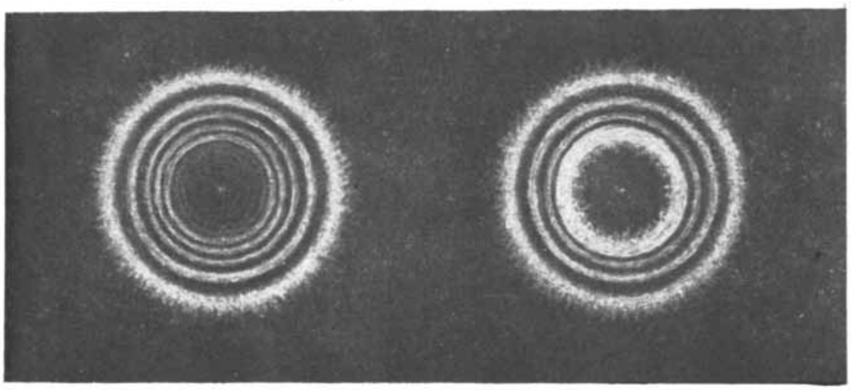
At last, one very windy night a clue presented itself. "Every time a strong gust struck the telescope the bright ring became temporarily one-sided—weaker on the windward side and stronger on the leeward side. The explanation," he continues, "is simple. The cell and mounting of the diagonal become colder than the atmosphere and chill the air immediately surrounding them. There is therefore a sheath or 'tube' of dense air, densest at the surface of the mounting and becoming progressively less dense radially outwardly, which acts as a weak collective lens. The effect of this air lens is precisely the same as that of a zone on the surface of the mirror, of shorter focal length than the rest of the surface and just outside the area of the shadow of the diagonal. I had been looking for such zones for years, and failing to find them."

Hargreaves put this diagnosis to the test by holding his hands on the mounting of the diagonal for a few seconds to warm it, taking care not to warm the diagonal also. "The immediate effect," he states, "was to reverse the appearance, the bright ring being transferred to the inside-focus image. After a few minutes the two images were exactly the same for a short time and then the original appearance returned" as the metal cooled.

"It must be borne in mind," he emphasizes, "that the abnormally bright ring *may* be due to spherical aberration or to a real defective zone on the mirror.

"In warm weather when the telescope is first opened up in the evening, the inside-focus image invariably shows a very strong bright ring round the central shadow. I now have no doubt that the effect is due to the diagonal mount being temporarily warmer than the surrounding air."

Hargreaves is a member of the recently organized firm of Cox, Hargreaves and Thomson of Kingswood, Surrey, England. All three partners began years ago as amateur telescope makers and, after much advanced experience, turned professional. Such has been the history of most professional telescope makers. The three partners retain their amateur status as astronomers. They have received a spate of work, including a 25-inch Schmidt camera, regrinding and refiguring the 30-inch mirror made 60 years ago by Common for Greenwich observatory, and a 51-inch mirror for the old Melbourne reflector in Australia.



Left: inside focus. Right: outside focus

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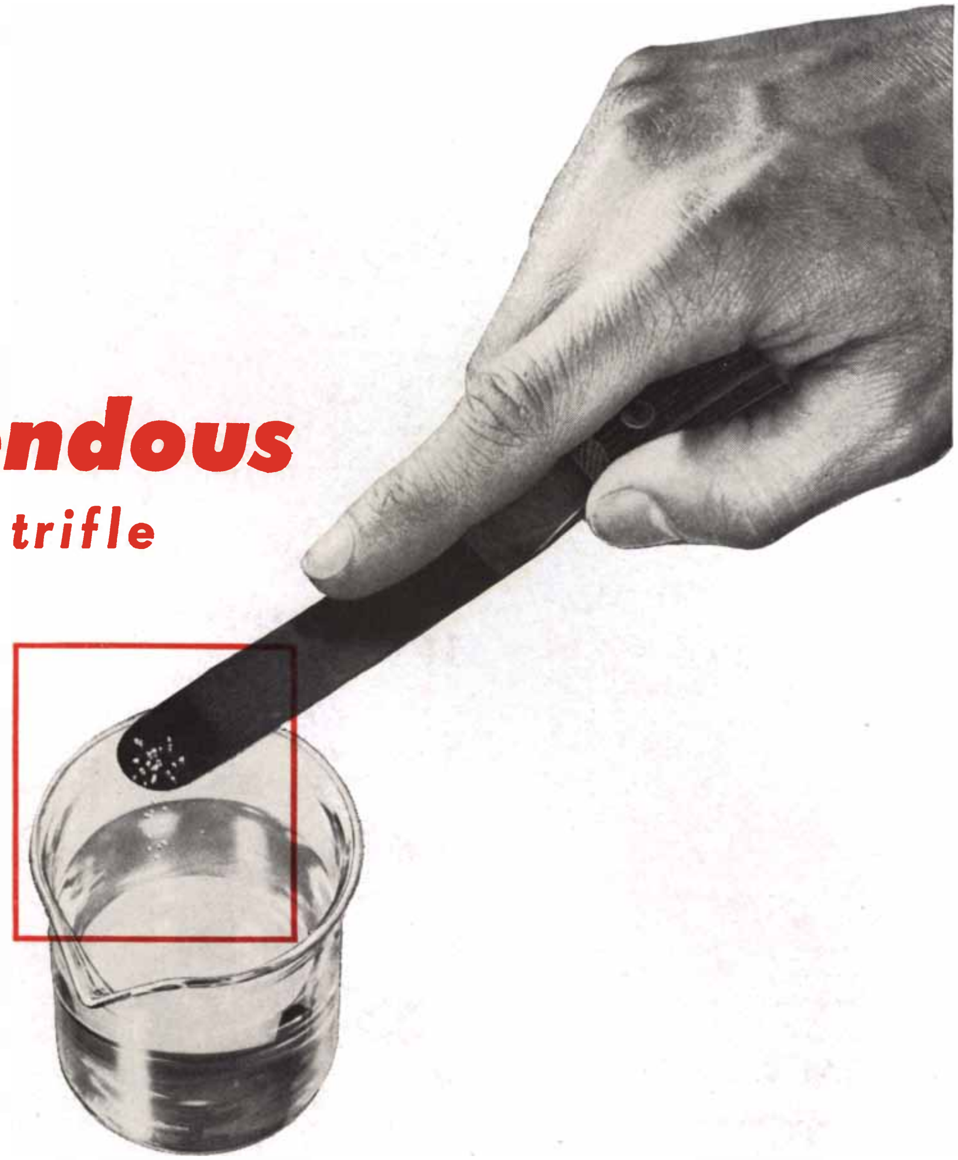

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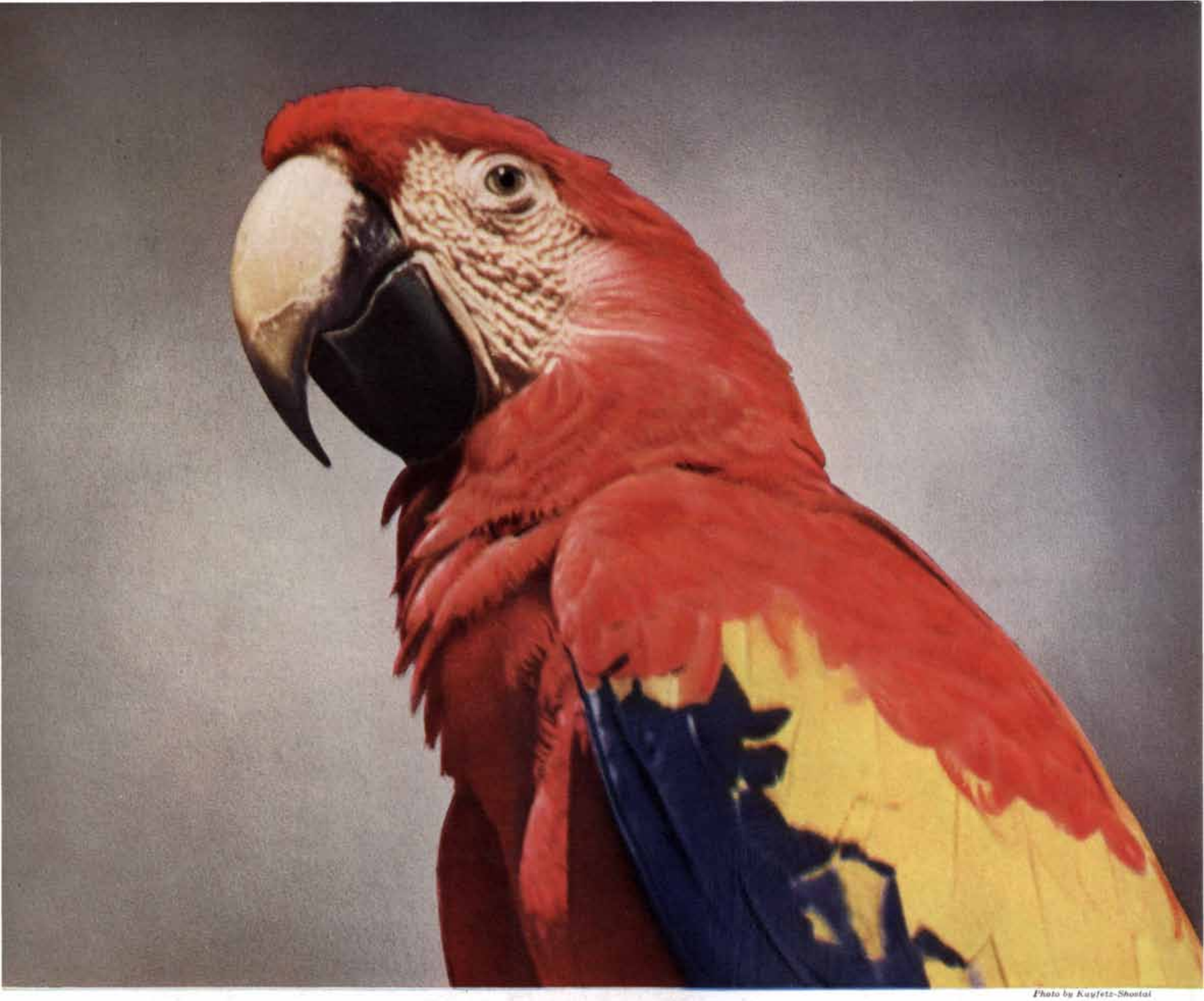

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