# SCIENTIFIC AMERICAN

**HOT ATOM CHEMISTRY**

**FIFTY CENTS**

*March 1950*

New scintillation counter, using electron tube developed at RCA Laboratories, gives faster, more accurate measurements of atomic radiations.

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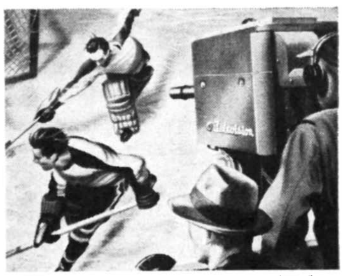

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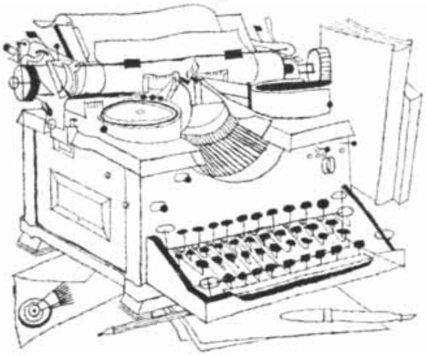

# LETTERS

Sirs:

In Theodosius Dobzhansky's article on genetics in your January, 1950, issue, his reference under "Genetics and Mathematics" makes much of the figure $2^{1000}$ as a number "utterly beyond comprehension."

I believe the author is taking this figure out of its proper scientific context. Certainly it is a very large figure in the particular physical terms to which it is referred. However, in terms of probabilities, and more specifically biological probabilities, it is a very small figure. It seems hardly necessary to point out that biology rather than cosmography is the proper frame of reference.

To illustrate the relatively small size of $2^{1000}$ in terms of probabilities generally, consider a crowd of 100,000 people watching a football game. At any moment any one of the spectators may be either standing up or sitting down. The total number of possible situations in terms of sitting or standing is $2^{100,000}$ (assuming, of course, an equal probability of sitting or standing for each spectator). Obviously, if the area of observation is extended to larger numbers of people, or over a longer period of time, this number can be increased practically without limit.

If the total number of (mathematical) ways in which body cells can, or cannot, participate in a particular function are examined in similar fashion, the possible combinations are almost inconceivably large. Assuming that the millions of brain cells, or cells of the muscle fibers, or nephrons of the kidney may, each one of them at any given moment, either participate or not in a particular biological action, the total possible situations are counted in numbers perhaps as large as two raised to a power in the millions. Such numbers are of the order of $2^{1000}$ multiplied by itself 1,000 times. Even these possibilities can be compounded indefinitely if, for example, the number of possible actions within the cell, and actions over a period of time, instead of cell action at just one instant, are considered.

Of course, some of the mathematical possibilities involving group cellular action may be assumed to be biologically impossible. Also, certain patterns of action are much more likely to occur than others, just as it is much more likely that certain people will stand up during the football game, and that the tendency to stand will be greater at certain times during the game.

It is questionable whether an estimate of the total possible number of biological (and human) actions can have any significance except in terms of a very general observation regarding their orders of magnitude. This suggests that if the figure of $2^{1000}$ has any meaning or significance at all, it might very well be one contrary to that suggested by Professor Dobzhansky. One might consider that this number seems altogether too small for the sum of all possible genetic combinations, when viewed against the tremendous scale of possible actions in various biological processes.

MANUEL GELLES

Great Neck, N. Y.

Sirs:

At the Christmas meetings of the American Genetical Society in New York, it was proposed that a small group of the Society be empowered to speak for the Society "as a whole" to the end that opposition to the antigenetical propaganda resulting from the Lysenko controversy could be expressed more effectively. This proposal was defeated. This does not mean that there is a single member of the Society who respects or supports Lysenko; if such a member exists, he did not make his presence known. It does mean, however, that unanimity of opinion is not so widespread as Professor Dobzhansky's recent article in *Scientific American* seemed to imply.

The relative importance of different factors in evolution is by no means agreed upon. This was dramatically emphasized in Stockholm in 1948 when Richard B. Goldschmidt, one of the most outstanding students of evolution, described experiments indicating that parts of the chromosomes which H. J. Muller had shown to be relatively free of genes (and which he had considered "inert" for this reason) may be of prime importance in effecting major steps in evolution. Professor Dobzhansky arose with the comment: "The evolutionary significance of this phenomenon is *zero*." Another example is supplied by the "plasmagenes" which Professor Dobzhansky refers to without reservation in his article. I, personally, do not believe that these hypothetical structures exist.

Professor Dobzhansky believes that evolution has been demonstrated in the laboratory. It would require more than a short letter to refute this view, but I am of the opinion that "progressive" evolution has never been observed in the laboratory. The minor fluctuations demonstrable in the laboratory which Dobzhansky calls "evolution" are, in my opinion, merely forward and backward changes comparable to the balancing movements which an acrobat on a tightrope has to perform to maintain his balance but which have nothing to do with his forward progress, except that if he failed in them he would fail completely.

The phenomenon which I believe has most to do with progressive evolution is unequal crossing-over of the chromosomes. This phenomenon was discovered by A. H. Sturtevant, in whose laboratory Dobzhansky studied for many years. Alexander and Bridges pointed out that it provided an additional amount of gene material which could be available for possible "progressive" evolution.

Professor Sturtevant also discovered the inverted sections in chromosomes. Inverted sections are the basis for the fluctuations in fly populations which Dobzhansky has studied so exhaustively. Dobzhansky's failure to list Sturtevant first among those who have contributed to the genetic basis of evolution is merely another example of the extreme differences in personal opinion on this highly debatable subject.

CARL C. LINDEGREN

Southern Illinois University
Carbondale, Ill.

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# 50 AND 100 YEARS AGO

MARCH 1900. "Up to the present time chemists have succeeded in discovering over seventy elements or simple substances. 'These elements,' Sir William Crookes has aptly remarked, 'perplex us in our researches, baffle us in our speculations, and haunt us in our very dreams. They stretch like an unknown sea before us, mocking, mystifying, and murmuring strange revelations and possibilities.' At the beginning of the century Prout advanced the theory that there was but one primeval substance. Prout believed it to be hydrogen. Accurate measurements, which could not be made in Prout's day, prove that the atomic weights of many elements cannot be expressed as multiples of that of hydrogen. But the existence of a substance which forms a constituent of all elements in common is supported by the well-known periodical system formulated by the Russian chemist, Demetrius Mendeljeff. The composite nature of the elements seems to be a well-founded theory, which investigators are justified in taking as the starting point of future researches. The first step has been taken in the attainment of new knowledge, when the dogma of impossibility has been set aside."

"M. Becquerel has given an account to the Academie des Sciences of a remarkable phenomenon which he has observed in the course of his experiments upon radio-active matter. He finds that a magnetic field has a marked effect upon the action of these bodies, and when placed between the poles of a powerful electro-magnet, the radiation which they emit is changed in direction and becomes concentrated upon the poles."

"Marconi thinks that the present limit of 86 miles for wireless telegraphy will shortly be raised to 150 miles."

"Immigration in 1899. The total arrivals for the year ending June 30, 1899, were 311,715, an increase of 82,416 or 36 per cent. There were 195,277 males and 116,438 females. According to age, 43,983 were under fourteen years; 248,187 were from fourteen to forty-five and 19,545 were forty-five years or older. As to illiteracy, 60,446 could neither read nor write, and 1,022 could read, but were unable to write. The total amount of money which they exhibited to the officers was $5,414,462; 174,613 had less than $30 each."

"Sir William Crookes has recently given an account to the Royal Society of his discovery of the new element which he calls victorium. The chemical properties of victorium differ in many respects from those of yttrium, but generally speaking it may be said to occupy an intermediate position between this element and terbium. Its atomic weight is not far from 117. The photograph of the spectrum given by the oxide shows certain definite lines which have not been observed with any other body."

"The bi-centenary of the Prussian Academy of Sciences was inaugurated on March 19 at the castle at Berlin in the presence of the emperor and prominent officials. The scene was of great splendor. Three Americans were elected: Prof. Josiah Willard Gibbs of Yale University, Prof. H. A. Rowland of Johns Hopkins University, and Prof. William James of Harvard."

"With the establishment of the Tripler and the Ostergren-Berger plants, atmospheric air has been liquefied in quantities which have surpassed the expectations even of those scientists who for years have made the physics of low temperatures their special field of investigation. As a scientific feat, the liquefaction of air in large volumes is certainly startling, but the practical value of the achievement is still to be demonstrated. A project for the industrial utilization of liquid air has been formulated by Prof. Raoul Pictet of Geneva, Switzerland. His industrial application of liquid air consists in the dissociation of its nitrogen, oxygen, and carbon dioxide, gases which are obtained in such large quantities and at such low cost that they can be profitably used in the arts. His process, if it prove successful, will affect the metallurgical industries, vastly influence steam and civil engineering, and introduce new methods for the commercial production of the most important chemicals used in the arts."

MARCH 1850. "A memorial has been sent to the House, asking the aid of Congress for carrying out a plan for carrying the telegraph across the Atlantic, by means of a cable from Halifax to Ireland. The estimated cost is from three to four millions."

"When the friends of Sir Humphry Davy were expressing their high admiration of his valuable discoveries, he interrupted them with this extraordinary remark: 'The greatest discovery that I have ever made, was the discovery of Mike Faraday'—a poor boy whom he picked up in a work-shop, now the world renowned Sir M. Faraday."

"A bill has passed the House of Delegates fixing ten hours a day as the period of labor in factories within the State of Maryland. It is before the Senate."

"Where is the Wilderness? At the beginning of this century it was in Ohio and Indiana. Twenty-five years afterwards it was in Michigan, Wisconsin and so-forth. Last year it was in Minnesota Territory. Next year we will have to seek it in Nebraska and around the Lake of the Woods."

"In M. Lombard's returns for Geneva, the average longevity of stone-cutters is stated at 34 years; sculptors, 36; millers, 42; writers, 51; surgeons, 54; merchants, 62; Protestant clergymen, 63; and magistrates, 69 years."

"A petition, signed by over 200 firms, corporations and individuals, is about to be presented to Congress, asking an amendment of the Patent Laws. They particularly complain of a patent which, they say, was unjustly granted to Charles Goodyear for the vulcanizing of india rubber."

"The American Association for the Advancement of Science met in Charleston last week. President Henry was absent but his place was filled by Prof. Bache."

"Passengers may now go from Pittsburgh to Philadelphia in fifty hours, without *staging* at all—taking the railroad at Jackstown. So says the Pittsburgh Mercury."

"The boiler of the steamboat Troy, exploded at Buffalo, on last Saturday. A great number were killed and injured. When will there be an end to such wholesale slaughter?"

### THE COVER

The apparatus that appears in the painting on this month's cover is characteristic of an experiment in a "hot atom" chemistry laboratory (*see page 44*). Presumably the experimenter has just received a lead container from Oak Ridge National Laboratory in which is a bottle of an artificially radioactive compound. Attached to the bottle is a string by which the experimenter lifts the bottle from the container to his laboratory table. There the experimenter erects a little fortification of lead bricks between him and the bottle so that he may work with the radioactive compound without suffering radiation effects. The string may be seen protruding between two of the lead bricks at left. Behind the bricks is a mirror in which the experimenter may observe his manipulations of the bottle. The bottle may be seen in the mirror through a gap in the bricks at the right. Extending from the mouth of the bottle is the tip of a remote pipetting device which is operated by the swivel-jointed pistol grip apparatus in the foreground. The pipette is used to transfer liquids from one vessel, such as the beaker at the left, to another. The pipette and the lead bricks that appear in the painting are manufactured by Tracerlab, Inc., of Boston, Mass.

### THE ILLUSTRATIONS

Cover by Walter Murch

| Page | Source |
|---|---|
| 12 | Adolph Brotman |
| 14-15 | Irving Geis |
| 17-19 | Irving Geis |
| 21 | Otto Jírovec, Charles University |
| 22 | K. Chester |
| 30-32 | Irving Geis |
| 38-43 | David Stone Martin |
| 44-47 | Eric Mose |
| 48-51 | Philip R. White, Institute for Cancer Research |
| 53 | Samuel R. M. Reynolds, Carnegie Institution of Washington |
| 54 | Samuel R. M. Reynolds, Carnegie Institution (*top*), Adolph Brotman (*bottom*) |
| 57 | The New York Public Library |
| 61-63 | Roger Hayward |

# SCIENTIFIC AMERICAN

Established 1845

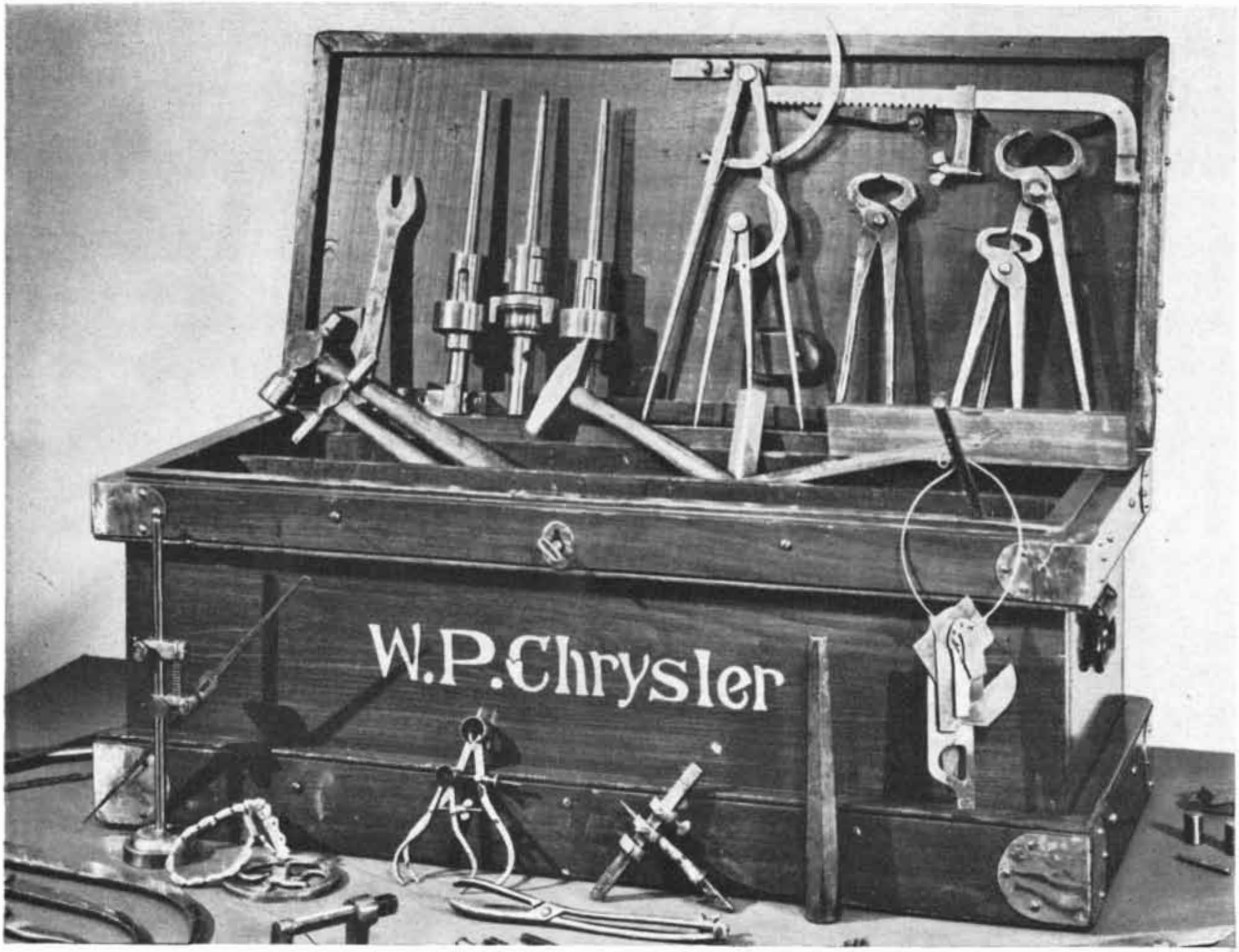
CONTENTS FOR MARCH 1950 VOLUME 182, NUMBER 3




## ARTICLES



## DEPARTMENTS




Walter Chrysler's original tool chest—on display in the Chrysler Automobile Salon, New York

## The tools that money couldn't buy

Walter Chrysler made them himself. He was 17, working in a railroad roundhouse. His mechanic's fingers itched for a kit of tools of his own. So young Walter took steel and made his own.

As he shaped them, he shaped a dream as well. It was a special American kind of dream—free-ranging imagination anchored to solid things like common sense, working a little harder, making things a little better. And asking no odds of anyone.

It led Walter Chrysler to success in railroading when he was young. It led him to study the automobiles of the day. Why couldn't a man build *better* cars than any known—nimbler, safer, more comfortable, handsomer.

So, 25 years ago, Walter Chrysler introduced the first Chrysler car. What he did changed the whole pattern of American motoring. He changed it with high-compression engines, 4-wheel hydraulic brakes, all-steel bodies, new ways of distributing weight for better riding . . . many originations the entire automobile industry eventually followed.

As Mr. Chrysler's birthday, April 2nd, approaches and as Chrysler Corporation this year observes its own 25th anniversary, it is fitting to pay this tribute to Walter Chrysler and his creative genius.

And the tools of his earlier mechanic's days? I remember when he found them in his mother's house. It was long after he had asked me to work with him. He brought the tools back from Kansas. A few of them needed fixing and he asked me to fix them. It was a compliment I have never forgotten.

The qualities Mr. Chrysler put into his own tools still mark the great organization he founded. He built not merely material things; he inspired men with a zeal to carry on his splendid ideals.

Chrysler Corporation is still young enough to feel his inspiration. He wished this company always to be a producer of fine automobiles of great value.

And those of us who were privileged to work with him believe that the new Plymouth, Dodge, De Soto and Chrysler automobiles live up to his tradition.

It is a tradition uniquely American—to live and work with the idea of finding better ways to make what people want.

K T Keller, *President*

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SCIENTIFIC AMERICAN

MARCH 1950 VOL. 182, NO. 3

# The Hydrogen Bomb

## Presenting an account of the theoretical background of the weapon and a discussion of some questions it has raised in regard to our present policy of security

by Louis N. Ridenour

DURING the first weeks of 1950 the national scene was enlivened by discussions of the so-called "hydrogen bomb." Should a full-scale effort, perhaps comparable to that required to develop the fission bomb, be invested in attempting to create the potentially much more powerful hydrogen bomb? What is the morality of doing this? How would it affect our national position in an uneasy world to undertake this task? Should we not seek agreement with the U.S.S.R. on atomic energy control before embarking on a development of such significance and magnitude? Americans were asking themselves and one another these questions.

On January 31 the President of the U. S. announced that he had instructed the Atomic Energy Commission to work on the hydrogen superbomb. Thus a major issue of public policy, one quite possibly involving our national existence, was decided in a fully authoritarian way. Not without public discussion, to be sure; but without anything that could have been called informed public discussion. The public did not even know, and still does not, what the actual questions at issue were. Indeed, the matter became accessible to public discussion only because a careless reference to it was made on a television broadcast by a Senator who professes devotion to the principle of suppressing important information from the public, in the name of what he calls "national security." But the Senator did not reveal the nature of the issues and alternatives presented for decision.

The military and political questions that are either raised anew or brought to their apotheosis by the possibility of the hydrogen bomb are important, and cannot be dissociated from the physical problems surrounding the bomb's design. Let us consider the physical problems first, for they lead to certain conclusions that bear directly on the other questions.

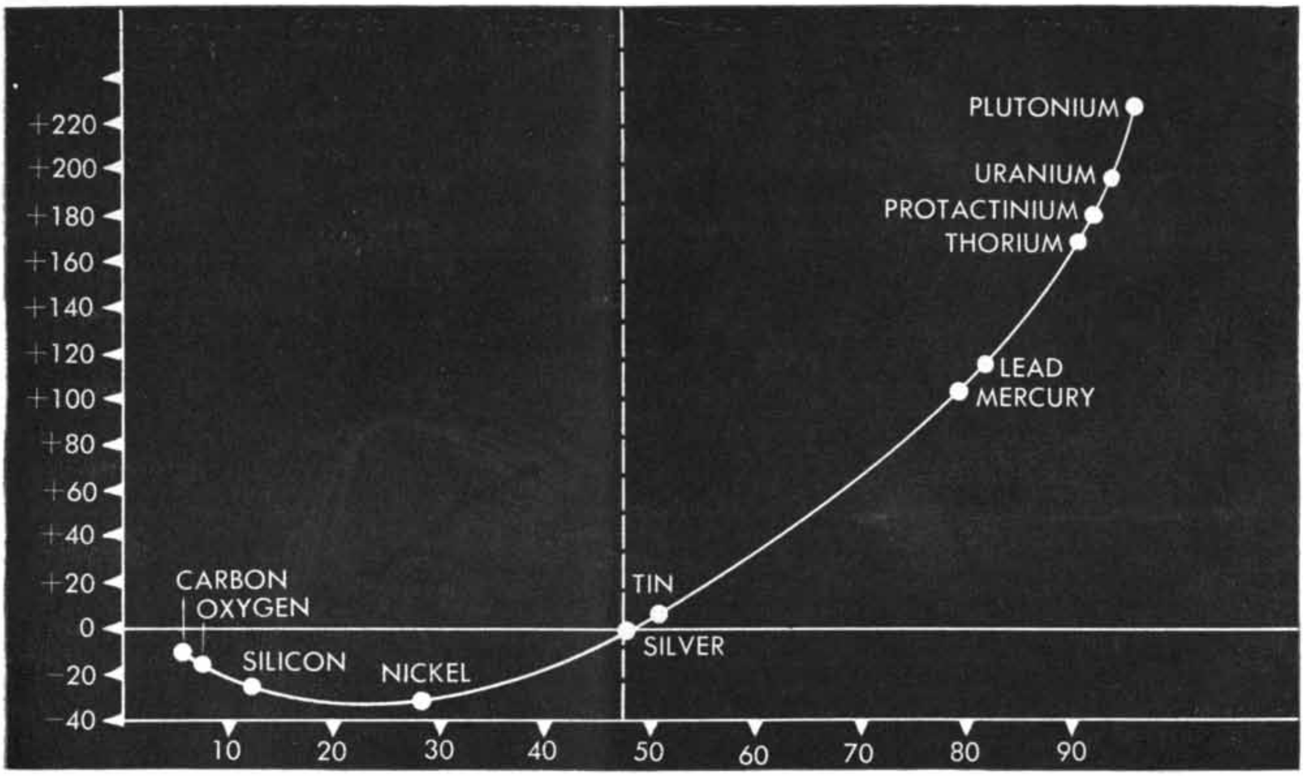
In the President's first announcement of the Hiroshima atomic bomb, it was stated that the bomb drew its energy from the same source that fuels the sun and the stars. This statement is true only in the loosest sense. To be sure, a uranium-fission bomb, like the sun, derives energy from the transformation of one atomic species into others, but the types of reaction involved in the two cases are quite different.

As Robert E. Marshak explained in the January, 1950, issue of this magazine, there is excellent reason to believe that the energy source of most stars, including the sun, is a rather complicated chain of nuclear transformations whose end result is to form one atom of helium out of four atoms of hydrogen. An atom of carbon, which plays an intermediate role in this chain of reactions, is finally recovered unchanged, and is thus available to participate once more in the stellar energy cycle. In the sun and the stars, then, the source of energy is a chain of so-called thermonuclear reactions that ends in fusing four light hydrogen nuclei into the heavier and more complicated helium nucleus. The old-fashioned atomic bomb, on the other hand, uses as its explosive the nuclei of some of the heaviest elements known to man: uranium and plutonium. Energy is released when one of these heavy nuclei splits, or fissions, into two lighter, simpler nuclei. Thus the lightest atoms liberate energy if they are combined into heavier atoms; the heaviest atoms liberate energy when they are split into lighter ones. Only near the middle of the periodic table of the chemical elements do we find atomic species that are fully stable, in the sense that energy cannot be liberated either by combining them into heavier atoms or by splitting them into lighter ones.

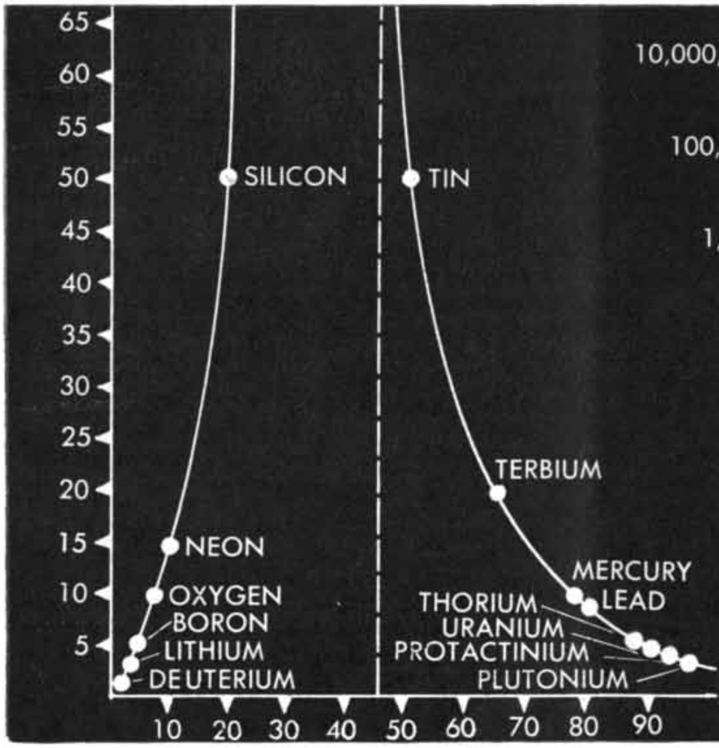
To paraphrase a remark of the physicist George Gamow, we live in the midst of an atomic powder magazine, where immense amounts of energy are locked in every bit of matter. Why, then, are we safe? Why does common matter, possessed as it is of tremendous stores of energy, seem so inert, so permanent? The answer is that in order to liberate the energy of a fusion or a fission reaction we must ourselves invest some energy, just as we must expend energy to strike a match.

IN the case of nuclear fission, the energy investment is small. Fission occurs when an atom of uranium 235, plutonium 239, or uranium 233 captures a neutron, even one of very slow speed. But these neutrons must be somehow produced, since they do not occur free in nature, and are in fact unstable. The nuclear "chain reaction" that is exploited in atomic bombs and in nuclear reactors like those at Hanford is possible only because the fission reaction itself releases neutrons, the very particles that are needed to keep it going.

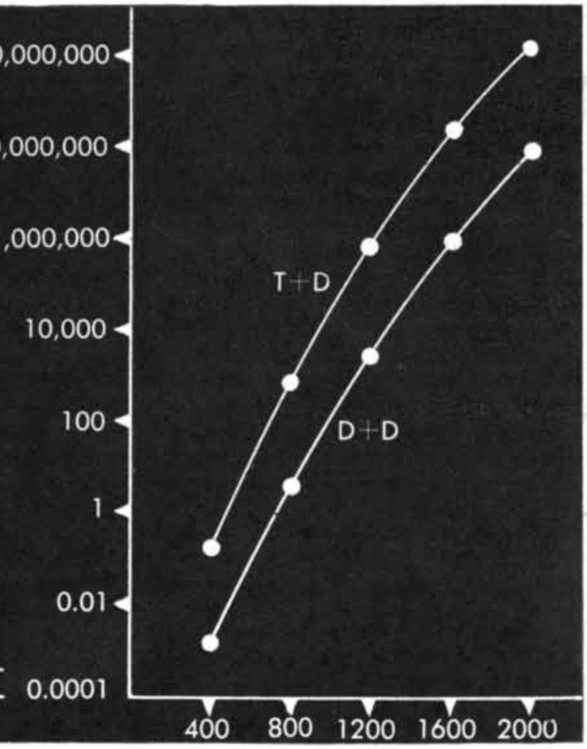
If the lump of uranium or plutonium in which these neutrons are liberated is




**FISSION AND FUSION** of nuclei are both energy-releasing processes. This diagram shows the amounts of energy released by the fission of various nuclei. The horizontal coordinate is atomic number; the vertical coordinate, the energy released in millions of electron volts. The fission of a nucleus with an atomic number larger than that of silver releases energy; the fission of a nucleus with an atomic number smaller than that of silver absorbs energy. Fusion of the lighter elements, the opposite of fission, releases large amounts of energy.




**ENERGY REQUIRED** to bring nuclei together so that they release energy is plotted against the same two coordinates. The lightest and heaviest elements require the least activation energy. The energy is released by two processes: fission for heavy elements and fusion for light.




**ENERGY RELEASED** by the fusion of deuterium with deuterium (*bottom curve*) and tritium with deuterium (*top curve*) is plotted against temperature. The vertical coordinate is energy in calories per second. The horizontal coordinate is thousands of degrees Centigrade.

large enough, the neutrons released by one fission process will cause other fissions before they escape from the lump, and the process will go on faster and faster until an atomic explosion has been produced. The lump of uranium is then said to have exceeded the "critical size."

This limitation on critical size dictates the design of fission bombs. Detonation of such a bomb requires the rapid assembly of an overcritical mass; as soon as this is assembled, it blows up in about half a millionth of a second. The greatest ingenuity is needed to achieve an instantaneous condition exceeding the critical by as much as a few per cent; no amount of ingenuity has yet allowed the design of an efficient fission bomb so much as two or three times critical size. Thus there are inherently narrow limits to the size of a fission bomb: as it begins to exceed the critical, it explodes at once; if it is smaller, it cannot be exploded at all.

At the opposite end of the scale, among the light elements, the explosive conversion of mass into energy is not so easily achieved in terrestrial laboratories. To cause two light atoms to fuse into a heavier one, we must overcome powerful forces of electrical repulsion, since each nucleus is positively charged. Up to now this has been accomplished by scientists only laboriously, with poor efficiency and on an extremely small scale, by striking target atoms with a fast-moving beam of atoms accelerated in an electronuclear machine, or "atom-smasher." Only at energies of hundreds of thousands or millions of volts do collisions between most types of light atoms produce fusion reactions with substantial likelihood.

In the centers of the stars fusion reactions go on all the time, because the temperature there is some 20 million degrees Centigrade. The average energy of an atom at this temperature is only some 1,700 electron volts, but some atoms have several times this energy, and collisions between atomic nuclei are so frequent that fusion reactions are produced in substantial numbers. We cannot maintain stellar temperatures on the earth, but we can produce them for very small fractions of a second. In the explosion of a uranium or plutonium bomb, the central temperature of the exploding mass has been estimated as high as 50 million degrees C. At such a temperature fusion reactions in a dense mass of light atoms occur often enough to liberate significant amounts of energy.

OBVIOUSLY the fusion reactions that are likely to be most effective for producing energy are those that will go best at relatively low collision energies, since even the highest temperatures reached in the explosion of an atomic bomb correspond to rather modest bombarding energies from the laboratory standpoint. For this reason, the stellar-energy reaction cycle is out of the question; this cycle involves the fusion of hydrogen with heavy atoms such as carbon and nitrogen, and therefore proceeds relatively slowly even at temperatures of millions of degrees. It has been known for some time, however, that fusion reactions between the rarer, heavier isotopes of hydrogen can take place much more rapidly at substantially lower temperatures.

A few years ago the reaction that would have been chosen as the most promising for a hydrogen bomb was the fusion of two atoms of deuterium, or hydrogen of mass 2, containing one proton and one neutron. This results in the formation of helium 3, with the emission of a neutron and the release of about four million electron volts of energy. Gamow has calculated the thermonuclear energy release from this reaction; the results were given in his 1946 book *Atomic Energy*. He remarked that if the reaction took place at a temperature of something over one million degrees C., "a small charge of deuterium could be used as an explosive with tremendous destructive power."

Nowadays we know that a more effective reaction can be obtained with hydrogen 3, known as tritium, a radioactive but long-lived isotope of hydrogen that has one proton and two neutrons in its nucleus. Tritium not only reacts faster than deuterium at low temperatures, but also liberates more energy when it does so. A fusion reaction of tritium with deuterium produces helium 4, with the emission of a neutron; its energy yield is 17.6 million electron volts. Tritium can also fuse with tritium, yielding helium 4, two neutrons and 11.4 million electron volts of energy; the cross section for this reaction is not available in the published literature, but it is probably large.

Ponderable amounts of tritium have been and are being made by the Atomic Energy Commission in its huge facilities. The designer of a fusion bomb clearly would start with a fission bomb of uranium or plutonium, the explosion of which would produce the high temperatures required for the thermonuclear fusion reaction. To the fission bomb he would add a certain mixture of deuterium and tritium to fuel the fusion process. The final energy release of the bomb—its total deadliness—would be determined by the amount of deuterium added. To say that the fusion bomb would be 2, 7, 10, 100 or 1,000 times as devastating as the conventional fission bomb is to speak from ignorance; the effective size of a fusion bomb will depend upon the intentions and the skill of its designers.

Note, however, that there is here no concept like that of critical size. The size of the bomb depends, and depends exactly, on the amount of the reacting elements built into it. The fission detonator itself must be made overcritical in order to explode, but the happenings thereafter will depend on the amount of fuel provided for the fusion reaction.

HERE, then, are the technical conclusions that one must draw about the fusion bomb:

First, it can be made.

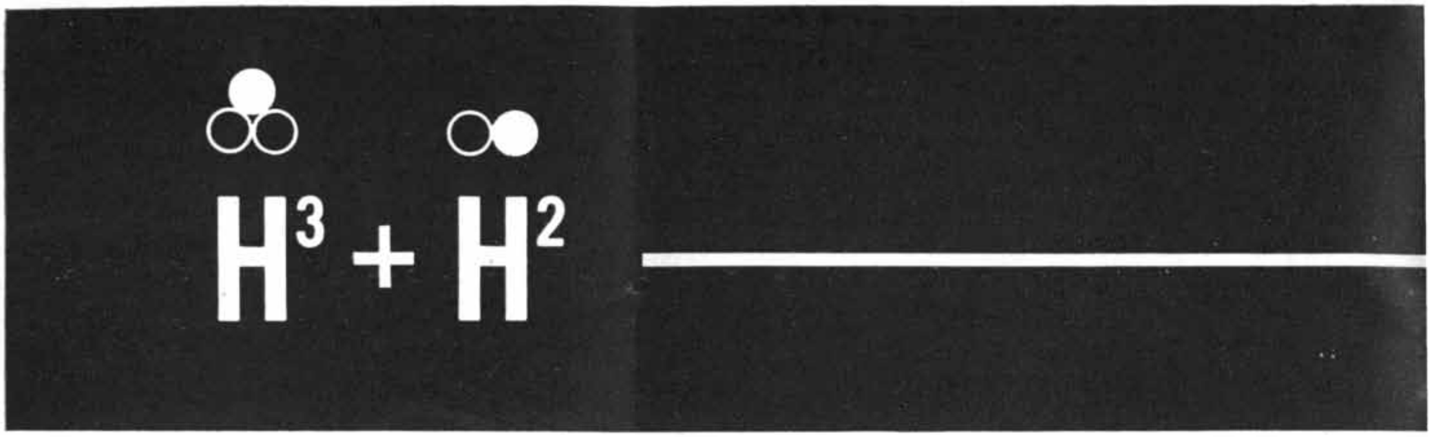
Second, there is no limit, in principle, to the size of a fusion bomb. It cannot be smaller than a fission bomb, since it must use a fission bomb as detonator, but it can be many times, perhaps thousands of times, bigger.

Third, while fission can be controlled in an orderly way to produce useful power in a reactor, the fusion reaction offers no prospect at the present time of any use except in terms of an explosion. We cannot find in the development of the fusion bomb any such peacetime values as are inherent in the development of nuclear fission. Except where the uses of peace demand the detonation of an explosive equivalent to, say, a million tons of TNT, there is no use for a fusion reaction. Thus when we discuss the "hydrogen bomb" we are clearly speaking of a weapon, and a weapon only.

Fourth, we are speaking of a very special type of weapon—one that is appropriate only to the destruction of large targets. A weapon of this sort is clearly of much greater significance to other nations, such as the U.S.S.R., than it is to us. We have several large targets; the U.S.S.R. has only one or two.

Fifth, the fusion bomb is not a brand-new possibility that has suddenly burst upon the minds of men. For example, J. Robert Oppenheimer, wartime director of the bomb laboratory at Los Alamos, wrote cryptically in late 1945 in the book *One World or None:* "In this connection it is clearly relevant to ask what technical developments the future might have in store for the infant atomic-weapon industry. . . . Proposals that appear sound have been investigated in a preliminary way, and it turns out that they would reduce the cost of destruction per square mile probably by a factor of 10 or more, but they would involve a great increase in the unit power of the weapons. Such weapons would clearly be limited in application to the destruction of very major targets, such as greater New York." Oppenheimer was talking of the fusion bomb. Physicists knew it then, of course; we all know it now. And it would be naive indeed to suppose that the U.S.S.R. has not given thought to it on its own account.

In view of all this, it seems a little curious that the fusion bomb should have been proposed—as it apparently was—in terms of a reply to the Soviet achievement of the fission bomb. To the detached observer, it would appear to be potentially a Pyrrhic reply, involving as it does the production of a weapon uniquely suited to the destruction of the




**TRITIUM AND DEUTERIUM** reaction would release more energy than any other reaction involving these heavy isotopes of hydrogen. Tritium is $H^3$, or the hydrogen isotope of mass 3. Its nucleus is composed of one proton (*small white circle*) and two neutrons (*small black circles*). Deuterium is $H^2$, or the hydrogen isotope of

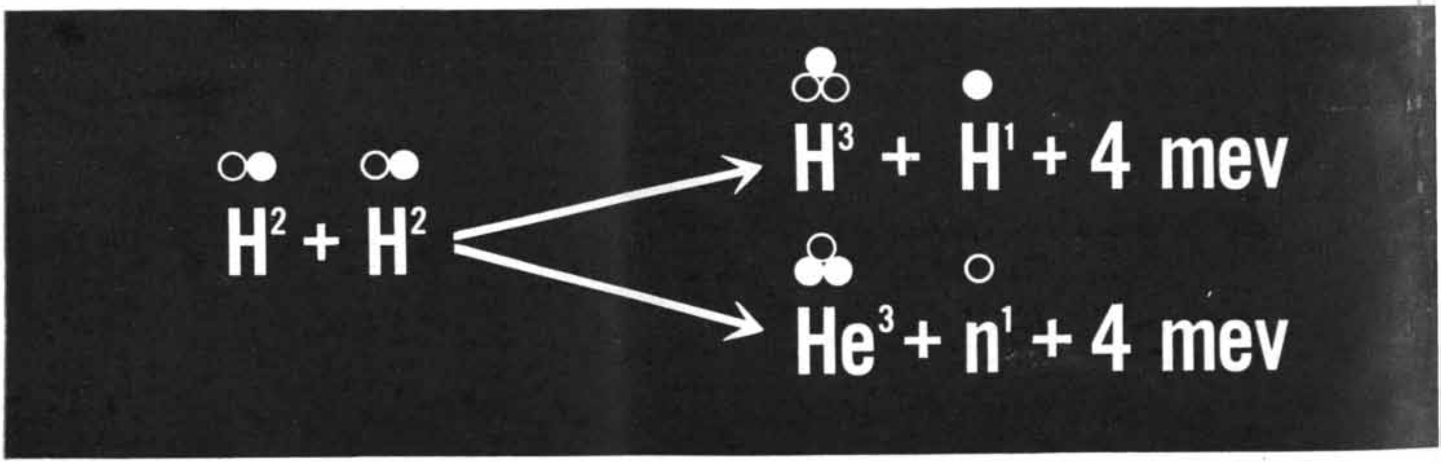
great cities around which our own economy and our own civilization are built.

Be that as it may, the decision to make the superbomb has been taken, and in the world of hotly nationalistic fear and jealousy that we now inhabit, one can suppose that it is the right decision—that is, for the arms race. We can be sure that a decision by us to forego making the bomb would not have persuaded the U.S.S.R. to forego it, unless she saw that her own self-interest lay in that direction. And we can dispose of the "morality" argument at once. Once it is decided that people are to be killed, the "moral" question is fully settled; the instruments of that killing are not at all affected with humane or moral questions. It was probably more unpleasant to be disemboweled by the 18-inch sword of the Roman soldier than it will be to vanish in the flash of a nuclear reaction.

YET important questions remain, even if one considers the superbomb only in the realistic terms of national self-preservation. Although the expense and trouble of designing this instrument of national policy cannot be very great, there are good arguments to show that, if national policy is our concern, other technical developments are more important. We are far more in need of means for the sure and accurate delivery of the bombs we already know how to make than we are of an improved and more destructive bomb, provided we intend to make a good showing in the current arms race. There is indeed a question, as James Bryant Conant has pointed out, whether the technical decisions being made in Washington are being arrived at in a manner to inspire confidence that they will promote the greatest security.

We have surrounded the atomic energy field with unusual safeguards designed to protect the national security, and the practical effect has been to cut off that field from the assistance of the majority of the nation's technical community. We have given the Atomic Energy Commission unusual powers, encroaching thereby on many of the principles basic to Western democracy. One gathers from recent news reports that, even after these sacrifices, we have still failed to obtain from the Commission the "efficiency" and boldness of decision that are sometimes urged as the major benefits of totalitarianism. Our general security policy plainly bears re-examination.

One may, for example, ask: If the decision to make the superbomb was necessary and inevitable, why has it been delayed until now? Why were the "sound proposals" mentioned by Oppenheimer in 1945 allowed to gather dust? The technical possibility of a hydrogen bomb has been discussed in whispers by our scientists for years. European scientists, of course, have not been so restrained. In 1946 an Austrian physicist named Hans Thirring published a semipopular book on atomic energy that contained a chapter discussing the design of such a superbomb. Yet reviews of the book published in the U. S. deliberately refrained from mentioning that chapter or anything it contained. It is difficult to see how any sensible person could have supposed that "national security" had




**DEUTERIUM AND DEUTERIUM** reaction can proceed in two directions that release approximately the same amount of energy. When two nuclei of deuterium are brought together, they yield (1) tritium, a proton and about four million electron volts; or (2) the light isotope of helium, a neutron and about the same energy.

$$\rightarrow He^4 + n^1 + 17.6 \text{ mev}$$

**mass 2. Its nucleus is composed of one proton and one neutron. When these two nuclei are brought together, they form helium of mass 4 ($He^4$), a neutron ($n^1$) and 17.6 million electron volts of energy (mev). Unlike the reaction of a neutron and a plutonium nucleus, this reaction does not yield products that can perpetuate it.**

anything to gain from this curious ostrichism, but the secrecy-lovers in this country are not accustomed to give thought to sensible considerations.

So the hydrogen bomb was not delayed because we lacked the idea. The effort to make it must, therefore, have been postponed by a deliberate policy decision. What were the issues or facts on which such a decision was based? About that we have no information whatever. The decision could hardly have been made on moral grounds, since the moral question nowhere enters into the present decision to make the bomb. Nor could there be any question about where the duty of the policy-making officials lay in an arms race; to make a unilateral decision not to do one's best in that race is a luxury permitted no citizen.

It is conceivable that the delay was due simply to the failure of responsible officials to make the most of their opportunities and responsibilities. This answer is strongly suggested by the AEC's patent and depressing failure with the important reactor program, which has only recently been rescued from the desuetude in which it rested for some time. On the other hand, it is also conceivable that the decision to postpone the superbomb was based on a sound judgment as to the urgency of pushing the development of old-fashioned fission bombs as against turning to work on a distant superbomb.

The main point is that you and I cannot know what considerations have influenced these most important decisions in national policy. In the present pattern of public knowledge, one may draw any of several quite different conclusions. But of one thing we can be sure: the whole experience demonstrates once more the truth for which the outcome of World War II provided such compelling evidence—an informed democracy is the strongest and most viable political form. A government does not adequately protect its citizens by taking decisions for them that they can neither know about nor take part in. Almost certainly, we would be better off to treat the atomic energy field like any other normal part of our complicated technology, such as the steel or the automotive industry.

Possibly the shock of the news about the superbomb may at last bring us face to face with reality. We may appreciate the bankruptcy of our secrecy policy when we see how it excludes us from decisions vital to us without in any way hiding the question under discussion. We may also see that an agreement for the control of atomic energy, or for the limitation of any other specific weapon, is not what we require for long-term safety. What we need is an international agreement amounting to the resolve of men not to kill other men, and we ourselves are not ready to sign that one today. Until all nations are ready to do so, the question of whether to make superbombs can have only one answer, and that answer has been given.

*Louis N. Ridenour, a physicist who worked on radar development during the war, is dean of the Graduate College of the University of Illinois.*

$$H^3 + H^3 \longrightarrow He^4 + 2n^1 + 11.4 \text{ mev}$$

**TRITIUM AND TRITIUM reaction would yield a nucleus of helium and two neutrons. It would also generate approximately 11.4 million electron volts, an amount of energy less than that given up by the tritium and deuterium reaction above but more than that yielded by the deuterium and deuterium reaction at the left.**

# POINT FOUR

*The President's declaration of last year paraphrases a whole concept of maintaining the peace of the world through technical assistance to underdeveloped areas*

by Stephen Raushenbush

ONE of the biggest building jobs in the history of mankind is slowly getting under way. The job is that of bringing the underdeveloped areas of the world—with two thirds of its people—into our 20th century of machinery and energy. The U. S. part of the program was outlined in President Truman's famous "Point Four" statement of January, 1949, pledging help to backward areas. It is a task, however, to which all nations are committed. It became inevitable when the nations of the world decided that it was their job to create the basic conditions of peace. In the United Nations Charter the nations agreed that economic stability and higher living standards were necessary foundations for peace, and pledged themselves to take both joint and separate action to promote "higher standards of living, full employment and conditions of economic and social progress and development."

The problem can be summed up in a few stark numbers. The underdeveloped nations, covering most of Asia, Africa and Latin America, have about 1,625 million people today. If they keep growing at the present rate, they will have about 2,935 million people in the year 2000. They are living at an unbelievably low level compared with ours: their per capita income averages much less than $100 a year, while ours is over $1,400. More significantly, this gap is widening, not narrowing. Between 1929 and 1949 we added about $22 a year to our income for each person; they added almost nothing. We are eating more; they are eating proportionately less than before. The world's peoples, in short, are not moving along together.

This growing disparity is due mostly to the fact that our techniques have been moving forward while those of the underdeveloped nations have been standing still. It is also partly due to the fact that the terms of trade have been against them: they have received less for their products than we have obtained for what we have sold them. Meanwhile our success has stimulated their desire to be independent, and to obtain for themselves some of the economic advantages we have. Their rapidly increasing population is forcing their governments into action. They want the help of our engineers, our soil and plant technicians and our capital.

The pressures for improvement in these areas are quite as real as any physical force. They have a direct impact upon the U. S. For example, the past neglect of the Western nations to help China establish a base for higher living standards obviously is a factor affecting the number of men we are now keeping under arms, and the amount we are spending on national security. Further neglects or failures will raise the price of our raw materials and affect our manufacturing costs and our own standard of living. The cost to us of these several items can easily exceed the annual investment that would be required of us and other nations to help industrialize the underdeveloped areas.

The Western nations have already learned that the building up of these areas is primarily a job for experts in applied science; it is beyond the capacities of statesmen or bankers. A great migration of skills to the underdeveloped areas is called for, and it has already begun. Technicians are now surveying the sites and trying out small-scale experiments in various types of construction. Most of the aid so far has come from the UN, principally through its Food and Agricultural Organization.

FAO has helped lay out developmental plans for Greece, Poland and Siam. It has acted as midwife in building up Europe's depleted cattle herds through artificial insemination. It has helped stop the cattle diseases rinderpest and hog cholera in Asia, and contagious abortion and mastitis in Europe; has assisted in eliminating some locust plagues; has aided the Chinese to set up a plant to produce pesticides; has trained local government men in forest care, in the elimination of waste, in the increase of yield, in the starting of new forests. FAO has also spread the use of American hybrid corn and has plans to develop hybrid poultry that will feed more people more pounds of protein with only a small increase in chicken feed. It has been distributing new varieties of disease-resistant chestnuts to Italy, and Chinese and Siamese frost-resistant apricots to the U. S. It has helped China and Czechoslovakia build refrigerated warehouses for storing vegetables and fish, and has made surveys of fishing opportunities for Siam and Haiti. It has set up canning centers in Greece. It has helped to build up soil and water conservation practices in several areas, using grasses and legumes from the U. S. It is collecting basic data on production, income and land use.

OF the other UN agencies, the UN Secretariat itself has made several investigations of regional economic possibilities; the World Health Organization has done much to prevent the spread of contagious human diseases, and UNESCO has begun a study of the ecology of the Hylean Amazon (SCIENTIFIC AMERICAN, May, 1948). As for direct U. S. participation, the Government has lent mineral, soil and water technicians to various nations. While Point Four has raised great hopes in the underdeveloped areas that U. S. public and private capital will back up the plans, so far the emphasis in Washington has been on limited aid for preliminary technical work.

From the work done to date the FAO technicians draw certain conclusions. In the first place, it is abundantly clear that many of the projects can be handled only on an international basis: insects, germs and watersheds do not stop at national borders. Secondly, they have found that the number of agricultural and industrial technicians available falls short of the need. Thirdly, in agriculture the technical work has gone far enough so that the principal need now is capital. Above all, if the job is to be successful it must be carried through on a large scale, for a half-hearted effort will defeat the objectives of the whole program by calling forth more population pressure on resources. An increase of the food supply will simply accelerate the population growth without raising the standard of living, unless it is accompanied by the complex of urbanization, industrialization and education that results in reduction of the birth rate (SCIENTIFIC AMERICAN, February, 1950).

What is the size of the job? We can only estimate the figures roughly at this point. It is suggested here that both the population pressures and the demands of the people for material betterment can be met by a steady improvement of one per cent a year in per capita income. Assuming that sufficient investment is provided at the outset to start producing this result, a gain in income at this rate would reduce the rate of population growth considerably and would make it possible for the underdeveloped areas to become almost self-supporting with a rising standard of living within 35 years.

To achieve this result certain objectives must be met in agriculture and in industry. In agriculture the objective is a 50 per cent improvement in the average diet—from 2,000 to about 2,900 calories per day—in 30 years. This will require an increase at the rate of one per cent a year in the productivity of the land, a goal which is not impossible with the present advanced techniques of hybrid-corn production and the use of better seeds and fertilizer. It also requires that during the next 50 years about 760 million new acres of land be added to the present 1,590 million acres of arable land in these areas. That, too, is not impossible. The 50-year investment required for these two jobs plus soil conservation is about $70 billion. To place that sum in its proper frame, consider what a mere charity handout to these peoples might amount to. Without industrialization their number may increase by about 1.3 billion in the next 50 years. To feed only these newcomers a single pound of rice a day apiece as charity—leaving the other

**THE UNDERDEVELOPED AREAS** are indicated in black on this polar projection of the world. The industrialized areas are in white. The terms underdeveloped and industrialized are here used rather loosely. Areas like the U.S.S.R. are far ahead of areas like India; areas like Canada are far behind areas like the U. S. Given a stable political situation, however, the U.S.S.R. could import technical assistance and Canada could export it.

1.6 billion to eke out their lives on their present skimpy rations—would cost about $83 billion. That is a good deal more than is needed to help all these people improve their land and bring in the necessary new acreage so they can produce enough food for themselves.

WHAT would industrialization cost? For rough survey-party purposes, we can say that the objective would be a shift of one fourth of the whole labor force, so that instead of three fourths being employed in the primary occupations of agriculture and fishing, half would be in those occupations and half in industry and services. (In the U. S. the proportions are 15 and 85 per cent, respectively.) A comparison of the 11 nations of lowest income, according to available figures, shows that national income increases with the amount of industrialization. The curve is logarithmic and gets steeper as industrialization increases. The suggested 50-year program of industrialization of the underdeveloped areas might increase their total annual income from $160 billion to $420 billion. It is estimated that an investment of about $450 billion would be required to accomplish this program.

When areas begin to industrialize, education and urbanization also increase. That combination pushes the rate of population increase downward. The experience of 33 nations for which figures are available shows that a shift of 10 per cent of the population from the primary occupations to industry results in a reduction of .118 per cent in the annual rate of population increase. On that basis the suggested shift of 25 per cent should reduce population growth in these areas from the present rate of 1.19 per cent to .89 per cent annually. In 50 years the reduction of the population increase would be 215 million. The pressure on land and resources would be reduced correspondingly.

The total investment called for, then, is $520 billion—$70 billion for raising food production and $450 billion for industrialization. Of this about $210 billion would be needed from outside sources. After 35 years the outside investment should create enough income and savings so these areas could finance most of the process themselves, as well as meet the capital charges on the outside investment. The program could be expected to raise the area income at the rate of almost two per cent a year, and individual incomes by a little more than one per cent a year. The people in the areas would be on their way forward, and would know it.

Before any such results can be achieved, an enormous amount of engineering and technical aid will have to be expended. Because the areas are just emerging from a primitive economy, much of the engineering will have to be of the type we had in 1800, using foolproof tools and machinery that can be repaired with a monkey wrench. The job is literally one of moving first from the hand hoe to the wheel.

THE logistics of a job of this scale are far from simple. The job may easily go wrong if the timing of the various steps is not carefully coordinated. For example, the leaders in India now know how they could increase their agricultural production enormously, but they do not have the funds to follow through after the technicians. On the other hand, agricultural improvement alone might simply lead to further population pressure. Indeed, we are in danger of repeating the mistake that was made half a century ago when our medical and sanitation experts took their new techniques to those areas. Though they saved life, none of the circumstances that lead to a reduction of the birth rate was created, so the population grew enormously. People remained as poor after the technicians came as before they had arrived. Today the FAO, by letting the agricultural technicians loose without teaming them up promptly with industrial technicians and capital investment, may be creating another population spurt, a still heavier pressure against resources.

The necessary logistics involve more than the avoidance of errors of timing. A climate of investment and activity must be created. Technical training at all levels must be started. Public works such as roads, without which industrial products cannot be manufactured, transported or marketed, must be built. All the components of success have to come together to produce the necessary momentum; no two or three alone will create the dynamics of progress.

Basically the tests for a job of this size are not unlike those for any engineering project. It must not only serve a necessary purpose but must produce values that exceed costs. It must also be the best way to do the job. The operational foundations must be adequate. All the parts must come together in time and place, and fit the specifications. The techniques, savings and other resources must be available in quantities adequate to allow the job to be finished once it is started. We cannot afford to start bridges that will stop halfway across rivers.

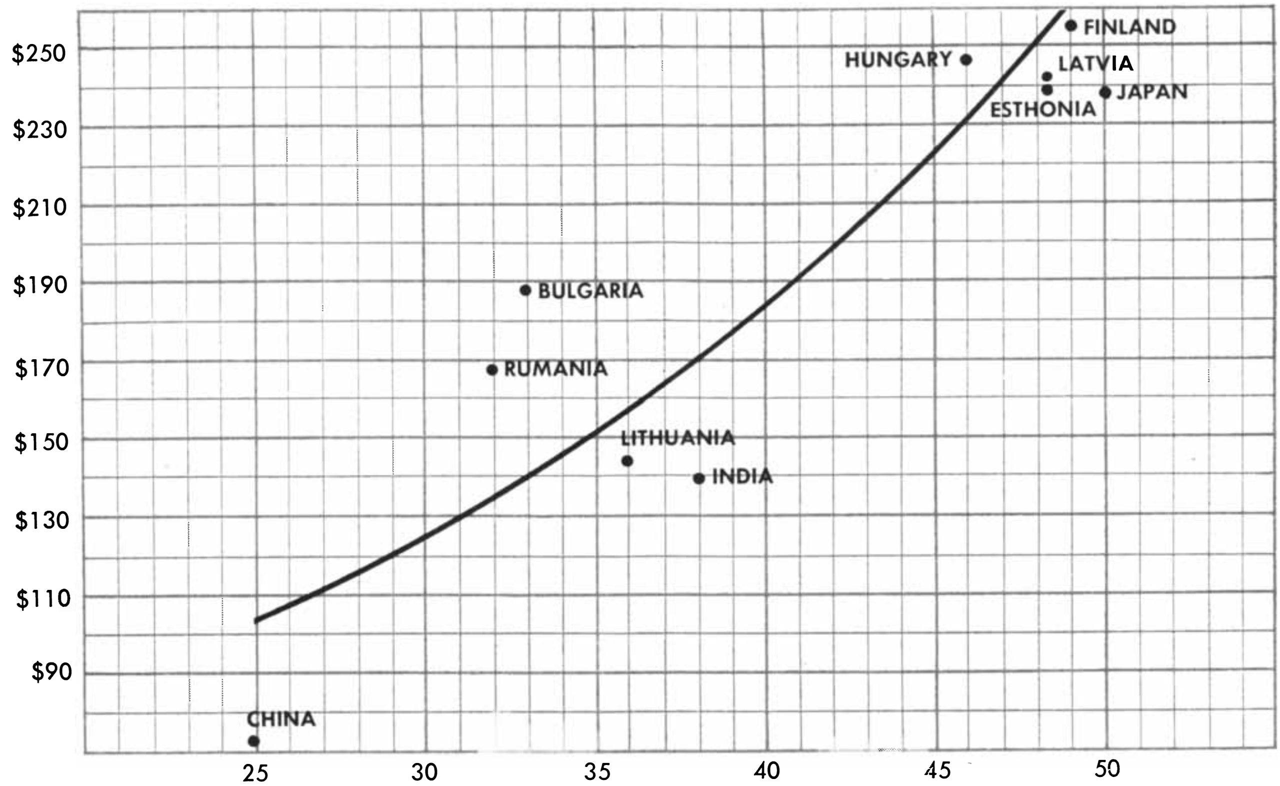
The job should yield an immense harvest in world prosperity and stability. We could reasonably expect it to produce more raw materials for our own growing economy and larger markets for ourselves, for the aided areas and for Europe. We could expect it to relieve us of some of the burden of financing Europe, for it would help close the trade gap that now forces us to take pieces of paper instead of products in return for our exports. We could legitimately expect that the peoples of the assisted areas would attach their hopes to free political systems rather than to closed ones, and this in turn would reduce our military burden. Finally, most of us would expect the enterprise to result in a strengthening of the UN, and an ending of the basic competition in the underdeveloped areas between misery with, and misery without, dictatorship.

THE UN is going to have a large part in this over-all job. Virtually all of the member nations are interested in this program. Each nation on its own level may have something to share with others. Even Puerto Rico has done leading work on very low-cost housing that others will want to study and copy. India expects to be able to teach something to neighboring nations with even lower living standards. The Belgian Congo is producing new work on tropical soils that will be useful over a large part of the earth. And because many of the jobs that have to be done necessarily cross national boundaries, international cooperation of a high degree will be needed.

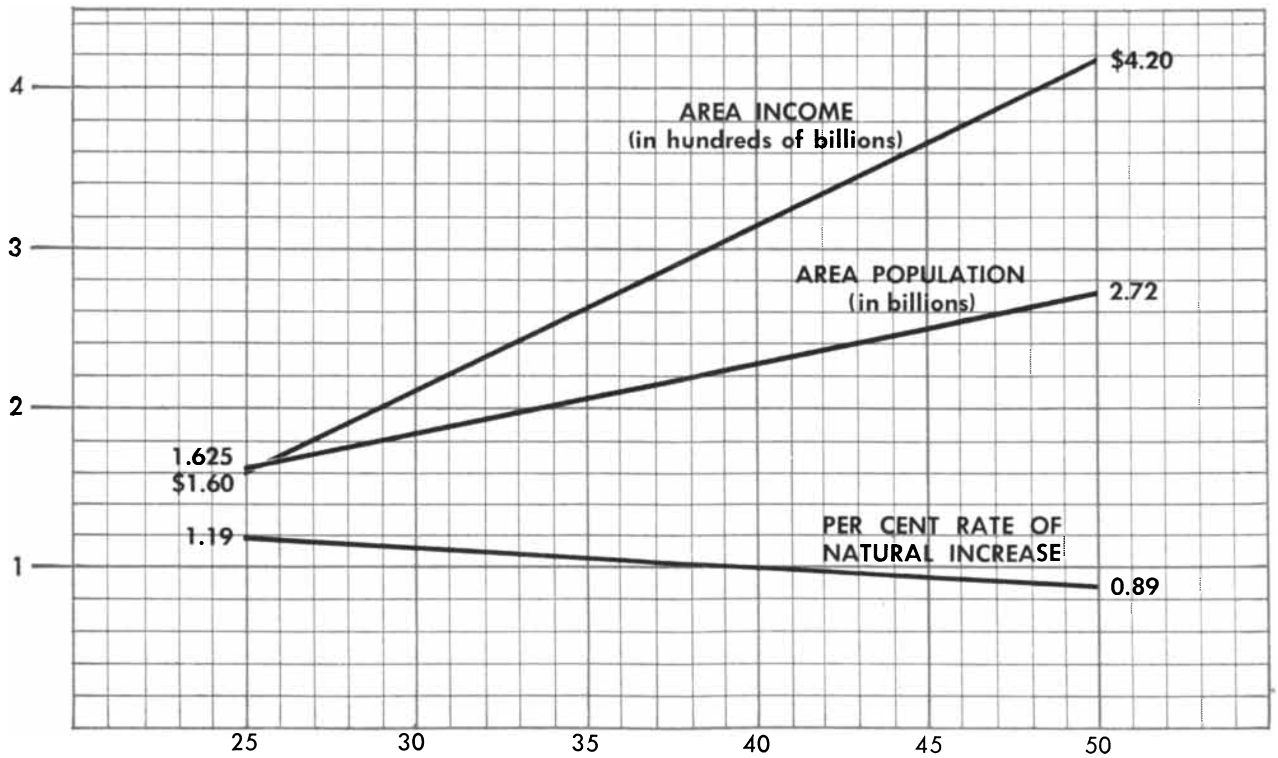
It will be necessary to make adequate provision to prevent capital and human energies from being wasted through inefficiency or corruption. Loans will have to be conditional on adequate plans and adequate performance. This clearly is a task that must be undertaken on an international basis, for the very simple reason that no loaning nation will want to get—or should get—into a policeman's suit. No nation could take such a job on alone without embroiling itself in a thousand disputes all over the world. There would be inevitable arguments over whether a young nation should receive a loan to build an uneconomic railroad, or over systems of sanitation, and so on. We would hardly appreciate having our Secretary of State involve our national prestige and influence in every sewer in Asia or anywhere else. The UN, with some reorganization of its staff, can do this type of work better than we can do it alone.

As an active participant in such constructive jobs, the UN will be able to grow in strength and international confidence. It cannot grow if it has nothing to do but debate principles of action. The program discussed is of a size and character to require the best efforts and the technical and engineering aid of all the nations. If it once gets started, the U. S. will necessarily be called upon to supply a large share of the investment. But the total job is beyond the single powers of any nation. It is one on which they will all have to pull together.

*Stephen Raushenbush is a former economist of the U. S. Department of the Interior. He is author of the forthcoming* People, Food, Machines.




**EFFECTS OF INDUSTRIALIZATION** are revealed by comparing 11 nations of low per capita income. The horizontal coordinate of this diagram is per cent of labor force in nonagricultural occupations. The vertical coordinate is per capita income. A curve plotted from these data is logarithmic; it gets steeper with the per cent in nonagricultural occupations. Eighty-five per cent of the labor force in U. S. is engaged in such occupations.




**POSSIBLE EFFECTS** of industrialization on the underdeveloped areas of Africa, Asia and Latin America are plotted over an indefinite period. The horizontal coordinate is again per cent of labor force in nonagricultural occupations; the vertical coordinate is an arbitrary scale embracing three quantities. Given an increase in nonagricultural workers, the area income will increase. Population will continue to increase but at a lesser rate.

# BLOOD PIGMENTS

## Hemoglobin is red, hemocyanin is blue, chlorocruorin is both red and green. All are studied together because they perform the same function in rather dissimilar organisms

by H. Munro Fox

BLOOD is red because it contains hemoglobin, a pigment essential to our life. We could not do without it because a hemoglobinless blood would be unable to carry from the lungs to muscles, liver and brain enough oxygen for their incessant needs. The body tissues may require 40 times as much oxygen as could be ferried in a simple watery solution; hemoglobin is the substance that enables the blood to perform its function as an oxygen carrier. It is a complex protein capable of attaching oxygen to itself and giving up the oxygen in places where it is wanted, such as the working muscles. Moreover, the muscle cells themselves contain hemoglobin, in a form that has an even higher affinity for oxygen than the hemoglobin of the blood cells. So the muscle hemoglobin takes up oxygen from the red blood corpuscles like a sponge, thereby storing an ever-ready supply of oxygen in the muscles for their greedy needs.

This vital respiratory pigment varies in concentration, even in individuals not afflicted with the pathological hemoglobin deficiency known as anemia. Two circumstances can produce an increase in the quantity of hemoglobin. One is continuous hard work by the muscles. If, for example, the muscles of a rabbit's leg are stimulated electrically to contract at intervals, this leg soon becomes pinker than its fellow, showing that it has gained hemoglobin. And blood also becomes redder when a man climbs and stays up some time on a mountain.

In both cases—the using up of oxygen by working muscle cells and the scarcity of atmospheric oxygen at high altitudes—we see that the production of extra hemoglobin is a response to a deficiency of oxygen. This reaction is not peculiar to land animals; it occurs in fishes also. In a poorly aerated aquarium the blood count of red cells in fishes goes up—so long as they are not suffocated by lack of air.

Somehow an oxygen deficiency alters the chemical processes in living cells. One result of this changed metabolism is the production of extra hemoglobin. We know that in human beings the factory where the red cells are manufactured is the marrow of the bones. We also know something about the complex chemistry of hemoglobin: we have a fairly good understanding of the chemical make-up of the colored part of its molecule and a little information about the huge protein part. But as yet we know practically nothing about the metabolic processes and chemical steps by which the body synthesizes this remarkable substance.

THIS is a large problem which may be approached from various directions; we shall here consider what has been learned by the investigation of hemoglobin in certain invertebrates. Among the best known are earthworms, the pond snails called *Planorbis*, and the so-called bloodworms—small, bright-red larvae of midges that live in millions in the muddy bottoms of ponds. In the red-blooded invertebrate animals, the hemoglobin is not inside the blood corpuscles, as in vertebrates, but is dissolved in the liquid plasma.

One of the most interesting of these animals is the so-called water flea *Daphnia*. It is a small crustacean, distantly related to shrimps, which is very abundant in some ponds. Aquarium keepers feed their fishes with it. These amateurs know that *Daphnia* may be red or pale, and many of them believe, quite unjustifiably, that the red ones are better food for the fish. The color differences in *Daphnia* are due to different amounts of hemoglobin in its blood. *Daphnia* can change from red to pale or *vice versa;* in the short space of a few days an individual may gain or lose hemoglobin tenfold. Research in the last few years has shown that a cause of these changes is the dissolved oxygen content of the pond water in which the animal lives. The less oxygen in the water, the redder the crustacean's blood becomes.

The same capacity of synthesizing hemoglobin in response to oxygen deficiency is common to other groups of crustaceans possessing the red-blood pigment. For instance, the primitive crustacean called Apus, a sort of living fossil found in muddy water, produces more hemoglobin the less air there is dissolved in the water. It is capable of living and flourishing in water that is only 10 to 20 per cent aerated. Like many "living fossils," Apus would long ago have become extinct had it not succeeded in mastering life in a habitat too difficult for its rivals. For Apus lives in pools of water that dry up each season. Tiny, drought-resisting, hard-shelled eggs tide it over the waterless season. Another primitive crustacean that has mastered a difficult habitat is the little brine shrimp *Artemia*. It lives in concentrated salt pans, such as those from which our table salt is extracted. *Artemia*, too, develops red blood when oxygen is deficient in the brine.

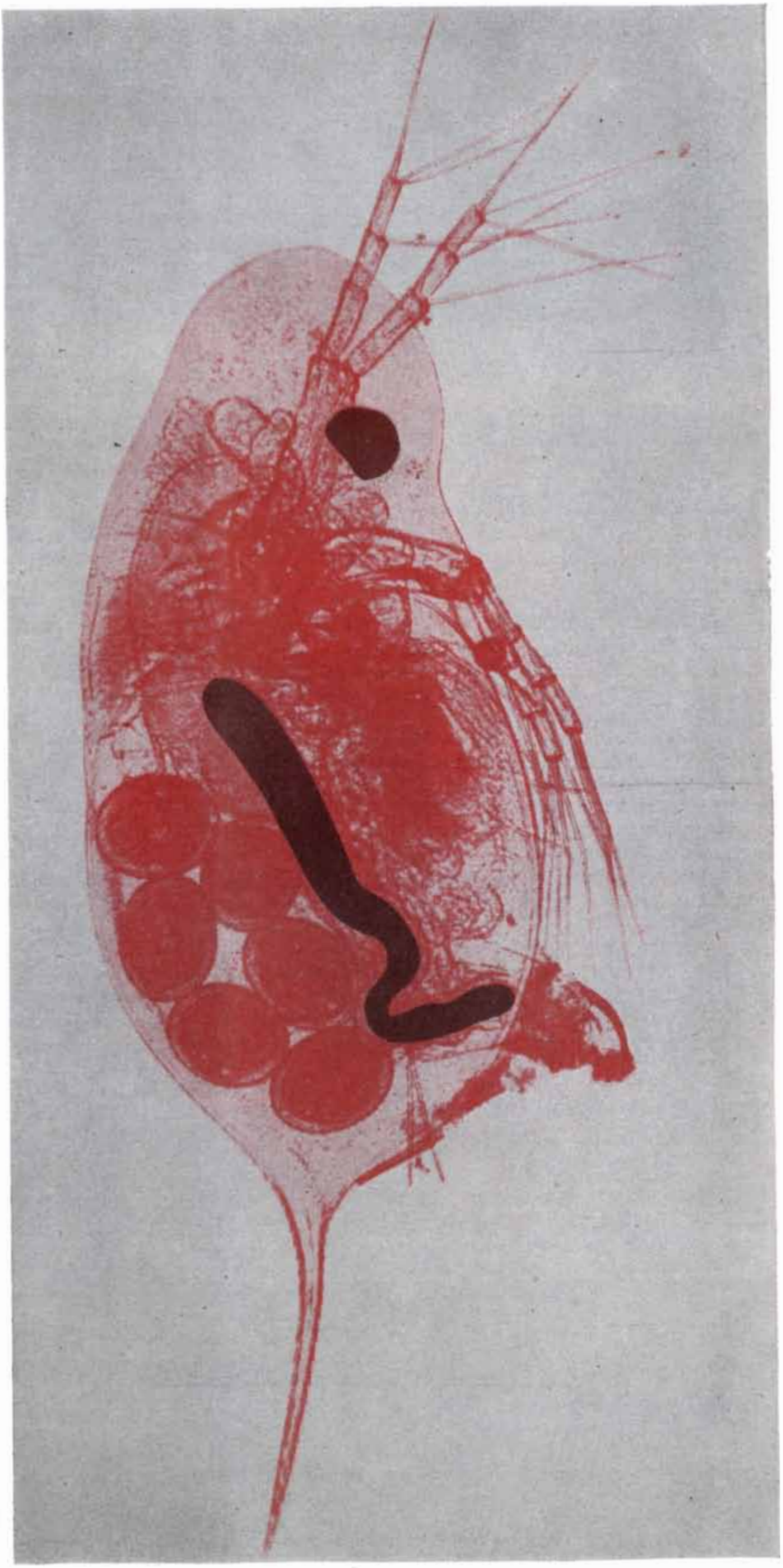
Zoologists are lucky people: they can make their research an excuse for travel to wild parts of our planet. To study an uncommon little crustacean named Estheria, which manages, like Apus, to survive in temporary pools, I lately made a journey into the Sahara, and found the creature swarming in small pools in a wady. Estheria lives its short life in the few weeks that these pools last after the brief spring rains. During this period it lays eggs which survive the scorching summer sun. From dried eggs brought back to London I raised separate hatches of young Estheria, one in water that was poor in oxygen, the other in well-aerated water. The former grew up red, owing to hemoglobin; the latter were brown, with very little hemoglobin in their blood.

So it turns out that in crustaceans as in vertebrate animals hemoglobin increases in the blood as a result of oxygen lack. It remains now to be seen if this synthesis in response to oxygen deficiency is a general characteristic of all animals that possess hemoglobin or similar respiratory pigments.

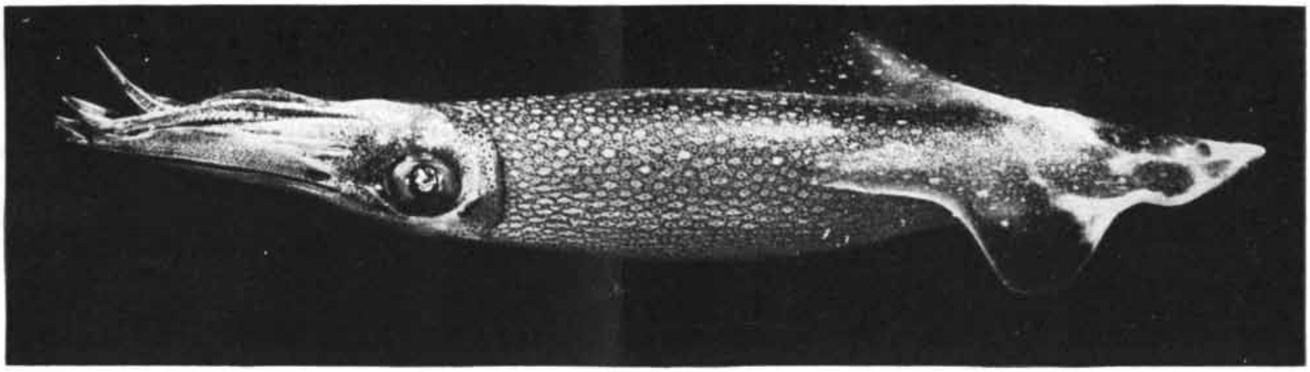
WE MAY begin by trying to find out whether hemoglobin serves the same purpose in all these animals. A simple experiment with coal gas is helpful here. Coal gas is fatal to human beings because it makes hemoglobin useless as an oxygen carrier. It contains carbon monoxide, for which hemoglobin has a great affinity. The carbon monoxide ousts the oxygen attached to hemoglobin and thereby prevents the pigment from transporting oxygen. Yet we find that carbon monoxide gas dissolved in the water of an aquarium containing *Daphnia* or *Artemia* is not lethal to these crustaceans. It unites with their hemoglobin, displacing the oxygen, but this does not kill the animals. Evidently the hemoglobin is not essential to their life, at least in an open aquarium.

It is true that in water very deficient in dissolved air the hemoglobin may be useful or even vital as an aid in picking up traces of oxygen. There is conclusive evidence, for instance, that in water containing very little oxygen those individual *Daphnia* and *Artemia* whose blood is pink with hemoglobin live longer than those with colorless blood. *Daphnia* also uses its hemoglobin in the reproductive process. This crustacean is unique among all known animals in having hemoglobin in its eggs. While *Daphnia* sometimes reproduces by eggs fertilized in the normal way by spermatozoa, more usually it indulges in virgin birth, developing young from unfertilized eggs. These eggs are carried around during their two-day period of development in a brood pouch on the back of the mother. When virgin mothers were treated with carbon monoxide, the embryos, though just as viable after hatching as untreated ones, developed more slowly. Oxygen is not abundant in the brood pouch of *Daphnia*, and with the hemoglobin inactivated by carbon monoxide, the development of the eggs was retarded. The eggs of *Daphnia* do not manufacture their own hemoglobin; they acquire it from the mother's blood while they are still in the ovary. So one function of the hemoglobin in the blood of *Daphnia* is to supply the eggs with the respiratory pigment.

Thus in these crustaceans, as in vertebrates, hemoglobin is formed as a consequence of oxygen deficiency. Of course there must have been a time, many millions of years ago, when hemoglobin in animals was functionless. When, very long ago, the pigment was synthesized for the very first time by an animal, it must have been just a by-product of some chemical reaction in the animal's body. Quite possibly when hemoglobin first appeared there was much less oxygen in the atmosphere than there is today, and animals lived a semi-anaerobic life. Once the pigment had been synthesized, its valuable ability to transport and store oxygen in the organism would ensure its perpetuation by Darwinian natural selection. Animals possessing hemoglobin would have an advantage, sometimes making the difference between life and death. Some of them, thanks to this asset, could evolve to higher forms. But may it not be that for other animals which synthesized hemoglobin the pigment



**THE WATER FLEA *Daphnia* is one of a number of invertebrate animals in which hemoglobin has been found. In such creatures, however, the pigment is carried in the liquid blood plasma instead of red blood cells.**



**THE SQUID,** in this case the Woods Hole variety *Loligo pealii*, is one of a number of related organisms that bear the blue pigment hemocyanin. In hemoglobin oxygen atoms are attached to iron; in hemocyanin, to copper.

remained unnecessary? They could live their quiet lives without using it, either retaining hemoglobin as a useless by-product or evolving into forms for which the pigment is a usable but unessential luxury, as it perhaps is in the embryos of *Daphnia*.

IT IS fortunate for our study of the evolutionary significance and the chemistry of hemoglobin that other respiratory pigments exist with which we may compare it. The distinctive component of hemoglobin is iron: each molecule contains one atom of ferrous iron, which can attach two oxygen atoms to itself, and it is this iron atom that in part accounts for hemoglobin's oxygen-carrying ability. Consider now another respiratory pigment called hemocyanin. This pigment is found in the blood of but a few members of the animal kingdom—the octopus, the cuttlefish, the snail and some other mollusks, the lobster, the crab, the scorpion. Hemocyanin is not red but blue. Like hemoglobin, it is a protein. Like hemoglobin, it contains a metal, but the metal is copper instead of iron. It comes as rather a surprise to find copper in the body of an animal, since copper salts, such as copper sulfate, are known to be very poisonous. But it is the free copper ion that is poisonous, not the metal incorporated in a large organic molecule. We also wonder how a snail could collect enough copper from its copper-poor food to supply the needs of its blood, or how an octopus could get copper from sea water. Animals have astonishing powers, however, of accumulating and concentrating scarce elements. Some marine animals, for instance, have vanadium in their blood, though this metal cannot be detected in sea water by chemical analysis.

Hemocyanin functions in blood as hemoglobin does. Oxygen, attached to the copper atom in hemocyanin, is ferried from the gills to the muscles and brain of the octopus. But hemocyanin is never found within cells, as hemoglobin is; it is simply dissolved in the blood. Why hemocyanin should not be in cells, we do not know at all. Nor have we any answer to the strange question of why crabs and lobsters have hemocyanin in their blood while other crustaceans, such as *Daphnia*, Apus and the brine shrimp, indulge in hemoglobin.

A third respiratory pigment is chlorocruorin, which means green blood. The only animals that possess it are certain kinds of sea worms. The word "worm" suggests something unpleasant to those who are not zoologists, but these particular animals, called sabellids and serpulids, are among the most beautiful creatures inhabiting the sea. The segmented body is concealed in a tough protective tube, from one end of which projects a most lovely crown of colored tentacles, serving as a food-catching and breathing organ. Chlorocruorin is actually a two-colored substance: although in dilute solution it appears bright green, in concentrated solution it is a deep red, like wine. The curious result is that when the translucent body of a small sabellid or serpulid is examined with a low power of the microscope, the larger, thicker blood vessels appear red while the small capillary vessels are green.

The few marine animals that have green blood are small; the biggest is no larger than an earthworm, and many are less than an inch long. Thus little blood can be extracted from them for investigation. But fortunately chlorocruorin possesses a characteristic absorption spectrum, so its chemical composition can be studied by spectroscopy. When white light is passed through chlorocruorin, the spectrum shows dark absorption bands at certain characteristic positions. A comparison of the absorption spectra of chlorocruorin and its breakdown products with the well-known similar spectra of hemoglobin has shown that chlorocruorin is chemically similar to hemoglobin. Like hemoglobin it has an enormous protein fraction, to which are attached one iron atom and a porphyrin. The latter structure, the colored part of the molecule, is composed of four pyrrole rings, each with side-chains. It has now been established that the porphyrin of chlorocruorin differs from that of hemoglobin only in one side-chain of one of the pyrroles, which consists in an aldehyde group, instead of a vinyl.

It appears that somewhere in the far-off ancestry of sabellids and serpulids there occurred a mutation which endowed these animals alone with a peculiar variety of hemoglobin. And a further strange finding is that one genus of these creatures, *Serpula*, which lives attached to rocks in the sea, has both chlorocruorin and hemoglobin—it is the only known animal possessing two respiratory pigments in its blood. This surely is a biochemical accident. No one has been able to suggest a functional reason for *Serpula's* possession of two blood pigments, particularly as side by side with it live well-adapted relatives that get along happily with one: chlorocruorin.

WHY should such trouble be taken in studying a sideline of biochemical evolution such as chlorocruorin? One can give the answer that applies to all scientific investigation: anything is worth studying for its own intrinsic interest. In this case, chlorocruorin is particularly interesting because its close relation to hemoglobin throws light upon that highly important substance itself. But there is more to it than this. Besides the respiratory pigments, living cells contain other substances derived from porphyrins. These substances form part of a chain of respiratory catalysts inside cells, essential links in the oxidation on which life depends. Like blood pigments, certain of these derivatives within cells are iron-porphyrin compounds; they are known collectively as cytochrome. Now one component of cytochrome is a compound containing the same porphyrin found in hemoglobin. Another component of cytochrome embodies a porphyrin very like that of chlorocruorin. Thus in a quite unexpected way the study of the green blood of marine worms throws light on an essential chemical substance in our own bodies.

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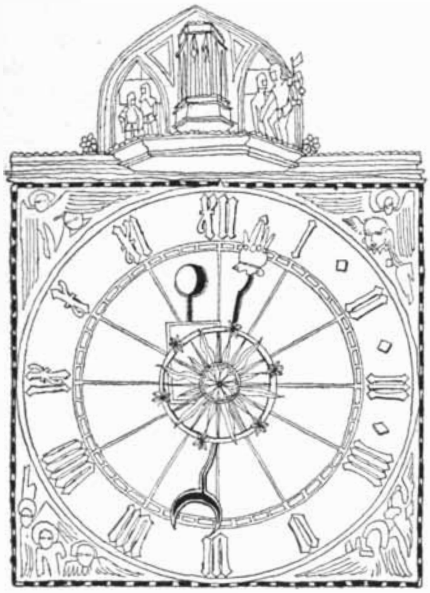
# SCIENCE AND THE



### *The Superbomb*

"EXCEPT for the atomic bomb itself, the existence of which was a wartime secret until it was dropped at Hiroshima, no weapon in the history of mankind became a national policy with so little understanding and discussion, though none so awful was ever projected before."

In these words Arthur Krock, chief Washington correspondent of the New York *Times*, described the reaction of many to President Truman's announcement that he had ordered the Atomic Energy Commission to make a hydrogen bomb. Even after the decision had been made, men found it difficult to grasp its awful potentialities, or to believe that the project could be anything but a bad dream. In the short space of two months the specter of the new superweapon had developed with the swiftness and hypnotic inevitability of Greek tragedy.

As Washington correspondents pieced the story together from indirect sources, the President himself had raised the question of the hydrogen bomb soon after the explosion of the Soviet atomic bomb last fall. He called in a few of his top atomic, military and diplomatic advisers for consultations in strictest secrecy. The first public intimation of the matter came when Senator Edwin C. Johnson, a member of the Joint Congressional Committee on Atomic Energy, said in a television broadcast last November 1 that U. S. scientists had made "considerable progress" on a superbomb 1,000 times as powerful as the Hiroshima model. On December 2 the syndicated Washington columnists Joseph and Stewart Alsop revealed that a hydrogen bomb which would devastate hundreds of square miles was under discussion, and that the President faced a decision on whether to undertake a project costing "$2 to $4 billion" to make it. This revelation was followed by further horrifying details from Drew Pearson; the story then became general, though there was still no Washington official who would permit himself to mention the words hydrogen bomb for quotation.

The debate, conducted almost exclusively in the gossip arena of newspaper columnists, developed a remarkable confusion of information: There was dispute as to whether the superbomb would employ hydrogen "fission" or hydrogen fusion; whether it would be thousands of times or only twice as powerful as the uranium-plutonium bomb; whether it would cost $4 billion or only $200 million. It was generally assumed that the possibility of creating the bomb itself had already been proved; all that remained was to manufacture it. The columnists divided the top officialdom of Washington into two camps: one for and one against making the bomb. Pearson had it that David Lilienthal and Lewis Strauss headed opposing factions in the Atomic Energy Commission, and that Lilienthal had resigned his chairmanship in protest against the hydrogen-bomb project. (After the President's decision, Strauss announced his own resignation from the Commission as of April 15, saying: "The issues involving national security which are my primary concern are now resolved as I had hoped and recommended.")

To White House visitors President Truman expressed strong displeasure that the hydrogen bomb had become a subject of public discussion. Lilienthal, denying that he had opposed making the bomb, assured reporters that the issue was not "the naked question: Do we or don't we?" It involved military, political and other considerations. What these considerations were never emerged, although the Joint Committee on Atomic Energy, the AEC's General Advisory Committee and other agencies held extended discussions of them. In the midst of the babble of private discussion in Washington, Harvard University's President James Bryant Conant, a member of the General Advisory Committee, made some public remarks that were taken to refer to the hydrogen-bomb issue. Speaking to a Harvard club in Rochester, he said: "The simple fact is that many important decisions are being made in Washington today without adequate evaluation." The Government, he added, had not developed "even the first approximation to a satisfactory procedure for evaluating technical judgments on matters connected with national defense."

In Washington the President told a press conference that when a decision was made on the hydrogen bomb it would be made by him, and by no one else. Four days later, on January 31, the President announced his decision in these words:

"It is part of my responsibility as Commander-in-Chief of the armed forces to see to it that our country is able to defend itself against any possible aggressor. Accordingly I have directed the Atomic Energy Commission to continue its work on all forms of atomic weapons, including the so-called hydrogen or superbomb. Like all other work in the field of atomic weapons, it is being carried forward on a basis consistent with the over-all objectives of our program for peace and security.

"This we shall continue to do until a satisfactory plan for international control of atomic energy is achieved. We shall also continue to examine all those factors that affect our program for peace and this country's security."

The President's decision won almost unanimous endorsement in Congress; it was accepted as inevitable by most scientists (*see page 11*). The columnist Walter Lippmann declared: "The President's statement should put an end to a public discussion which was bound to be very foolish when it was not very dangerous, and in any event was sure to be misleading." But the public discussion was only beginning. Whether the military strategists liked it or not, the hydrogen bomb was a matter of inquisitive interest to its potential victims in all countries, including the U. S.

Many U. S. citizens quickly expressed the feeling that the President's "naked" announcement had failed to do full justice to the opportunity to promote peace and security. Senator Arthur H. Vandenberg urged the President to assure the world that the U. S. would "suspend all our activities in respect to mass destruction the first moment these weapons can be dependably outlawed." The columnist David Lawrence pleaded: "The President has an unexampled opportunity to call for a re-examination of Russian-American relations in every aspect. . . . Has our diplomacy always been fair and just? Is it really helpless to find even an unorthodox approach to a solution? Is ingenuity confined solely to the laboratories of nuclear physics? The conscience of a Christian world may soon begin to press for the answers."

At a session of the American Physical Society in New York 12 of the nation's outstanding physicists, led by Hans A. Bethe of Cornell University, urged that the U. S. Government "make a solemn declaration that we shall never use this bomb first." The physicists said:

"Few of the men who publicly urged the President to make this decision can have realized its full import. . . . We shall not have a monopoly of this bomb; it is certain that the Russians will be able to make one too. In the case of the fission bomb the Russians required four years to parallel our development. In the case of the hydrogen bomb they will probably need a shorter time. . . . Even if the power [of the bomb] were limited to 1,000 times that of a present atomic bomb, the step from an A-bomb to an H-bomb would be as great as that from an ordinary TNT bomb to the atom bomb. . . . New York, or any other of the greatest cities of the world, could be destroyed by a single hydrogen bomb."

Among others who did not believe that the President's statement should put an end to public discussion of the hydrogen bomb was Senator Brien McMahon, chairman of the Joint Committee on Atomic Energy. Two days after the President's announcement McMahon delivered an address before an attentive session of the Senate. With an enthusiasm rare on cynical Capitol Hill, Senators of both parties rushed to shake his hand when he had finished. By a single bold, constructive proposal McMahon showed that the prospect was not hopeless if men did not think so. He proposed that the U. S. spend $50 billion to launch "a moral crusade for peace," end the atomic armaments race and "save mankind from destruction by fire." His suggestion was that $10 billion of the $15 billion the U. S. now spends annually for armaments be used during each of the next five years for the Point Four program (*see page 16*), for useful development of atomic energy and for "general economic aid and help to all countries, including Russia." In return for this "global Marshall Plan" other nations would be asked to accept an effective program for international control of atomic energy and to divert two thirds of their present spending on armaments to constructive purposes.

The alternative, McMahon observed, would be the destruction of free institutions in the U. S. and the necessity of remaining "ceaselessly poised to meet an attack that might incinerate 50 million Americans—not in the space of an evening but in the space of minutes." The Senator said: "Let me warn with all the solemnity at my command that building hydrogen bombs does not promise security for the U. S.; it only promises the negative result of averting, for a few months or years, well-nigh certain catastrophe."

Although the spirit of McMahon's approach elicited a warm response, the conditions of his proposal were widely questioned. Lippmann noted that in effect the Senator had proposed to attempt to buy acceptance by the U.S.S.R. of "the obsolete Baruch plan" for international control of atomic energy—an unrealistic hope. Said Lippmann: "I venture to believe that nothing would accomplish so much to restore the confidence of mankind as a statement by the President that he had not only instructed the Atomic Energy Commission to proceed with the hydrogen bomb but that he had also instructed the Secretary of State to institute a new inquiry into the American policy and the American proposals [for atomic energy control]. . . . That . . . would revive hope and open the minds of men, now frozen in the awful realization that we have nothing to offer except an obsolete plan to deal with the new horrors to which we are committed."

The Federation of American Scientists asked the President to appoint a commission of experts in various fields, like the board that drafted the Acheson-Lilienthal plan of 1946, to restudy U. S. atomic policy and "make a fresh start, looking toward a policy which offers some real hope of breaking the present stubborn deadlock."

The answer of the White House to all these pleas was No. Secretary of State Dean Acheson replied that agreement with the U.S.S.R. was impossible; the only possible choice for the U. S. was to build up its strength. President Truman told a press conference that the position of the U. S. was unchanged; he saw no reason to reconsider the Baruch plan; no new approach or commission to restudy the question was necessary.

## *Stockpiling and Defense*

ON the same day that the President made his statement on the hydrogen bomb the Atomic Energy Commission issued its seventh semi-annual report. It said that the development and stockpiling of atomic weapons had "moved on at a growing pace" during 1949 and the output of fissionable materials had "set new records." The AEC had also completed a report, still not fully declassified, on the effects of atomic weapons. One section of the report was made public recently. It deals with the medical defenses that would be required in case of an atomic attack.

For illustration, it is assumed that a bomb of the Hiroshima or Nagasaki type is dropped without warning on a clear day over an American city. The maximum area of damage and casualties would be about 12.6 square miles. On the basis of these premises, the AEC estimates that 250,000 pints of whole blood would have to be on reserve to treat the injured. Ideal care for a single severely burned person would require three nurses, 2.7 miles of gauze, 36 pints of plasma, 40 pints of whole blood, 42 tanks of oxygen and 100 pints of additional fluids—plus morphine, antibiotics and other drugs. The report points out that "obviously such ideal treatment would be impossible under catastrophic conditions." It suggests two major measures of medical preparation for civil defense: 1) wide dispersion of hospitals and other medical facilities, and 2) organization of mobile reserve teams to administer emergency treatment and evacuate casualties.

Another section of the report, issued last month, deals with the problem of constructing buildings to resist air-blast damage from an atomic bomb. Its conclusion: the only really safe refuge is a cave deep underground. Still another section will discuss methods of detecting and dealing with radioactive contamination. The report as a whole will form the basis for forthcoming discussions in Congress of a new program and legislation for civil defense.

Meanwhile, the National Security Resources Board, charged with responsibility for civil-defense planning, has created a Civilian Mobilization Office headed by Paul J. Larsen, former associate director of the Los Alamos Laboratory. And the Department of Defense has started a drive to recruit 150,000 volunteer aircraft spotters.

## *Rochester Star*

A NEW member has been added to the growing family of mesons by physicists at the University of Rochester. Mesons are the mysterious particles born of the shattering of atomic nuclei by high-energy bombardment. Physicists had already proved the existence of two types of charged mesons: the so-called *pi* mesons of mass 284 times that of the electron and *mu* mesons tipping the atomic scales at 215 electron masses, both types having positive and negative varieties. At Rochester Morton F. Kaplon, Bernard Peters and Helmut L. Bradt discovered strong evidence for a neutral meson, which had first been suggested by experiments conducted more than two years ago by British investigators.

The new meson left its mark in a recent spectacular photograph of the largest nuclear explosion ever recorded. The picture was obtained from a stack of 24 plates carried by balloons to a height of about 100,000 feet. It showed a cosmic-ray alpha particle with an energy of more than 10,000 billion electron volts shattering a silver atom in the photographic emulsion. The impact broke the atom into 74 fragments—more than twice as many as had previously been found in photographic or cloud-chamber records. Their tracks formed a striking pattern which was promptly named the "Rochester star." About 50 of the secondary particles were identified as charged mesons with lives measured in millionths of a second. But a few tracks were created by particles, with a life of less than one ten-thousandth of a billionth of a second, that had not before been observed. They were judged to be neutral mesons with a mass about 300 times that of an electron. Studies of the photograph indicate that they disintegrate into gamma rays with energies of several billion electron volts.

This observation checks with indirect evidence obtained recently at the University of California, where physicists bombarding nuclei in the 184-inch synchro-cyclotron also found records of gamma rays of the same order of energy. Calculations showed that such radiation could have been produced by the disintegration of neutral mesons. Robert E. Marshak of the University of Rochester summed up the evidence as follows: "If the analysis of the Rochester star is combined with the results of the Berkeley experiment on high-energy gamma rays, the most likely picture which emerges is [that] the . . . rays originate in both experiments from the rapid decay of neutral mesons with a mass of about 300 electron masses."

### *New Theories*

INCLUDING the neutral meson, there are, according to the latest count, 10 subatomic particles—the electron, positron, proton, neutron, neutrino and five mesons. Many physicists suspect that the growing list is already too long. They think that some of the so-called fundamental particles are actually built up of more elementary ones. The problem is to discover which of the "fundamental" particles are really fundamental and which are compound structures. In a recent issue of *The Physical Review* Enrico Fermi and C. N. Yang of the University of Chicago suggested a new theory which would strike the three heavy mesons from the list of the basic constituents of matter.

Fermi and Yang assume the existence of "anti-protons," or negatively-charged particles with the same mass as protons, and "anti-neutrons," which possess the peculiar property of being attracted by protons and repelled by anti-protons. They suggest that the positively-charged *pi* meson is a complex particle formed by the combination of a proton and an anti-neutron. This is something like saying that the whole is a good deal less than the sum of its parts, for the mass of a *pi* meson is less than a thirteenth of the combined mass of a proton and the theoretical anti-neutron. But the apparent discrepancy is accounted for by assuming that the lost mass has been converted into binding energy which is required to "glue" the particles together. Similarly, they propose that the negative *pi* meson represents the union of a neutron and an anti-proton, and that the neutral meson can be formed by the combination of either a neutron and an anti-neutron or a proton and an anti-proton.

At its present stage the theory, while eliminating three particles from the list of fundamental ones, adds two new particles, neither of which has been found experimentally. But Fermi and Yang explain that they have tried to indicate a promising line of attack "more as an illustration of a possible program of the theory of particles than in the hope that what we suggest may actually correspond to reality."

A far more comprehensive and radical theory has just been proposed by Hideki Yukawa, the Japanese physicist who won the 1949 Nobel prize in physics for his prediction of the meson 16 years ago. Yukawa's theory, developed after more than two years of work, attempts to deal with one of the most fundamental difficulties in modern quantum physics.

Subatomic particles are so small that in setting up mathematical equations to describe their behavior and interaction it seems reasonable to consider them as dimensionless points, to a first approximation. This assumption works when either the equations of quantum theory or those of relativity theory are used separately. But a complete description of matter requires that both theories be used together, and efforts to apply quantum-relativity equations to hypothetical point-particles have led to a serious contradiction—the particles turn out to possess infinite masses, infinite charges and infinite energies.

Yukawa believes he has solved the problem of "false infinities" by making it possible to consider particles not as points but as units with specific dimensions. They are treated as fields rather than as particles of matter. Nuclear physicists have considered that a field is a portion of space at every point of which a force is acting. Yukawa's new equations, however, involve a mathematical abstraction known as the "nonlocal" field, in which energy or mass is not located at a point but is "smeared" through a region of space. In present quantum theory a particle is imagined to be located at some definite position with a certain probability, although that position cannot be determined precisely. Yukawa suggests that all elementary particles are distributed in space as nonlocal fields with finite dimensions.

In a sense, his work provides a "unified field theory" for atomic phenomena, but it is not to be confused with Einstein's new generalized theory of gravitation (SCIENTIFIC AMERICAN, January, 1950). Yukawa is concerned primarily with tiny regions of space some 25 trillionths of an inch in diameter—about the size of an atomic nucleus. He is now working on another phase of his theory which will consider the possible types of nonlocal fields, or elementary particles, that can exist in nature. It will also tackle the most difficult problem of all—how to handle equations describing the interactions of various particles, so as to obtain theoretical results that can be checked with experiment.

### *A Question of Priority*

EUCLID is generally credited with the first proof of the famous Pythagorean theorem: the square of the hypotenuse of a right-angled triangle is equal to the sum of the squares of the other two sides. The Greek geometer presented the proof more than 2,200 years ago as Proposition 47 in Book I of his *Elements*. Recent excavations by Iraqi archaeologists suggest that an unknown Sumerian mathematician may have discovered the theorem 1,700 years before Euclid. A baked clay tablet unearthed near the site of the ancient city of Shaddipur contains a clear line drawing that closely resembles the Pythagorean diagrams in today's high-school textbooks.

Previously discovered records had shown that the Babylonians also were acquainted with some of the facts that led to the Pythagorean theorem. They knew that the theorem held for certain right-angled triangles—for example, those having sides of 20, 16 and 12 units or 17, 15 and 8 units. But they did not find a general proof that this relationship holds for all right triangles. Whether the Sumerian tablet provides such a proof will not be determined until the cuneiform text that accompanies the diagram is translated. Naji al-Asil, Director General of Archaeology in Iraq, has invited American oriental-research experts to help in this difficult task, which will not be completed for at least a year.

### *Element 97*

THE partial lifting of secrecy from developments in atomic energy at the end of the war revealed that four new artificial elements had been added to the periodic table. They were neptunium, element 93; plutonium, 94; americium, 95; and curium, 96. Last summer it was rumored that the chemist Glenn Seaborg and associates at the University of California had discovered a fifth transuranian element, but the gossip was denied as "completely unfounded." Now the news is officially confirmed. Stanley G. Thompson, Albert Ghiorso and Seaborg have found "good evidence" for the existence of element 97, tentatively named berkelium for the Berkeley campus where it was made.

Berkelium represents the culmination of four years of work sponsored by the Atomic Energy Commission. In accordance with secrecy requirements, the report gives no details about how the substance was produced, aside from the statement that the process involved the Radiation Laboratory's 60-inch cyclotron. The Berkeley scientists emphasized that "theoretical considerations rule out its use in production of atomic weapons." Their report, plus a new rumor that element 98 may be announced later this year, raises the question of whether there is any upper limit to the number of transuranian elements that can be created in the laboratory. Physicists point out that one theory allows for new elements up to number 137, sometimes called "cosmium." But most of these atoms would split spontaneously, so the practical limit may be only half a dozen transberkelian elements.

### *About Long-Range Forces*

FOR several years a lively controversy has been going on among chemists concerning an eerie apparent phenomenon known as "long-range forces." It was started by certain observations of Alexandre Rothen of the Rockefeller Institute for Medical Research. He found that some molecules seemed to have the power to react chemically with one another at relatively great distances, even though they were separated by a plastic barrier (SCIENTIFIC AMERICAN, October, 1948). Since this finding was in defiance of all chemical theory, which assumes that molecules can interact only when they are in contact, chemists were both mystified and skeptical. Many tried to disprove or explain Rothen's results. Two investigators now report that they have found an orthodox explanation of his findings.

In a typical experiment Rothen covered a layer of albumin 50 Angstroms thick (one Angstrom is about 1/40,000,000-inch) with a 200-Angstrom layer of inert plastic. On top of the plastic he placed a film of antibody proteins which combine specifically with albumin. Despite the plastic barrier the antibody on top reacted with the albumin underneath.

Chemists who questioned the theory that the reaction was effected by long-range forces decided that the plastic must be less impervious than it seemed. Somehow the molecules must have migrated through the plastic, either through accidental cracks in it or through some unknown opening. Hans J. Trurnit of the Army Chemical Center in Maryland now reports that he has established how the molecules get through. The plastic "barrier," he says, is actually a fine mesh screen with holes due to its natural physical structure. The antibodies Rothen studied are normally suspended in a phosphate salt solution. Trurnit deposited pure phosphate solution, completely free of antibodies, on top of plastic-albumin preparations. After 10 minutes, he found some of the underlying albumin in the phosphate solution. His observation indicated that the solution seeped through holes in the plastic and made contact with the bottom layer. Some of the albumin molecules then dissolved and "floated" to the upper surface of the plastic screen.

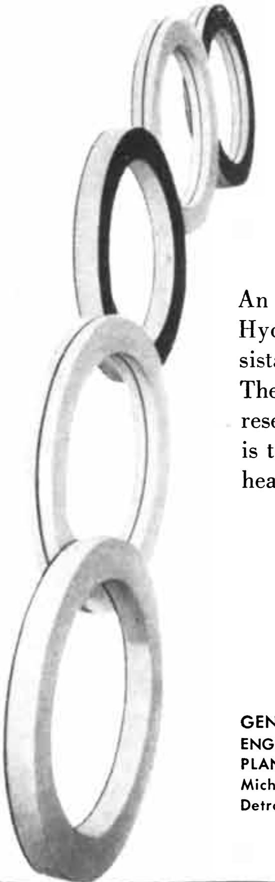
Further proof that the plastic has holes in it will be published shortly by S. J. Singer of the California Institute of Technology, and Rothen himself has found similar evidence. Rothen still believes, however, that the new facts do not explain all his experiments and long-range forces may act in certain cases.

### *Psychopathic Personality*

WHAT is psychopathic personality? This little-understood mental disorder received wide publicity during the Government's perjury trial of Alger Hiss, when a psychiatrist and a psychologist testified that Whittaker Chambers, the chief witness against Hiss, showed evidences of the ailment. The testimony listed as some symptoms of the condition "chronic, persistent and repetitious lying, stealing and deception . . . vagabondage . . . and a tendency to make false accusations." The diagnosis puzzled many laymen, who in general are inclined to suppose that all mentally ill persons fall into two broad classes: 1) the psychotic, and 2) the neurotic. The classification of psychopathic personality is also confusing to many psychiatrists, who agree in recognizing the existence of the condition but are not entirely clear on its diagnosis or treatment.

A recent review of research on the subject in the *Journal of Clinical Psychopathology* helps remove some of the confusion. Sydney B. Maughs of St. Louis shows that true psychopathic personalities are borderline cases and do not fit neatly into the neurosis or psychosis category. The psychopath, in contrast to the psychotic, is fully aware of society and his fellow men, and cannot be declared legally insane. In this sense he resembles the neurotic, but he is far more likely to commit crimes and is rarely troubled by the pangs of conscience. A psychopath usually lacks sympathy, fails to recognize the rights and feelings of others, and is predominantly a "predatory" person. His dreams tend to be as emotionally shallow as his waking life. They show "none of the deep-seated sense of guilt so commonly found in the dreams of neurotics."

The St. Louis psychiatrist cites recent research at the University of Iowa as evidence that psychopathic personalities may often be due to physical disorders of the brain. Irregular brain-wave patterns were 58 per cent more common in a group of psychopaths than in a control group of normal persons. Although such patterns alone are not enough for a positive diagnosis, Maughs feels that they should be used in all studies of the condition. He concludes, however, that the psychopath is rarely cured. Results with electric-shock treatments and drugs have been inconclusive. Psychoanalysis occasionally helps.

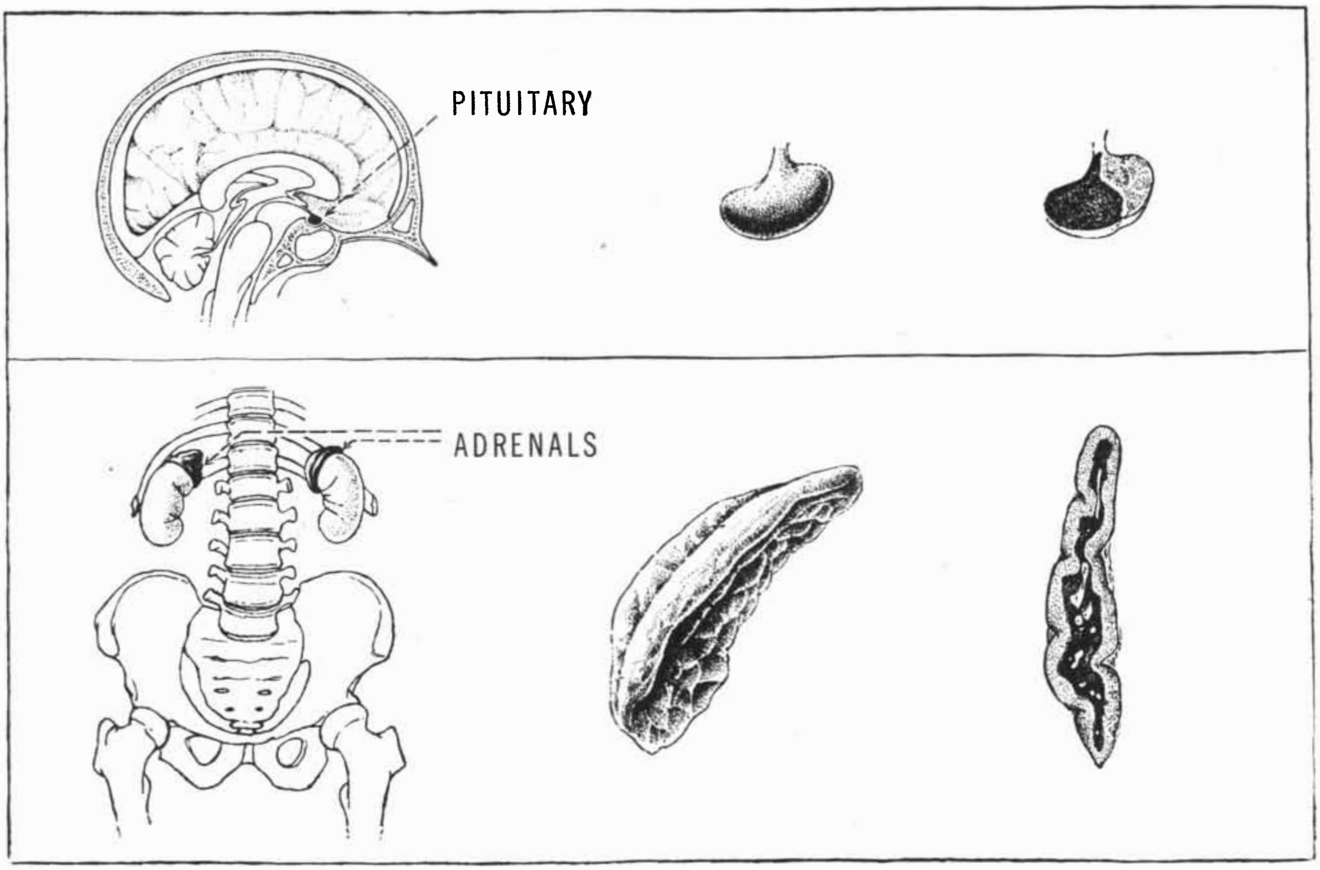




# Cortisone and ACTH

*The startling results of their administration in several rather different diseases suggest the beginnings of a unified theory of medicine*

by George W. Gray




**PITUITARY AND ADRENALS** collaborate in the body's first line of defense against any kind of damage. The pituitary, located at the base of the brain, is divided into anterior and posterior parts. The adrenals, located atop the kidneys, have a medulla and a cortex. The pituitary produces the adreno-cortico-tropic hormone, or ACTH, which stimulates the adrenal cortex to manufacture hormones. One such cortical hormone is cortisone.

THE adrenal glands, two wrinkled pads of yellowish-brown tissue that lie on top of the human kidney like miniature pancakes, rarely weigh as much as a quarter of an ounce—but on that glandular quarter-ounce depends the health of the whole body. Animals from which the adrenals are removed die in a few days, and persons whose adrenals become involved in the condition that brings on Addison's disease rarely can be kept alive except by injections of adrenal hormones.

Each adrenal consists of an inner core, the medulla, and an outer bark, the cortex. The medulla manufactures only one hormone: adrenalin. The cortex, however, turns out 20 to 30 different compounds. Although these cortical hormones have long been studied, until recently chemists were able to isolate only a few of them, and those few were obtained in such microscopic amounts as to be useless for medical purposes. The treatment of victims of adrenal deficiencies had to depend on extracts dissolved out of cortical tissue, which, of course, were mixtures of a number of different compounds.

World War II brought a great impetus to the research on cortical hormones. During the war it was rumored that pilots of the *Luftwaffe* were being injected with hormones of the adrenal cortex and that these injections enabled them to fly at ease at altitudes of 40,000 feet. When this rumor (eventually found to be false) was first received in Washington in the fall of 1941, it galvanized the medical departments of the Army and Navy into action. They called on the National Research Council for large supplies of cortical hormones. The Council made a quick survey and found that 22 laboratories had been engaged in investigations of the adrenal cortex. The resources of these institutions were immediately enlisted, and a coordinated team effort was organized. Under this accelerated program, several methods of obtaining cortical hormones in pure form were explored. Eventually one of the investigations yielded a marvelous result: the production of cortisone.

### Cortisone

The father of cortisone was Edward C. Kendall, chief of the biochemical laboratories of the Mayo Foundation for Medical Education and Research. As early as 1935 he had isolated the first few granules of the substance. It was the fifth in a series of hormones that he had separated from cortical extract, and so he called it compound E. Tests of these hormones on rats and mice showed that three of them—A, B and E—apparently played some part in metabolism. Compound E had a marked effect on muscular activity, and apparently it increased an animal's ability to resist exposure to cold, poisons and other physiological stresses. But to find out what compound E and the other hormones could do for human disease required much larger supplies of the substances than could then be procured. Dr. Kendall had obtained his hormones by crystallizing them out of the mixture of fats, proteins, water and other materials extracted from the cortex, but at the rate this production was going it would take decades to isolate enough of each hormone for a medical man to evaluate it. It was clear that a more efficient method of production had to be devised.

Chemists have a technique, known as partial synthesis, by which they remodel one molecular structure to produce another of different form. There is a well-known bile acid whose structure, it was believed, might be reshaped into the configuration of either compound A or E. But many steps would be involved, and whether partial synthesis could be applied to convert the acid into one of the hormones was pure speculation. Kendall and his associates were studying the possibilities of this molecular reconstruction when the German rumor of 1941 suddenly made cortical hormones an emergency problem. The Mayo laboratory at once became a center in the government's accelerated research program, and it soon joined forces with a laboratory of Merck and Company, Inc., another important outpost in this research. By 1944 the Mayo group had produced a sample of compound A from bile acid, and in 1945 the Merck group made a larger quantity by the same method. But compound A proved to be a disappointment. Tried on cases of Addison's disease, it had no beneficial effect at all. So the chemists of both groups turned their efforts to the production of compound E.

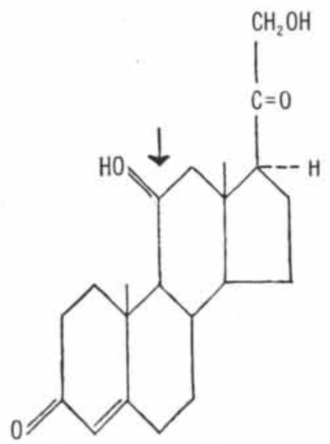
Early in 1946 Lewis H. Sarett of the Merck laboratory delivered the results of the first partial synthesis of compound E. This method, however, yielded too minute a quantity to be of clinical use, so the chemists tried again. Two years were spent working out the 37 steps of a new synthesis. Finally, in May, 1948, this effort was crowned with success. By September of that year compound E was being manufactured by the gram instead of the milligram. For the first time there was enough compound E, now named cortisone, to test it on human illness.

### Rheumatic Diseases

The first tests were made at the Mayo Clinic. For many years Philip S. Hench, chief of the Clinic's department of rheumatic diseases, had been investigating two curious phenomena connected with arthritic disease. He had noticed that when an arthritic woman became pregnant, the arthritis usually ceased to trouble her, and that jaundice also seemed to cause arthritic symptoms to fade away. The remissions were only temporary, however, for after the patient had given birth or had recovered from jaundice, the old swellings, stiffness and pain returned. Other doctors had remarked on these coincidences, but apparently Hench was the first seriously to seek an answer. Beginning in 1929 he spent several years in careful observation of arthritic patients during pregnancy and in attacks of jaundice. He came to the conclusion that rheumatoid arthritis might not be of microbial origin, as many authorities held, but might be caused by some basic disturbance of the body's chemistry. He conjectured that the anti-rheumatic factor was probably a substance which the body produced normally at all times but poured into the bloodstream in greater quantities during jaundice and pregnancy. This suggested that the adrenal glands might be the source, for it was already known that under other conditions of stress, such as those imposed by anesthesia, surgical operations and certain bacterial invasions, these glands rapidly increase their secretions.

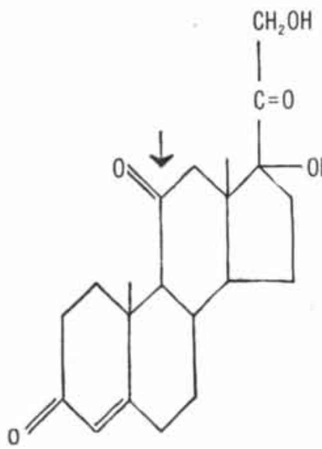
If it was indeed true that jaundice and pregnancy stimulated the adrenals to secrete a hormone that neutralized rheumatism, then the injection of the hormone into arthritic patients ought to have a similar effect. Hench and Kendall had often discussed this hypothesis. They had actually made a trial in a few rheumatoid volunteers with a cortical extract, but this mixed extract produced no conclusive results. Then came the great day when cortisone was available. Dr. Hench selected for his initial test a 29-year-old woman who had had severe rheumatoid arthritis for more than four years. She had undergone many different treatments with no success. Destructive changes in her right hip and in other joints had made them stiff, swollen, tender and painful when moved; her symptoms had progressively increased in intensity, and by the morning of September 21, 1948, when the cortisone test was undertaken, she was hardly able to get out of bed.

The treatment was begun with the daily injection of 100 milligrams of cortisone. No change appeared in the patient's condition the first day or the second, but when she awoke on the third day she moved in bed with ease. By the fourth day stiffness was gone, appetite was good, life was a joy instead of a painful endurance test. Walking became so easy that on the eighth day the patient went downtown on a three-hour shopping tour, and returned with no feeling of stiffness or soreness. Thereafter the daily dose was reduced to 50 milligrams for 4 days and then to 25 for 10 days. These amounts soon demonstrated their insufficiency, for rheumatic symptoms



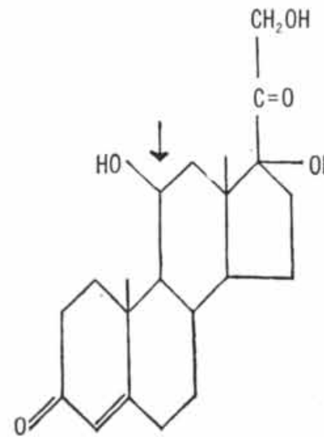
## COMPOUND B

$\Delta^4$ pregnene-11B, 21-diol-3, 20-dione



## COMPOUND E

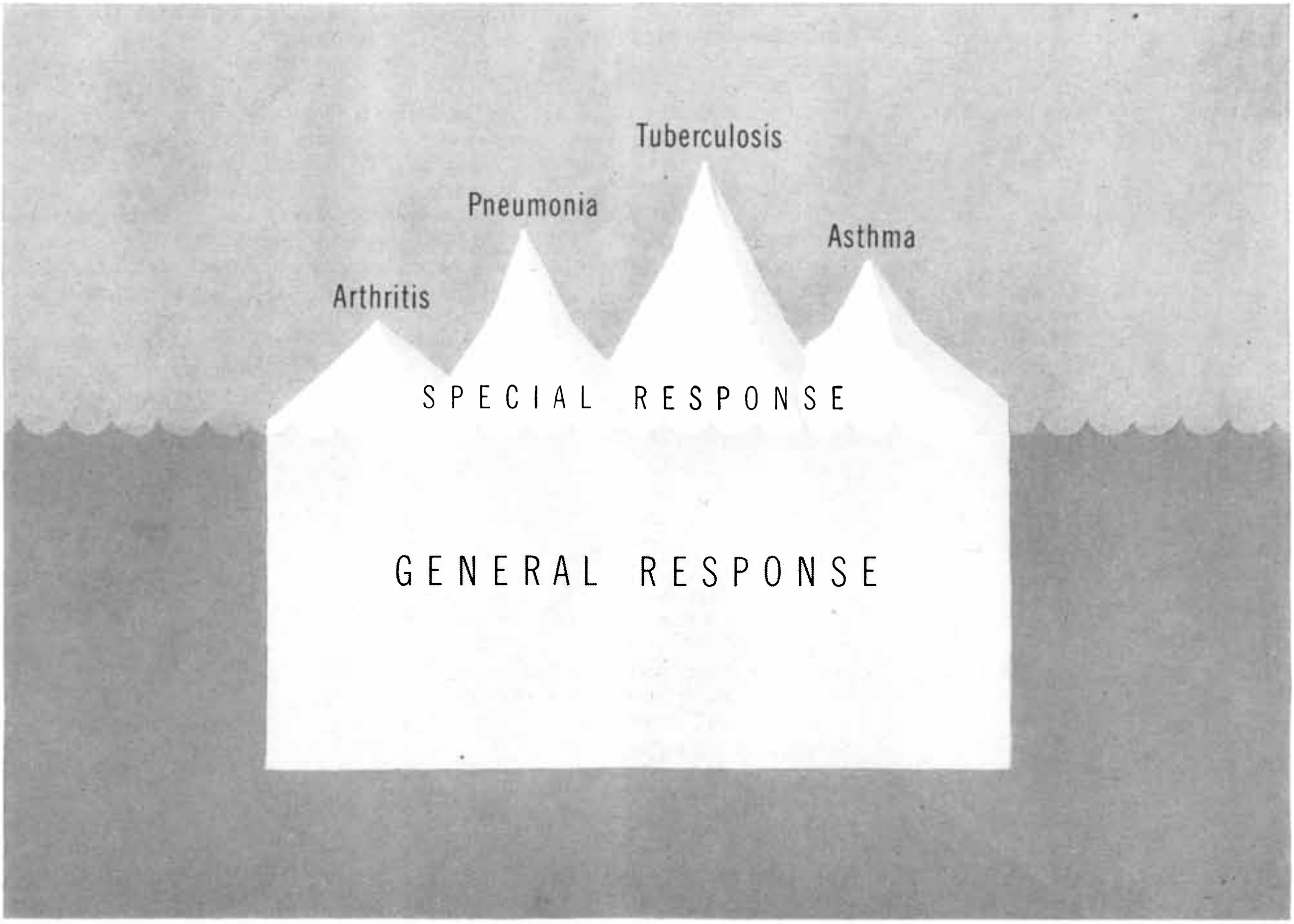
17-hydroxy-11-dehydro corticosterone



## COMPOUND F

17-hydroxy-corticosterone

**THREE HORMONES** produced by the adrenal cortex have almost identical molecular structures. They are all steroids of the glycogenic type, characterized by a linkage with oxygen at the same position on their four-ring skeleton *(arrows)*. Compound E is Edward C. Kendall's original name for cortisone. Compound F has been found as effective as cortisone in treating rheumatoid arthritis, but it has been isolated only in small amounts.




**ICEBERG THEORY** of disease is suggested by the early trials of cortisone and ACTH in several apparently unrelated infectious and degenerative disorders. Small amounts of the hormones have suppressed the symptoms of arthritis; larger amounts, the symptoms of asthma, pneumonia and tuberculosis. This implies that the symptoms of disease are merely aspects of a general response, or peaks on the iceberg of body's defense.

reappeared and it was necessary to return to the larger dose.

Following this trial, Hench and his associates, Charles H. Slocumb and Howard F. Polley, administered cortisone to 13 other arthritic patients. In each instance improvement began within a few days, continued as long as the full dose was given, and was followed by relapse as soon as the dosage was reduced or discontinued. Thus the evidence was unanimous. There could be no doubt that cortisone had the property of opposing rheumatism. And this suggested an explanation for the curious ups and downs in the disease that Hench had observed: apparently the extra burdens imposed on the body by pregnancy and jaundice somehow increased the supply or utilization of cortisone.

But what was the mechanism of this stimulation? How did the adrenals know that the body was overburdened and needed extra cortisone to reinforce its resistance? Such questions to an endocrinologist pointed a finger in one direction, toward the master gland: the pituitary.

### ACTH

The very position of the pituitary gland marks it as an organ of superior importance. It is suspended within a bony cavity beneath the brain, and not only enjoys the protection of the surrounding skull but the advantage of close association with the central organ of the nervous system. Nerves and blood vessels connect it to the hypothalamus, in an evolutionary sense one of the oldest segments of the brain, and there is evidence that the hypothalamus exerts a control over the pituitary. But the fact of immediate interest to our story is that the pituitary exerts a control over the adrenal glands.

The pituitary is even smaller than the adrenal body, being about the size of a grain of corn. It consists of two distinct parts: a bulbous front section known as the anterior lobe, and a smaller rear, the posterior lobe. The anterior lobe is the executive office that controls the internal secretions of many other glands, including the thyroid, gonads and adrenals. It exercises this control by means of specific hormones which it releases into the circulation. The pituitary messenger to the adrenal cortex is a substance known as adreno-cortico-tropic hormone, or, more simply, ACTH. It is ACTH that commands the cortex to release cortisone. Presumably, therefore, pregnancy and jaundice suppress arthritis through the pituitary. By some means—through the hypothalamus or another agency—these states of the body cause the pituitary to secrete ACTH, the ACTH in turn causes the adrenal cortex to secrete cortisone, and the cortisone counteracts the rheumatism.

This sequence of cause and effect suggested an alternative method of treating arthritis. Instead of injecting cortisone, why not inject ACTH? A small quantity of the pituitary hormone might excite the adrenal glands to send out a larger quantity of the cortical hormone, and thus the body would provide its own anti-rheumatism factor.

Chemists of Armour and Company, applying methods worked out by Choh Hao Li at the University of California, had been working for years on the extraction of ACTH from the pituitary glands of hogs slaughtered in the packing houses. In 1946 John R. Mote, medical director for Armour, had supplied research workers with a few grams, but it had not been tested on arthritis. On February 8, 1949, Hench and his associates began to administer ACTH in daily injections to two arthritic patients at the Mayo Clinic. Within a few days all symptoms of the disease began to diminish, and this continued progressively as long as ACTH was given at its full dosage. The anti-rheumatic effects of ACTH paralleled those of cortisone in practically every particular.

When, in the spring of 1949, reports of Hench's pioneering treatments were made to groups of medical men, Armour was immediately flooded with requests for ACTH, and Merck with requests for cortisone. Last October Mote called a conference of those to whom he had given supplies of ACTH for an exchange of reports on the results of their use of the hormone. They met in Chicago for two days. "Never have I attended such a conference," reported one physician on his return home. "It was like a religious meeting, with men popping up all over the house to tell of some seeming miracle. No medical gathering in history ever heard reports of so many different diseases yielding to treatment with a single drug." Acute asthma, pneumonia, chronic alcoholism, rheumatic fever—diseases described in the medical books as widely contrasting disorders, each with its own pattern of symptoms—had all been mastered, at least during treatment, by daily injections of ACTH. After listening to two days of such reports, Walter Bauer of the Harvard University Medical School remarked that "the astonishing ability of ACTH apparently to turn diseases off and on at will marks the opening of a new era in medicine."

### The Body's Defenses

A good place to explore the background of these exciting developments is Montreal. A visit to the endocrine research laboratory of J. S. L. Browne at McGill University found him in much the same state of mind as Bauer. "The emotional impact of that Chicago conference was terrific," he said. "As disease after disease was reported on, I sat enthralled, feeling that we were witnessing the beginning of a revolution." The revolution, if revolution it be, was foreshadowed in certain research results that have been accumulating in Montreal over the last dozen years.

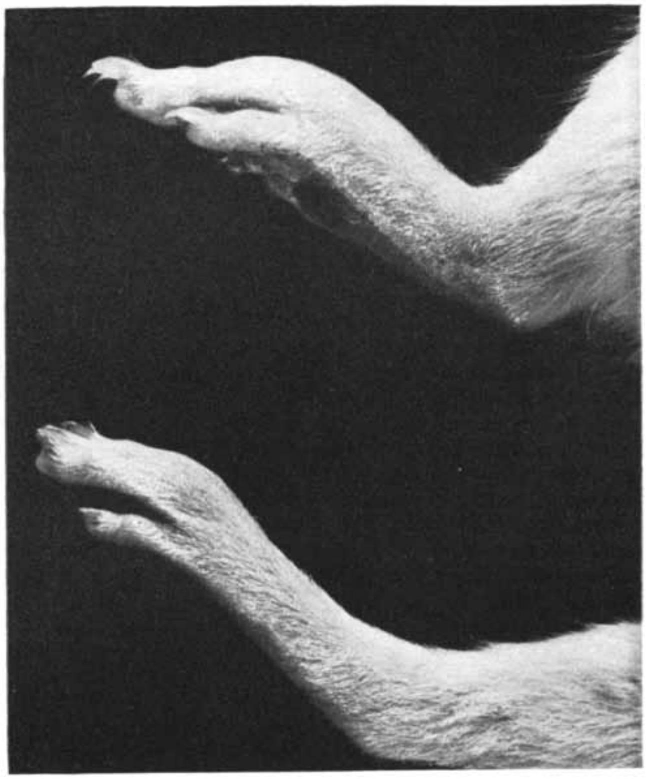
Dr. Browne is an authority on the adrenal glands. A colleague in this same field is Hans Selye, who carried on research on the adrenals at McGill from 1932 to 1945 and then transferred to the neighboring University of Montreal, where he now heads the Institute of Experimental Medicine and Surgery.

It was at McGill that Selye and his group began their now-famous studies of how the body reacts to damage (Scientific American, March, 1949). Working with animals, Selye found that the body responds in the same general way to a variety of injuries—exposure to cold, burns, fractures, infections, poison, terror and other emotional traumas. Irrespective of the nature of the stress, the physiological response of a healthy animal is always marked by three stages: 1) the alarm reaction, signaled by drastic physical changes, including extreme variations in blood pressure; 2) the resistance stage, in which these symptoms subside but the body is extraordinarily sensitive to other forms of damage; 3) the exhaustion stage, the tragic climax to prolonged stress, when the body runs out of its capacity for defensive reactions and dies. This three-stage pattern was named the "general adaptation syndrome."

Selye found that the adrenal cortex played a critical role in the body's defenses. When it was defective, the alarm reaction was feebler and covered a briefer period of time, some of the symptoms did not appear at all, and the animal passed rapidly to the stage of exhaustion. When the adrenals were entirely removed, resistance to stress practically disappeared and death came quickly. Selye later showed that if the adrenal response to stress goes wrong, this response itself can lead to diseases, such as arthritis and high blood pressure. His studies indicated that two hormones from the cortex—one known as desoxycorticosterone, the other named compound S by its Swiss discoverer, T. Reichstein—brought about these abnormal changes. Further experiments demonstrated that cortisone counteracted these hormones and caused the diseases to disappear in animals. Thus the adrenal cortex can both cause the disease and cure it. Selye also demonstrated, in a crucial experiment of this series, that the organism always produces ACTH in response to stress or injury, and that it plays a master part in the body's defense mechanism.

"We were greatly stimulated by these discoveries," related Browne, "and took up the general adaptation syndrome as

**SWIMMING RATS** are part of a study of how a whole organism responds to stress. The study is conducted by Hans Selye and his associates at the University of Montreal. The rats are subjected to various kinds of prolonged stress to observe its many physiological effects.



**ARTHRITIC ANKLES** of two rats have been treated with desoxycorticosterone (*top*) and cortisone (*bottom*). The former has aggravated the disease; the latter has inhibited it. This response illustrates the delicate balance among the adrenal cortical hormones in the body.

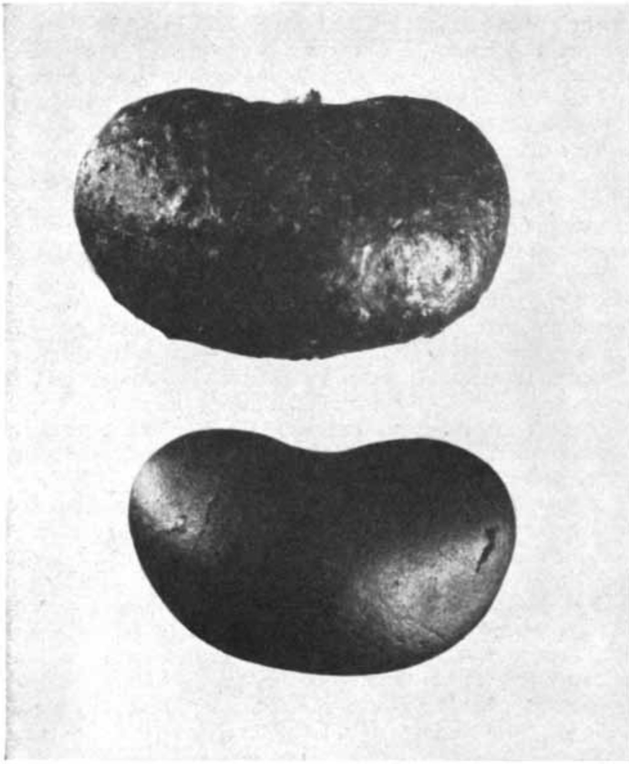
a major subject for research in human beings as well as in animals. By 1939 Selye and Victor Schenker had devised a method of measuring the amount of cortical hormones in a solution; using this, Paul Weil found that patients suffering from Cushing's disease had high quantities of the hormones in their urine. Cushing's disease is a disorder in which the adrenal cortex is chronically overactive; therefore this result was to be expected. Next it was shown that the cortical hormones were in excess quantity in the urine of patients suffering from burns, infections and surgical operations. These studies demonstrated that Selye's theory, originally derived from studies of animals, was also true of man, and we were able to transfer findings from lower animals to the human."

In 1942 Eleanor Venning, an associate of Browne, devised a more sensitive method of measuring cortical hormones and applied it to pregnant women. She found that the cortical output progressively rose during gestation, and in the eighth month was equal to that of a victim of Cushing's disease. Dr. Venning also found that in the first three to five days of a newborn infant's life the infant has an extremely low supply of these hormones. It had been known before that the adrenal gland is not fully developed in unborn babies but matures within a few days after birth. Does this account for the poor resistance of newborn infants? J. A. F. Stevenson, a medical student on duty in the Montreal Foundling Hospital, had occasion to test this theory. A girl infant in the hospital who had been born prematurely at seven months and weighed only three pounds became desperately ill of pneumonia at the age of five days. Even in oxygen she was blue with cyanosis. The death rate from this combination of prematurity and pneumonia is close to 100 per cent. Stevenson asked if it would be safe to administer an extract of cortical hormones to the dying baby, and Browne told him to give 50 cubic centimeters per day—a dose considered to be enormous at that time. Half an hour after the first injection the baby ceased to be blue, and within five days she was well. "An infant, especially one born at seven months, does not have adequate adrenal protection against the stresses of the outside world," observed Browne.

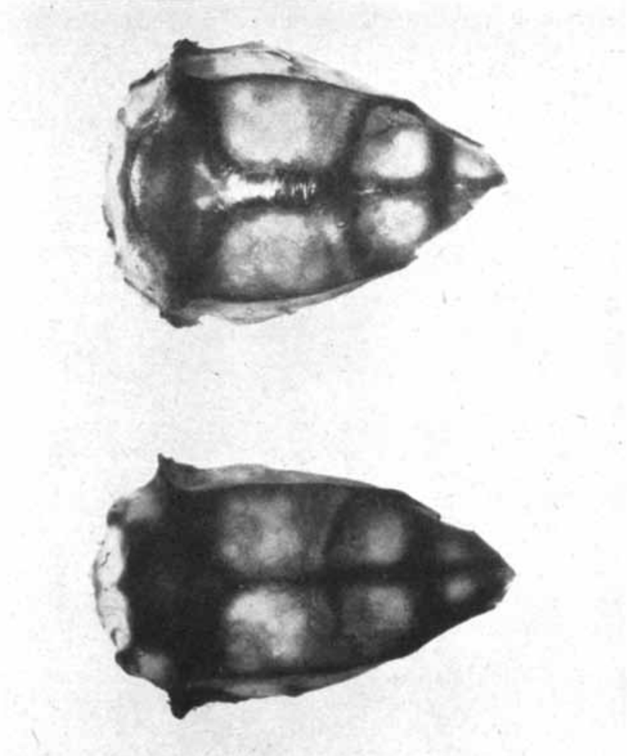
The repair of tissue after injury is reflected in the body's metabolism. Members of the McGill group studied changes in the utilization of proteins and of vitamin C by persons recovering from burns, surgical operations and infections. They found that the same kind of changes occurred in all these conditions and also during and following many different illnesses. They learned, however, that when persons who had been in good health were stricken with acute disease or other injury, their responses were different from those of patients who were chronically ill. It was further learned that the sensitivity of animals to the allergic factor histamine was markedly influenced by hormones of the adrenal cortex.

Studies of emotional stress gave additional evidence of the adrenal cortex's function as the body's defender and repairer. Dr. Venning, examining a woman directly after an outburst of hysteria, found that her cortical hormones, which had normally been 40 to 60 units, rose within 24 hours to 300 units. The cortical hormones of another patient shot up to 250 units upon her receipt of news that her sister was dangerously ill. "These measurements show that mental or emotional upset is just as truly an injury to the body as a bone fracture, a burn or a bacterial infection," remarked Browne.

Since the adrenal cortex acts only under orders from the pituitary, the complete picture of how the body responds to damage awaits a better understanding of the relationships of the master gland. We know that persons whose pituitaries are underdeveloped or atrophied invariably have small, sluggish adrenals. The administration of the pituitary hormone ACTH to such patients brings about regeneration of the adrenals with



**ENLARGED KIDNEY** of a rat (*top*) is the result of the administration of adreno-cortico-tropic extracts of the pituitary. The resulting excess of adrenal cortical hormones caused the rat to develop hypertension and nephrosclerosis. A normal rat kidney is at bottom.



**OPEN SKULL** of a young rat (*top*) is the result of the administration of desoxycorticosterone. The bones in the dome of the skull were pushed apart by the high blood pressure produced in the brain by the hormone. The closed skull bones of a normal rat are at bottom.

revival of normal functioning. However, when ACTH is administered to subjects in whom the adrenals themselves are atrophied or missing, the hormone has no effect. In short, ACTH exactly bears out its name—adreno-cortico-tropic; it acts only through the adrenal cortex. For patients with defective adrenals, only cortisone will do. But if the adrenals are normal, either cortisone or ACTH will be effective, the first acting to supplement the body's natural output of cortisone, the second acting to stimulate the adrenal glands to increase this natural output. In either instance, the effect is to raise the level of cortisone in the bloodstream and thus increase the body's resistance to stresses of all kinds.

Some kinds of stress require more cortisone than others. For example, the amount of cortisone called into circulation by pneumonia is sufficient to overcome the damage imposed by rheumatism, but not necessarily sufficient to overcome that of pneumonia. However, as was shown at the Chicago conference, it is possible by means of ACTH injections to call sufficient reserves of cortisone into the circulation to overcome even pneumonia. Maxwell Finland of the Boston City Hospital reported the case of a boy afflicted with lobar pneumonia. Twenty-four hours after administration of ACTH all the pneumonia symptoms had disappeared, and the boy felt fine even though large numbers of pneumococci appeared in his blood. Ordinarily such a heavy invasion would make even a grown man feel very sick, but with the extra molecules of ACTH-induced cortisone circulating through the boy's system, it seemingly paid no attention to the bacteria.

Smith Freeman of Northwestern University Medical School reported similar results in a case of tuberculosis. Seventy-two hours after treatment with ACTH began, the telltale sedimentation rate was down, fever was down, appetite was up. With daily injections the patient's condition steadily improved. All signs of tuberculosis disappeared except one—his sputum still swarmed with bacilli. This meant, of course, that he was still a source of infection to others, and more dangerous because the familiar signs of the disease were missing. On the 21st day administration of the hormone was stopped. At once, as if the lid had been lifted from a cauldron, the symptoms erupted again.

Even cancer, in some forms, seems to yield temporarily to the influence of ACTH. O. H. Pearson and a group at the Memorial Hospital reported to the New York Academy of Medicine in January that five patients with leukemia showed improvement within a few days after daily injections began.

"The picture of disease which these recent developments suggest is that of an iceberg," said Browne. "Seven-eighths of an iceberg is submerged, and so is the greater part of the processes of a disease. This invisible area represents the body's basic response to stress of all kinds. It is described in Selye's general adaptation syndrome. But just as certain parts of an iceberg protrude above the water, so certain specialized responses of the body become visible as manifestations of specific stresses. For example, the symptoms of tuberculosis are the manifestations of the injury inflicted by the tubercle bacilli. But underlying them is the general response of the body to damage, any damage, and it has just as great a significance as the special response to the bacilli. Without both the special and the general responses, the disease does not exist.

"Each disease is made up of this special pattern outcropping above the general response of the body. Cortisone melts the iceberg so that the symptoms fall below the surface. But if you stop administering the hormones, the iceberg freezes again, and then the tuberculous fever returns, the arthritic stiffness and pain reappear, the asthmatic wheezes and gasps recur, and all other symptoms become visible.

"This philosophical point of view greatly alters our concept of disease," concluded Dr. Browne. "It presents the picture of a basic pathological process at work which when it mounts to a certain magnitude is the disease. And this idea, I may add, is completely at variance with the older views of scientific medicine. It is at variance with the idea of compartmentalized disease, which is the central dogma of modern medical practice. Medical men who recognize the revolutionary and shattering nature of these developments realize that a great adjustment in our thinking has to be made. Here is the pool of Bethesda."

### Panacea?

The Bible relates that the pool of Bethesda stood by the sheep gate to Jerusalem, and hundreds of the sick, the crippled, the withered of body and mind waited at its edge. They waited for the moment of healing. According to tradition, an angel descended into the pool at certain seasons and troubled the water. Whoever then first stepped in was healed, no matter what his affliction.

The idea that there exists a universal remedy which is sovereign over all diseases has persisted through the centuries. The medieval search for the elixir of life has been succeeded in more recent times by the familiar examples of homeopathy, osteopathy and chiropractic, each with its one cause and one cure. Scientific medicine has consistently frowned on all unitary theories of the healing art. But the demonstration of what hormones can do brings this whole subject under a new scrutiny. To be sure, there are many blanks in the hormone picture, many questions yet to be answered, many byways to be explored. For example, ACTH may stop acute attacks of gout; but when administered in the quiet period between attacks it may also bring on an upflare of the disease. Like a valve, the hormone seems to work in either direction, depending on which side exerts the greater pressure.

Nor can one overlook the various side effects of the use of these hormones: heightened blood pressure, severe headaches, edema, excessive hair growth, skin eruptions and occasional confused mental states which some patients have had to endure as the cost of being freed from rheumatism. A 10-year-old child who had severe arthritis was quickly relieved by the hormones, but immediately developed diabetes; when the cortisone treatment was stopped, the diabetes disappeared but the arthritis reappeared. At last accounts her physicians were trying to moderate the dosage to a level that would keep her arthritis mild without raising the diabetes to an acute stage. Apparently until science learns more about the treatments, this child will have to endure some symptoms of both diseases.

A fuller understanding is needed of the other hormones produced by the adrenal cortex, for cortisone is only one among many manufactured by this prolific tissue. Desoxycorticosterone and Reichstein's compound S have been mentioned as possible causes of rheumatism; they seem to produce other disorders of connective tissue as well. Other hormone products of the adrenal cortex include a masculinizing hormone similar to testosterone, the pregnancy hormone progesterone, and corticosterone (Kendall's compound B)—all of which are remarkably similar in structure to cortisone. Still another cortical product is compound F, the sixth hormone isolated by Kendall. The only structural difference between it and cortisone is the presence of an extra hydrogen atom in compound F. Tests show that F will suppress the symptoms of rheumatism quite as effectively as cortisone. But compound F is yet to be purified in quantities sufficient for clinical use.

Cortisone and ACTH continue to be very scarce drugs. ACTH, because of the size and complexity of its molecule, cannot be synthesized. It can be obtained only by extraction from pituitary glands, and it takes the pituitaries of more than 500 hogs to provide one gram—the amount necessary to treat one case of rheumatoid arthritis for 20 days. The processing and extraction of the hormone is intricate, laborious and time-consuming; at the end of 1949 ACTH was being produced at the pitiful rate of only five pounds per month. Up to that time Armour and Company donated its output of ACTH to hospitals, clinics and laboratories for use in research, but beginning in January it adopted the policy of selling the hormone at its cost of production—approximately $200 per gram.

Encouraging news was reported from the University of California in December. The chemist Choh Hao Li, an outstanding specialist in the chemistry of pituitary hormones, said that with the aid of the enzyme pepsin he had succeeded in breaking down the giant ACTH molecule into submolecules consisting of not more than eight amino acids. These fractions, tested on an arthritic patient by L. W. Kinsell, proved as effective in suppressing the disease as ACTH itself. Since the submolecules are relatively simple in structure, it seems possible that they can be synthesized in ample quantity.

The cortisone molecule is smaller than the ACTH, and there is hope that eventually it may lend itself to full synthesis. The partial synthesis by which it is now being made is said to be the most complicated chemical process in use in pharmaceutical manufacturing. It requires the bile acid of 4,000 cattle to produce one gram of cortisone. Present production is about 200 grams per month; until January this meager supply was allocated among research workers by a special committee of the National Academy of Sciences. Merck now makes the allocations, charging $150 per gram. One gram is just enough to treat an arthritic patient 10 days.

**PERFUSION APPARATUS at the Worcester Foundation for Experimental Biology pumps blood through a beef adrenal (*glass vessel at top*). Blood is then aerated in sphere at left center and returned to adrenal.**

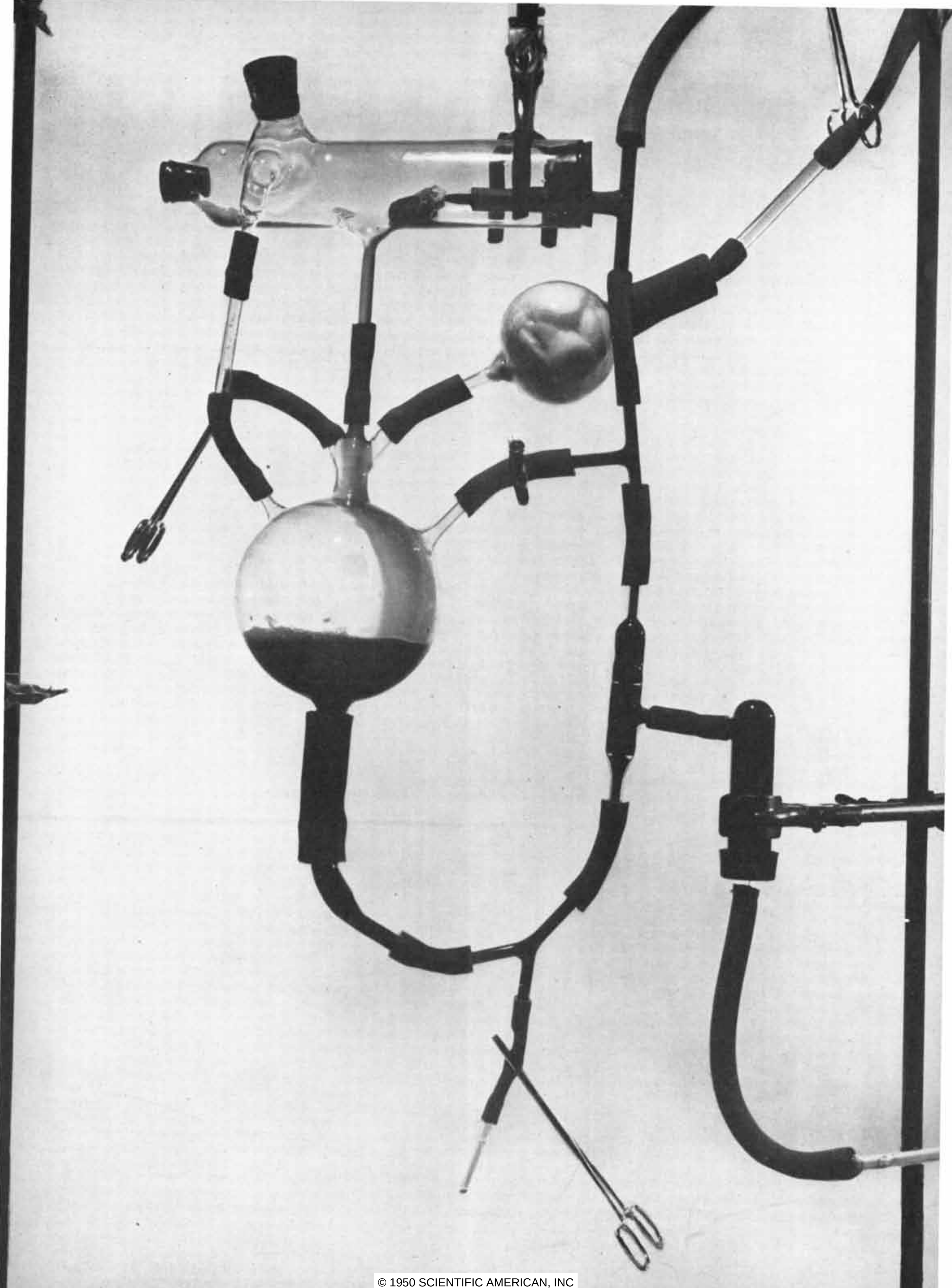
Some think it may be possible to grow adrenal glands in glass vessels for their secretions, just as we keep cows for their milk. This experiment is actually under way at the Worcester Foundation for Experimental Biology. Using the adrenal glands of cattle, Gregory Pincus, Oscar Hecht and their associates have installed the glands in glass vessels and kept them functioning for many days by circulating through their blood vessels a fluid containing the necessary nutrients and metabolites. They have demonstrated that when desoxycorticosterone is supplied in the circulating fluid, the gland transforms this into corticosterone. When compound S is supplied, the gland produces compound F.

A substance from which cortisone can be made is found in certain plants, and the vegetable kingdom is now being prospected as a possible source of supply for this raw material. There is further hope in recent reports that pregnenolone, a synthetic hormone akin to cortisone which is relatively easy and cheap to make, has produced beneficial results like cortisone's in the treatment of arthritis.

In view of the present small supply, the use of both cortisone and ACTH is limited to research. Even if production could quickly be multiplied a hundred times, the greatest gain would still be realized by applying it to the speeding up of research rather than to treatment, for the hormones are still in the investigation stage, and the material is so scarce that many opportunities now begging for investigation must be passed by.

Despite the fragmentary nature of our knowledge of how cortisone works, it is clear that the pages of history have turned a new chapter in man's long search for the mechanism of disease. Thus far we have been able to read only a few disconnected sentences of that new chapter. But they are so amazing in what they tell and so revolutionary in what they imply that the medical world today is watching avidly, one might almost say breathlessly, for the next development.

*George W. Gray, author of* The Nobel Prizes *and numerous other articles in this magazine, is a member of the staff of the Rockefeller Foundation.*



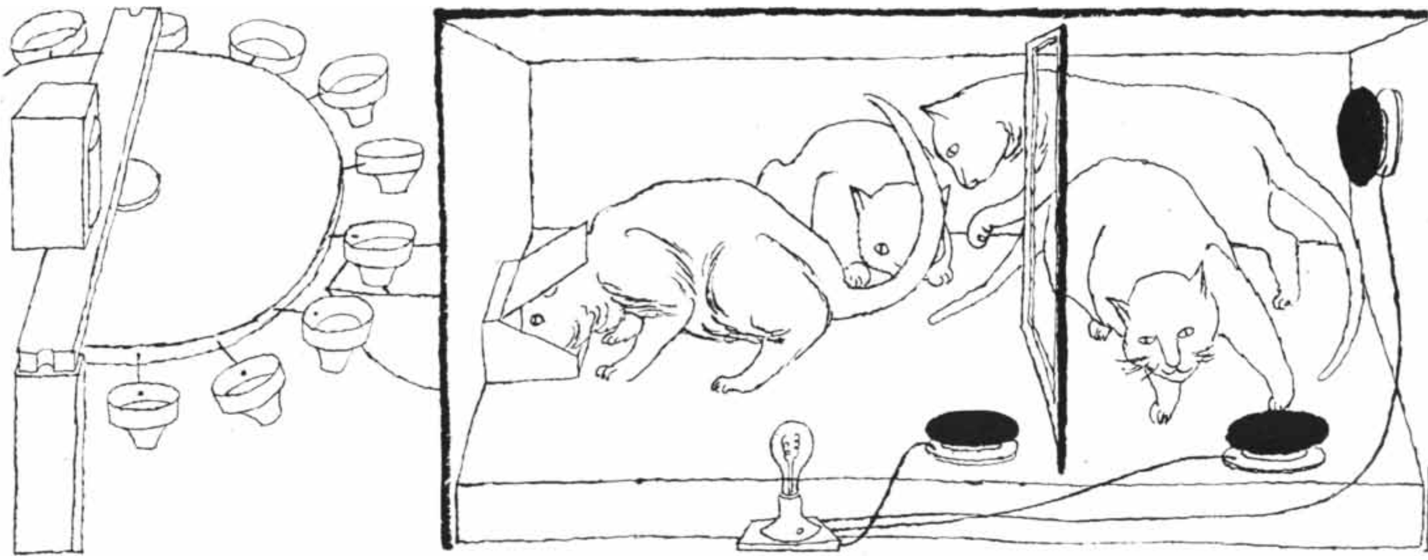
# EXPERIMENTAL NEUROSES

## In which cats (1) learn complex patterns of behavior, (2) are subjected to contradictory influences and (3) develop neuroses which are relieved by psychotherapy

by Jules H. Masserman

As AUGUSTE COMTE pointed out a century ago, a science generally develops through three phases of evolution: mystic, taxonomic and dynamic. Psychiatry, the branch of medicine devoted to the study and treatment of disorders of behavior, admirably illustrates Comte's generalization. Its first phase—the mystic, ritualistic approach—lasted well beyond the Middle Ages: as late as 1783 an insane woman in Switzerland was judged to be an emissary of the devil and burned as a witch. About two centuries ago psychiatry entered the second phase: that of recording and classifying behavior. Man's first observations of the complexities of his own conduct were understandably biased and inaccurate, and his classifications arbitrary and dogmatic; indeed, we are even yet prone to appraise one another with clinical stares and smug appraisals, such as "compared to me, you are an introvert," a "schizoid," a "cyclothyme"—or some other deviate with a resoundingly meaningless appellation.

It would be tempting to assert that in modern times psychiatry has at last left such gaucheries behind and is now a truly scientific discipline devoted to a dynamic understanding of man's behavior and the application of rational methods for readjusting unhappy deviations from the golden norm. Most psychiatrists wish this were completely true, yet we must admit that there are residues of mysticism and irrational dogmatisms in our field. Without adequate diagnosis or justification, patients are still being partially burned or suffocated to cure their evilness—although the *auto-da-fé* is now confined to the brain under the guise of "shock therapy," and the suffocation is euphemistically termed "carbon dioxide inhalation treatment." Even in relatively enlightened spheres of psychiatry there are relics of animistic thinking: *vide* the substitution of the Freudian terms of "Id," "Ego" and "Super-ego" for the gods that in ancient times were thought to be in control of man's passions and intellect; or the attempts by some psychoanalytic mythologists to use the Narcissus and Oedipus legends, not as poetic allegories but as proofs of the supposed nature of man's unconscious conflicts!



**CAT EXPERIMENTS** described by the author were performed in a special glass cage. At the left end of the cage is a food-box with a hinged lid. The cats quickly learned that they could lift the lid and obtain a pellet of food in the box. The apparatus at the far left automatically drops another pellet of food in the box

Is psychiatry, then, really the most backward of our medical specialties? Perhaps so, but in all fairness we must note that in psychosomatics it has recently achieved a reunion with clinical medicine, that modern psychoanalysis is steadily becoming more scientific and less doctrinaire, and that social psychiatry is establishing productive relationships with anthropology, sociology and other humanistic disciplines. Moreover, psychiatry has begun to re-explore its data, hypotheses and methods by experimental research.

The laboratory and clinical studies of Ivan Pavlov, Horsley Gantt, H. A. Liddell, J. Hunt, David Levy, O. H. Mowrer, Curt Richter and many others have indicated that certain basic tenets on which much of modern dynamic psychiatry implicitly rests are demonstrable in nearly all behavior—animal as well as human, "normal" as well as "abnormal." This article will describe how these tenets, incorporated into a more comprehensive system of biodynamics, have been developed and elaborated in various experiments conducted during the last 15 years in the Division of Psychiatry of the University of Chicago and, more recently, in the Department of Nervous and Mental Diseases of Northwestern University.

THE principles of biodynamics may be condensed into four relatively simple statements:

1. *All behavior is actuated by the current physical needs of the organism in the processes of survival, growth and procreation.* Thus a simple want for calcium or for warmth or even for relief from bladder tension, if sufficiently urgent, will take precedence over more complex physiological "instincts" which are considered basic in some systems of psychology.

2. *Behavior is adaptive to the "external" environment not in any objective sense, but according to the organism's special interpretation of its milieu, which depends upon its own capacities ("intelligence") and its unique association of experiences.* Thus two crossed pieces of burning wood may signify only a marshmallow-toast to one human being, self-congratulatory "white supremacy" to another, and abject terror of death to a third.

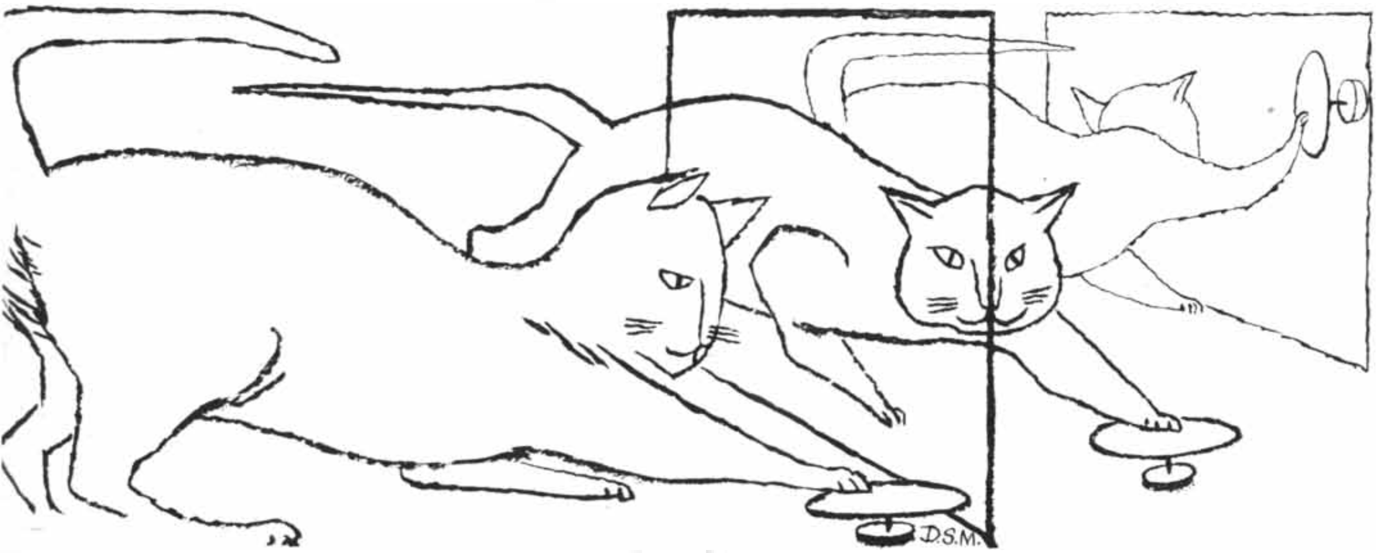
3. *When accustomed methods of achieving a goal are frustrated, behavior turns to substitute techniques or becomes oriented toward alternate goals.* Thus if a man's methods of wooing a girl meet with rebuff, he tries (a) other methods, (b) another girl or (c) another goal, such as success as a religious prophet, as a jazz drummer or perhaps as a psychologist.

4. *When two or more accustomed modes of response become mutually incompatible, physiologic tension, or "psychosomatic anxiety," becomes manifest and behavior becomes vacillating, inefficient and unadaptive ("neurotic") or excessively substitutive, erratic and regressive ("psychotic").*

To study these general principles of biodynamics experimentally, one might utilize any animal with sufficiently high capacities for perception, integration and reaction—the rat, the dog, the cat or the monkey. In most of the experiments to be described we employed the cat, because it has fairly simple motivations and relatively high intelligence. To actuate the animal's behavior we might have chosen any one of several stimuli—thirst, cold, pressure or pain, erotic excitement or the like. We found that hunger for food, though a relatively complex need, is the most convenient: it is easily renewable, is satiable in easy stages, and is neither as climactic nor potentially as traumatic as are sexuality, cold, pain or other physiologic tensions.

IN a typical experiment a cat was deprived of food for a day, then placed in a glass-enclosed experimental cage at one end of which was a food-box with a partly open hinged lid. The animal readily learned to obtain pellets of food from this box by prying the lid farther open so it could reach them. The animal was then taught (a) to wait for various combinations of sound and light signals before attempting to feed, (b) to manipulate various electrical switches so as to set off these signals for itself, and (c) to close two or more switches a given number of times in definite sequence or in response to cues. If the training of the animal was too rapid for its age and capacities—and cats seemed to vary in intelligence as much as human beings do—the animal sometimes became recalcitrant, inept and resistive. If, however, the training process was adjusted to the individual cat, its behavior was efficient, well integrated and successful; indeed, pussy presented the appearance of a "happy" animal, as indicated by her eagerness to enter the laboratory, her avidity for the experimenter and the food-switch, and her *legato sostenuto* purring while she worked for her reward.

The animals were then subjected to various frustrations. For example, after a cat had been trained to depress a disc-switch to obtain food, the switch was so rearranged that its manipulation produced little or no reward. The animal would then develop a marked tendency to push down upon other objects in its



**when the lid closes. The cats were then trained to lift the lid only in response to a signal such as the flash of a light. Later they learned to manipulate switches and set off the signals themselves. Finally they learned to obtain food by more complicated patterns of behavior such as pressing switches in various positions (*right*).**

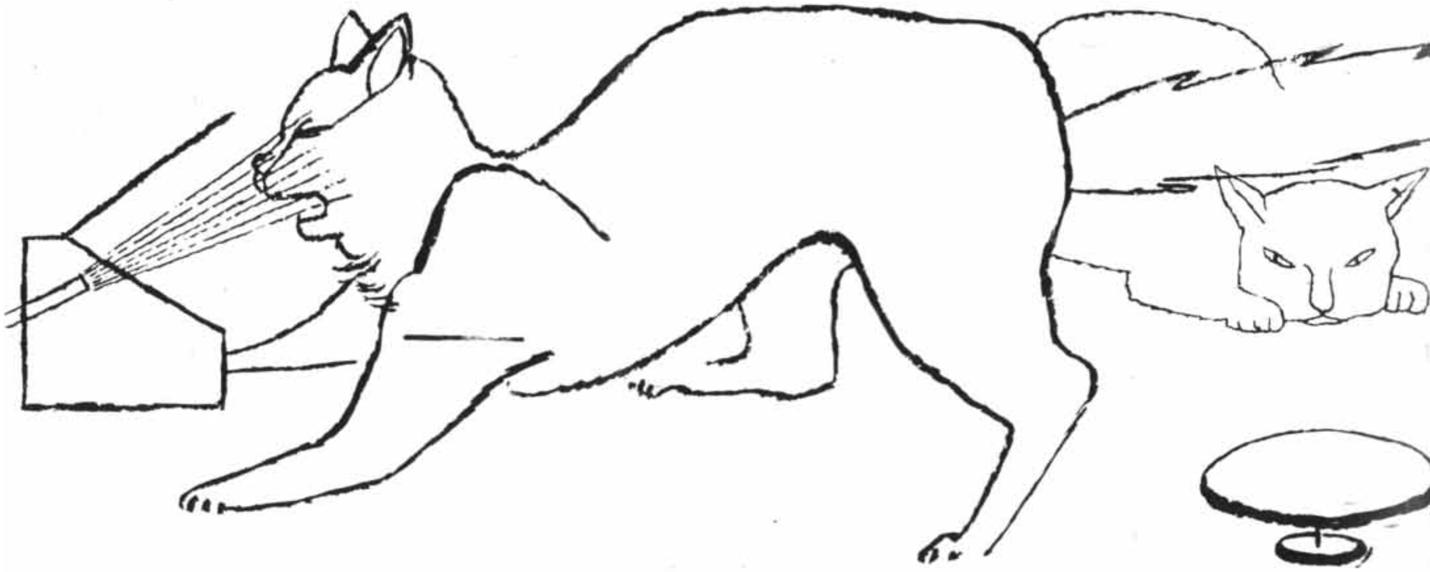
environment, such as saucers, loops, boxes or other cats. This obsessive manipulative activity took many forms: sitting on the switch or on similar small platforms rather than in more comfortable places, prying into the experimenter's clothes instead of into the food-box, and so on.

Under other provocations the animals even exhibited conduct patterns which, when seen in human beings, have been called, misleadingly, "masochistic." Thus a cat was trained to accept a mild electric shock as a signal for feeding, and then taught to press a switch and administer the shock to itself in order to obtain the food. The intensity of the shock was then gradually increased to as much as 5,000 volts of a pulsating 15-milliampere condenser discharge; yet the animal continued to work the switch avidly for the food. Even when the reward was discontinued for long periods, the animal persisted in its accustomed pattern of depressing the switch, apparently solely for the substitutive experience of a "painful" electric shock. The observations suggest, however, that, contrary to Freud's paradoxical postulate of a death instinct, "masochistic" behavior is not basically "self-punitive" but rather a seeking for survival by patterns of response that seem awry only to an observer unacquainted with the unique experiences of the organism. In the light of the reactions revealed by these experiments, and by clinical investigations, we can understand why a woman may enjoy only certain "painful" forms of sexual intercourse when we learn that she reached her first orgasm while being beaten or raped; she may thereafter value all aspects of this erotic experience, including those considered by others as "painful." Similarly, we can cease to wonder why a man marries a succession of shrewish wives if we determine under deeper analysis that what appears to others to be nagging and persecution simply represents to him the security he had once experienced with his overattentive but devoted mother.

MORE complex frustrations, arising from social interactions, can also be demonstrated in animal groups with revealing clarity. In one type of experiment two trained cats, after a given feeding signal, are faced with a single food reward. At first they may skirmish a bit at the food-box. Soon, however, all external evidences of competition abate and only one of the animals—usually the more alert and intelligent—responds to the signal while its partner, though hungry, waits patiently until the "dominant" animal is either satiated or removed from the cage. Stable hierarchies of "privilege" can be produced in groups of four or more animals. The same animals may, however, range themselves in different orders of hierarchy for different activities. In short, there evolves a stratified "society" with fixed rankings in various activities.

One particularly enlightening variant of these experiments seemed to reproduce in cats "worker-parasite relationships" that are usually seen only in more elaborate forms of social organization. Two cats, each of which had been trained to manipulate a switch to obtain food, were placed in a single cage. The cage was equipped with a barrier between the switch and the food-box, so that the animal which essayed to work the switch could not reach the food-box until after its less enterprising partner had eaten the pellet. Under these circumstances some pairs of cats evolved a form of cooperative effort; they alternately worked the switch to feed each other. This cooperation, however, lasted no longer among cats than it does among men. One animal sooner or later showed tendencies toward "parasitism"; it ate the pellets produced by its partner's efforts but refused to leave the food to manipulate the switch. The worker animal, finding its own "cooperative" behavior completely unrewarding, in turn ceased to produce food. Both animals, the parasite usually near the food-box and the worker near the switch, lolled about the cage for hours in a travesty of a sit-down strike. But as hunger increased, the relatively undernourished cat that had worked the switch usually would discover that if the switch were depressed six or eight times in rapid succession to release as many food pellets, he could scramble back to the box in time to get the last pellet or two before the parasitic partner gulped them all. In these experiments the end result was that the "worker" animal labored hard for a meager living while supporting its parasitic partner in leisure—a form of relationship apparently accepted by both animals. In two cases out of some 14 studied, however, the workers solved the situation with a flash of technological genius not anticipated by the experimenter: they learned to wedge the switch into a recess in the cage, so that, with the electrical circuit closed and the mechanical feeder operating continuously, both animals could feed without further effort by either.

Now it is a noteworthy fact that even in circumstances of direct rivalry these animals seldom became hostile or combative toward one another. Indeed, overtly aggressive behavior occurred so infrequently that special experiments had to be devised to determine the spe-



**CAT NEUROSES were experimentally produced by first training the animals to obtain food by manipulating a switch that flashed a light, rang a bell and deposited a pellet of food in the food-box. After a cat had become thoroughly accustomed to this procedure, a harmless jet of air was flicked across its nose as it lifted the lid of**

cific circumstances under which such behavior could be elicited. These studies demonstrated that animals are likely to become overtly belligerent only under two sets of conditions: (1) when they are displaced from a position of social dominance to which they have become thoroughly accustomed, or (2) when their goal-seeking activities are internally inhibited by neurotic conflicts.

The first situation is illustrated by this series of experiments: Let four cats, designated as Group A, compete for food under controlled conditions until Cat A1 emerges dominant, with A2, A3 and A4 in order below him. Let another group, B, range themselves correspondingly as B1, B2, B3 and B4. If A1 is now paired with B4, the latter, accustomed to permit all other animals to feed before it, will offer no competition. But if A1 and B1 are paired after each has been accustomed for weeks or months to dominance in its respective group, a new contest of speed and skill occurs. As before, each animal at first strives for the food directly and diverts none of its energies into physical attacks on the other. Once again, of course, one animal emerges dominant—say B1. A1 now gives up its efforts to obtain the food reward as long as B1 is in the cage. But between signals A1 may sit on the food-box menacing B1 with tooth and claw, or it may even attack B1 viciously, although it makes no effort to follow up such attacks with sallies at the food. Other pairings (A2-B3, B2-A3, etc.) evoke less definitive reactions ranging between the above-described extremes of peace and hostility.

The second type of situation that leads to aggression—the production of a neurotic conflict in an animal—can also be demonstrated experimentally. If, for example, the dominant animal in a group is made fearful of feeding on signal he will abandon this learned response and permit a subdominant animal to feed instead—yet attack the latter between feedings.

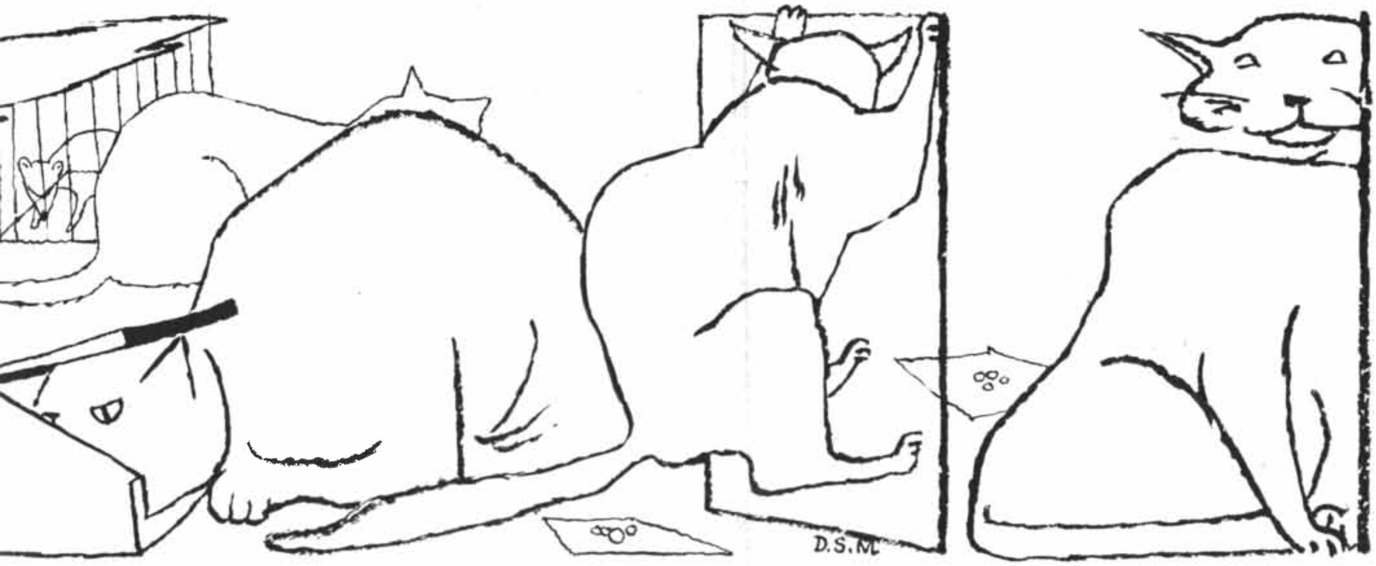
We shall consider briefly how these experimental neuroses are produced in animals and the methods by which the behavior of such animals may be restored to "normal." This portion of our work is perhaps the most relevant to clinical psychiatry, in its older, limited sense as the study of the "abnormalities" of behavior.

THE concept of "conflict" has been central to many theories about the causes of neurotic aberrations. In biodynamics this concept is somewhat clarified by postulating that patterns of behavior come into conflict either because they arise from incompatible needs, or because they cannot coexist in space and time. This general statement can be exemplified by a relatively simple method of producing an experimental neurosis in animals:

A cat was trained to manipulate an electric device which first flashed a light, then rang a bell and finally deposited a pellet of breaded salmon in a food-box. The animal was permitted over a period of months to become thoroughly accustomed to this routine of working for the food. One day, however, just as the animal was about to consume its reward for honest labor it was subjected to a physically harmless but "psychically traumatic" stimulus, *e.g.*, a mild air-blast across its snout or a pulsating condenser shock through its paws. The animal dropped the food, beat a startled retreat from the food-box and began to show hesitation and indecision about again manipulating the switch or approaching the food-box. When it did try again, it was permitted to feed several times but then subjected once more to the disruptive blast or shock. After from two to seven repetitions in as many days of such conflict-inducing experiences, the animal began to develop aberrant patterns of conduct so markedly like those in human neuroses that the two may be described in the same terms.

Neurotic animals exhibited a rapid heart, full pulse, catchy breathing, raised blood pressure, sweating, trembling, erection of hair and other evidences of pervasive physiologic tension. They showed extreme startle reactions to minor stimuli and became "irrationally" fearful not only of physically harmless light or sounds but also of closed spaces, air currents, vibrations, caged mice and food itself. The animals developed gastro-intestinal disorders, recurrent asthma, persistent salivation or diuresis, sexual impotence, epileptiform seizures or muscular rigidities resembling those in human hysteria or catatonia. Peculiar "compulsions" emerged, such as restless, elliptical pacing or repetitive gestures and mannerisms. One neurotic dog could never approach his food until he had circled it three times to the left and bowed his head before it. Neurotic animals lost their group dominance and became reactively aggressive under frustration. In other relationships they regressed to excessive dependence or various forms of kittenish helplessness. In short, the animals displayed the same stereotypes of anxiety, phobias, hypersensitivity, regression and psychosomatic dysfunctions observed in human patients.

In nearly every case these neurotic patterns rapidly permeated the entire life of the animals and persisted indefinitely unless "treated" by special proce-




**the food-box (*left*). The cats then showed neurotic indecision about approaching the switch (*left center*). Some of them were uninterested in mice (*right center*), others assumed neurotic attitudes. One put its head in the food-box, another tried to climb out of the cage, a third tried to shrink into the cage walls.**

dures. By experiments too numerous and varied to be recounted here in detail, a number of such therapeutic techniques were worked out. Some of them are strikingly similar to those used in the treatment of human neuroses.

A NEUROTIC animal given a prolonged rest of three to 12 months in a favorable home environment nearly always showed a diminution in anxiety, tension, and in phobic-compulsive and regressive behavior. The neurotic patterns were prone to reappear, however, when the animal was returned to the laboratory, even though it was not subjected to a direct repetition of the conflictual experiences. To draw a human analogy, a soldier with severe "combat fatigue" may appear recovered after a rest in a base hospital, but unless his unconscious attitudes are altered his reactions to latent anxiety recur cumulatively when he is returned to the locale of his conflicts.

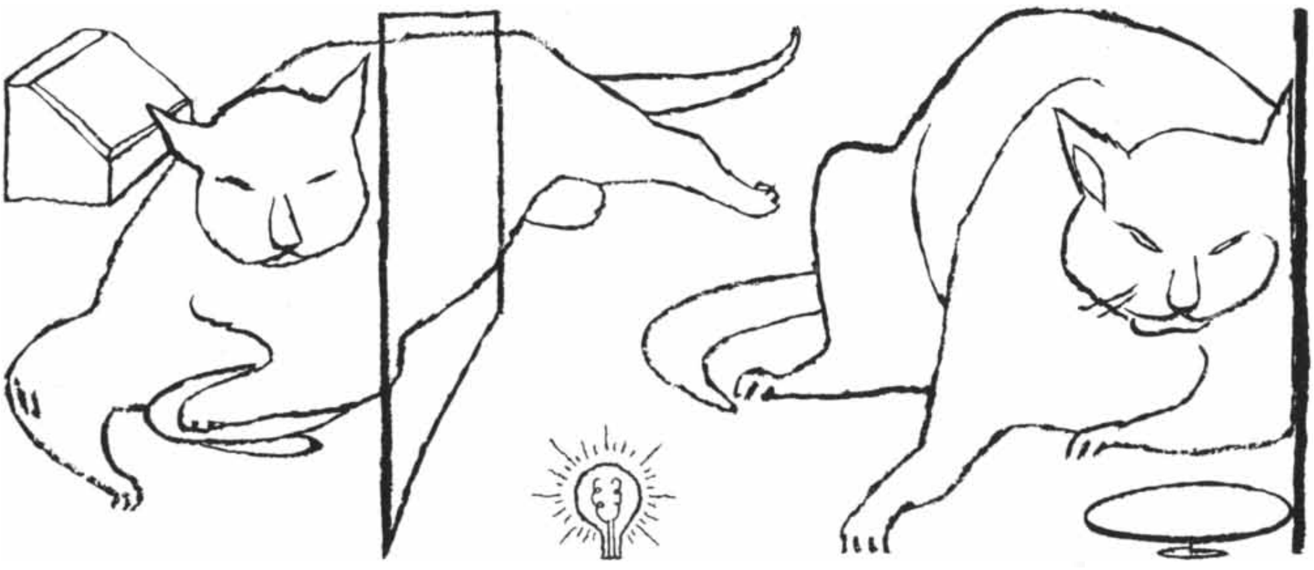
If a neurotically self-starved animal which had refused food for two days was forcibly tube-fed, the mitigation of its hunger reduced its neurotic manifestations. Hippocrates is reported by Soranus (perhaps apocryphally) to have utilized a parallel method in human psychotherapy. Hippocrates, it seems, was called into consultation to treat a strange convulsive malady that was keeping a recent bride virginal. Discerning, after a private interview, that she was torn between strong sexual desires and fears of injury, Hippocrates advised the husband "to light the torch of Hymen" with or without the patient's consent. The results of the therapy are not recorded, but Soranus parenthetically comments that, in general, it is only of temporary advantage "to substitute one Fury for another."

In another experiment a hungry neurotic cat was prevented from escaping from the apparatus and was pushed mechanically closer and closer to the feeder until its head was almost in contact with a profusion of delectable pellets. Under such circumstances some animals, despite their fears, suddenly lunged for the food; thereafter they needed less mechanical "persuasion," and finally their feeding-inhibition disappeared altogether, carrying other neurotic symptoms with it. This method is a variation of the Hippocratic one mentioned above, but entails a greater degree of spontaneity on the part of the patient. In some ways the "therapy" is akin to pushing a boy afraid of water into a shallow pool. Depending on what his capacities are for reintegrating his experiences, he may either find that there was no reason for fear or go into a state of diffuse panic. Because of the latter possibility, ruthless force is generally considered a dangerous method in dealing with neurotic anxieties.

THE example of normal behavior sometimes has favorable results. An inhibited, phobic animal, after being paired for several weeks with one that responds normally in the experimental situation, will show some diminution in its neurotic patterns, although never complete recovery. It is well known, of course, that problem children improve in behavior when they have an opportunity to live with and emulate the more successful behavior of normal youngsters—although more specific individual therapy is nearly always necessary to complete the "cure."

A neurotic animal becomes exceedingly dependent upon the experimenter for protection and care. If this trust is not violated, the latter may retrain the animal by gentle steps: first, to take food from his hand, next to accept food in the apparatus, then to open the box while the experimenter merely hovers protectively, and finally to work the switch and feed without special encouragement from the "therapist." During its rehabilitation the animal masters not only its immediate conflicts but also its generalized inhibitions, phobias, compulsions and other neurotic reactions. This process may be likened to the familiar phenomenon of "transference" in clinical psychotherapy. The neurotic patient transfers his dependent relationship to the therapist, who then utilizes this dependence to guide and support the patient as the latter re-examines his conflictful desires and fears, recognizes his previous misinterpretations of reality and essays new ways of living until he is sufficiently successful and confident to proceed on his own.

WE have also tested on these animals the effects of drugs, electroshock and other physical methods used in the treatment of behavior disorders. Sedative and narcotic drugs were first tried on normal animals. In one series of experiments an animal was taught (1) to open a food-box, (2) to respond to food-signals, (3) to operate the signal-switch, (4) to work two switches in a given order, and finally (5) to traverse a difficult maze to reach one of the switches. If the animal was then drugged with a small dose of barbital, morphine or alcohol, it became incapable of solving the maze but could still work the food-switches properly. With larger doses, it could "remember" how to work only one switch; with still larger doses, earlier stages of learning also were disinte-



**ALCOHOLIC CATS appear to forget their most complex learned patterns of behavior. The two animals at the left are normal cats that have been trained to obtain food by pressing a switch that flashes a light. They have then been fed alcohol. The two cats now show a drunken lack of interest in the switch and flash-**

grated, until finally the animal lost even the simple skill required to open the food-box. In other words, in moderate doses a drug disorganizes complex behavior patterns first while leaving the relatively simple ones intact.

Now if an animal is made neurotic and then is given barbital or morphine, its anxiety reactions and inhibitions are significantly relieved. Instead of crouching tense and immobile in a far corner or showing fear of the feeding signals, it opens the food-box and feeds (albeit in a somewhat groggy manner), as though for the time being its doubts and conflicts are forgotten. Obviously the recently formed, intricate neurotic reactions are relatively more vulnerable to disintegration by the sedative drugs than the animal's preneurotic patterns.

In one variant of these studies, animals which were drugged with alcohol and experienced relief from neurotic tensions while partly intoxicated were later given an opportunity to choose between alcoholic and nonalcoholic drinks. Significantly, about half the neurotic animals in these experiments began to develop a quite unfeline preference for alcohol; moreover in most cases the preference was sufficiently insistent and prolonged to warrant the term "addiction." This induced dipsomania generally lasted until the animal's underlying neurosis was relieved by nonalcoholic methods of therapy. In still another series of experiments we observed that the administration of hypnotic drugs, including alcohol, so dulled the perceptive and memory capacities of animals that while thus inebriated they were relatively immune to emotionally traumatic experiences. It hardly needs pointing out, in this connection, that many a human being has been known to take a "bracer" before bearding the boss, flying a combat mission or getting married, and that temporary escapes of this nature from persistent anxieties often lead to chronic alcoholism.

We also investigated the effects of cerebral electroshock on neurotic animals. The shock produced by the 60-cycle current usually employed in this treatment acted upon animals like an intoxicant drug, disintegrating complex and recently acquired patterns of behavior in both "normal" and "neurotic" animals. Unlike most drugs, however, electroshock produced permanent impairment of behavioral efficiency and learning capacity. Weaker or modified currents such as are now being tested clinically (*i.e.,* the direct square-wave Leduc type) produced lesser degrees of deterioration in our animals, but also had less effect on their neurotic behavior. All in all, these experiments supported the growing conviction among psychiatrists that electroshock and other drastic procedures, though possibly useful in certain relatively recent and acute psychoses, produce cerebral damage which charges the indiscriminate use of such "therapies" with potential tragedy.

ALL this is only a condensed summary of a long series of experiments designed to analyze the biodynamics of behavior and to discern principles that may apply to human behavior and to psychotherapy. To be sure, the gap between the responses of cats, dogs or monkeys in cages and the conduct of man in society is undeniably wide; certainly man, of all creatures, has developed the most elaborate repertoire of "normal," "neurotic" and "psychotic" behavior patterns. Yet, as elsewhere in medicine, the best way to unravel an especially complex problem is to take it into the laboratory as well as the clinic, to investigate it by specially designed experiments, to check the results with a rigid self-discipline that eliminates subtle errors and cherished preconceptions, and so to advance bit by bit toward clearer formulations of general principles and more pertinent applications of them. Such experimental and operational approaches, when correlated with clinical practice, may dissolve the verbal barriers among the various schools of medical psychology and foster a needed rapprochement between psychiatry on the one hand and scientific medicine and the humanities on the other.

Beyond this, the work in biodynamics presents some fundamental social implications. Our observations of the causes of aggressive behavior among animals support the clinical and sociological conclusions of Karen Horney, John Dollard and others (including the author) that hostilities among human beings also spring from the frustrations and the anxiety-ridden inhibitions of their persistently barbaric culture—not, as Sigmund Freud believed, from an inborn, suicidal "death instinct." If aggression is truly innate, we should perhaps join Freud and some of his disciples in resigning ourselves, with apocalyptic erudition, to our inevitable self-destruction. But if aggression is simply a blindly destructive reaction to misconceived threats, then it could be dissipated by the abolition of the tragic wants and anxieties that underlie the individual and mass neuroses and psychoses of mankind.

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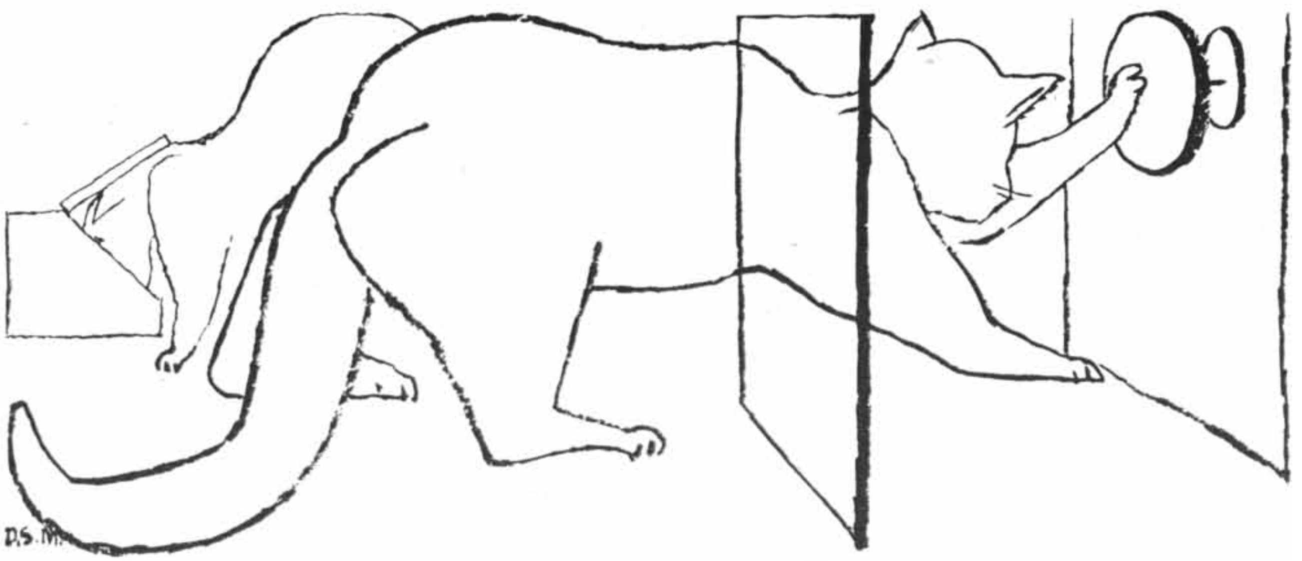
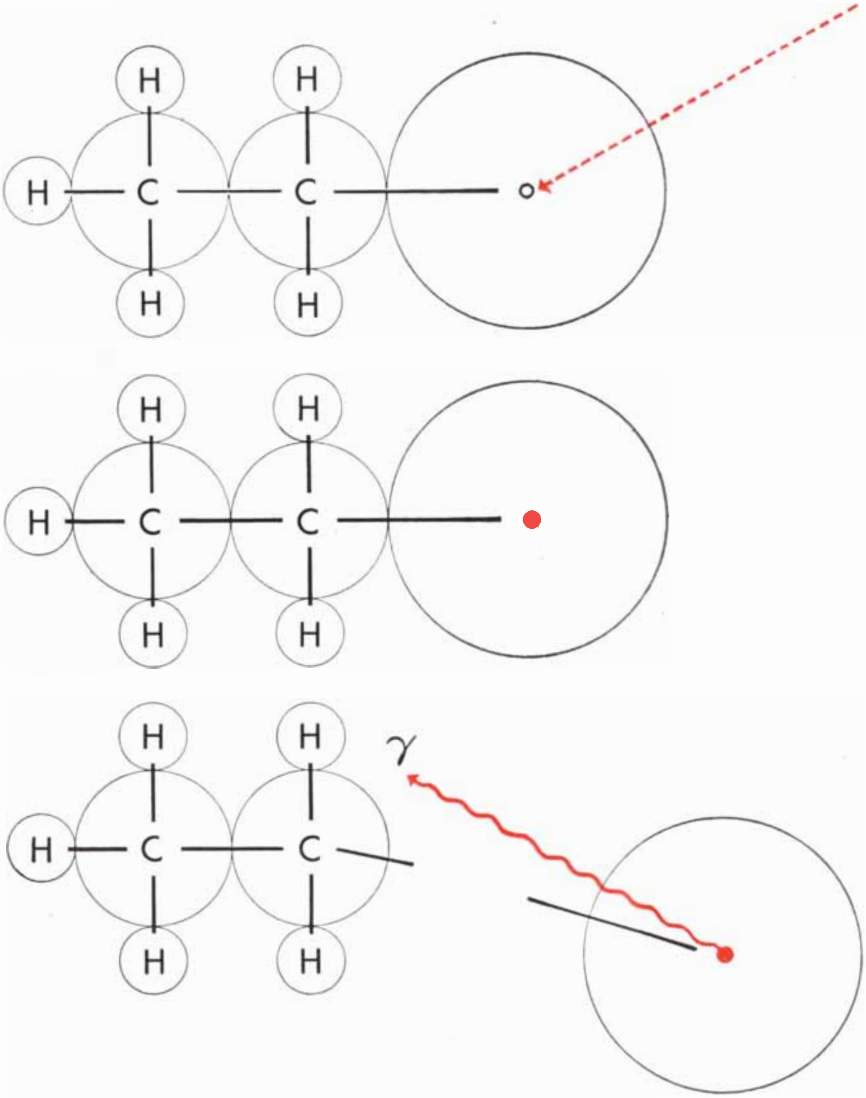



ing light. The two cats at the right are neurotic cats that have been fed alcohol. Their inhibitions disappear and they repeat an earlier learned pattern of obtaining food by pressing a switch. Such activity suggests that the latest learned patterns of behavior are the first destroyed by alcohol and other drugs.

# HOT ATOM CHEMISTRY

## The molecular combination of radioactive and stable atoms results in some bizarre and potentially useful chemical reactions

by Willard F. Libby




**ETHYL-IODIDE MOLECULE** is constructed of five atoms of hydrogen, two of carbon and one of iodine. When a neutron enters the nucleus of the iodine atom (*top drawing*), the nucleus becomes radioactive (*middle*). The nucleus then decays by shooting out a gamma ray, and the iodine atom recoils with such violence that its bond to the molecule is broken (*bottom*).

ONE of the first things a beginning chemistry student learns is that the chemical behavior of an atom depends solely on the electrons circulating around the nucleus, and not at all on the nucleus itself. In fact, the classical definition of isotopes states that all the isotopes of a given element are identical in chemical activity, even though their nuclei are different. Like all generalizations, even this one has a little bit of falsehood in it. The truth is that the chemical behavior of an atom may be strongly influenced by events in its nucleus, if the nucleus is radioactive. The bizarre chemical effects sometimes produced by radioactive atoms have given rise to a fascinating new branch of investigation known as hot atom chemistry.

Unusual chemical reactions among hot atoms were noticed soon after the discovery of radioactivity. The serious study of hot atom chemistry began as early as 1934, when Leo Szilard and T. A. Chalmers in England devised a method, known as the Szilard-Chalmers process, for utilizing such reactions to obtain concentrated samples of certain radioactive compounds for research purposes. But not until the end of the recent war, when chemists began to work with large amounts of radioactive materials, did the subject begin to attract wide interest. Since the war, reports of investigations in this intriguing field have come from laboratories in all the leading scientific countries of the world.

So few are the reactions that have been thoroughly studied, and so unusual are the phenomena observed, that perhaps the best approach to the subject is to consider a typical reaction in detail. This article will be confined largely to a description of the results of one type of nuclear transformation that well illustrates the strange kind of phenomenon with which we are dealing.

The particular set of reactions we shall consider is the behavior of radioactive iodine in the compound ethyl iodide—$CH_3CH_2I$. We begin with an ordinary liquid sample of the compound and transform some of the iodine atoms in it into a radioactive variety by irradiating them with neutrons from a chain-reacting pile or a cyclotron. Neutrons have no chemical properties, since they consist of pure nuclear matter with no associated external electrons. Because they have no external electrons, and are themselves electrically neutral, their penetrating power is amazing. They readily proceed through several inches of solid material until they chance to interact with some of the tiny atomic nuclei in their path. (The average nucleus has an area only about a hundred millionth that of the atom of which it is the center.) This interaction is not likely to occur when the neutrons are moving at the very high speeds that they possess when they are first created in the pile or the cyclotron. But when, having bounced around among the atoms surrounding them, they are slowed down to the so-called thermal velocity (roughly the speed of a rifle bullet) at which all atoms and molecules move about at room temperature, the neutrons are readily captured by normal atoms.

Suppose, then, we expose a bottle of liquid ethyl iodide to a source of neutrons. The neutrons penetrate the glass, and a certain proportion of them are captured by the iodine atoms. When the nucleus of a normal iodine atom, I-127, takes in a neutron, it is transformed into the radioactive isotope I-128. This new species is extremely unstable: in much less than a millionth of a millionth of a second it emits a gamma ray of huge energy—several million electron volts. To appreciate the magnitude of this release of energy, remember that the heat of chemical combustion of a carbon atom corresponds to only four electron volts. After giving off this tremendous energy, the I-128 atom is reduced to a lower state of excitation. It is still unstable; the atom continues to decay, and gradually, with a half-life of 25 minutes, the I-128 atoms degenerate into xenon 128 by emitting beta particles. But we shall disregard the latter reaction, except to note that it is by means of radiation emitted in this step that the I-128 atoms are detected and measured. The reaction that interests us is the capture of a neutron by iodine and its immediate release of the high-energy gamma ray.

The emission of this energy gives the I-128 atom in the ethyl-iodide molecule a large recoil energy, just as the firing of a bullet from a gun makes the gun recoil. The atom's recoil energy is calculated to be some 200 million electron volts. Now the chemical energy with which the iodine atom is bound in the ethyl-iodide molecule is only about three or four electron volts. The energy of recoil is so much greater than the strength of the chemical bond that every I-128 atom is ejected from its molecule with considerable force. Hot atom chemistry is concerned with the unusual chemical reactions that these high-velocity iodine atoms undergo after they are expelled from the molecule. Since the I-128 atoms are radioactive, it is relatively easy to trace them through their subsequent activities.

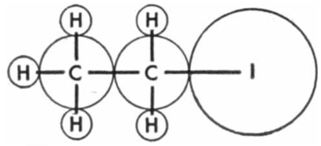
To see what may happen to the ejected iodine atoms, one mixes the irradiated ethyl iodide with a water solution of sulfite ions. Ethyl iodide is insoluble in water. But any free iodine that has been ejected from the ethyl-iodide molecules can react with the sulfite and thereby become soluble in water as iodide ions. When the two liquids are put in a bottle, they separate into two layers. They are shaken together to give the free iodine atoms in the ethyl-iodide layer an opportunity to come in contact with the sulfite, and the two liquids are then allowed to separate again. Now the radioactive iodine atoms should be found in the water layer. When the experiment is actually performed, it turns out that about 60 per cent of the radio-iodine atoms have indeed been extracted into the water layer. But the other 40 per cent are still found in the ethyl-iodide layer, bound to ethyl-iodide molecules.

What happened to that 40 per cent? Is it possible that in spite of their large recoil energies they were never ejected from the ethyl-iodide molecules at all? This question can be settled by a variation of the experiment, the rationale for which we shall consider presently. If, instead of starting with ethyl iodide in the liquid form, we vaporize it and irradiate it with neutrons in that state, and then condense the vapor and mix the ethyl iodide with the sulfite solution as before, we find that this time nearly all of the radioactive iodine appears in the water layer. This is nearly complete proof that all hot atoms must be ejected from ethyl iodide in the first instance.

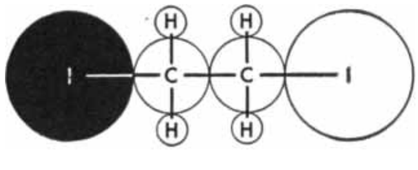
How, then, did 40 per cent of the radioactive atoms get back into the ethyl iodide in the first version of this experiment? It is known that normal iodine atoms, moving at thermal speed, do not react with ethyl iodide. The answer must be that in liquid ethyl iodide the hot iodine atoms, with their high recoil energies, can somehow force their way into the ethyl-iodide molecules and bring about reactions that would not normally occur.

What kinds of molecules could the hot atoms create by such forced reactions? There are three possibilities: 1) the energetic iodine atom could knock out one of the hydrogen atoms in the $CH_3CH_2I$ molecule, forming either $CH_2I^*CH_2I$ or $CH_3CHII^*$; 2) it could rupture the carbon-carbon bond, breaking the molecule in two and forming either $CH_3I^*$ or $CH_2II^*$; or 3) it could simply bump out the normal iodine atom and replace it, forming $CH_3CH_2I^*$. (The asterisk in each case designates the radioactive atom.)

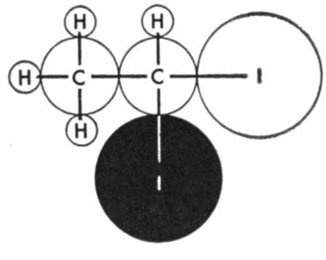
To determine which of these compounds are actually formed, one adds nonradioactive samples of all the possible compounds to the irradiated liquid and extracts them by fractional distillation. Each fraction will bring out with it any of the same compound that may have been formed by the hot atoms in the original liquid, and the amount that was thus formed can be determined precisely by measurement with a Geiger counter. Actual measurements made by this method show that most of the radioactive iodine is found in the compound $CH_3CH_2I^*$; in other words, the usual reaction is a simple replacement of the



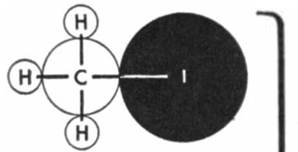
$CH_3CH_2I$



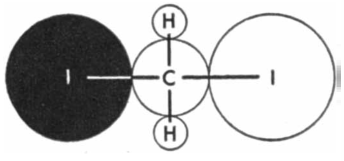
$CH_2I^*CH_2I$



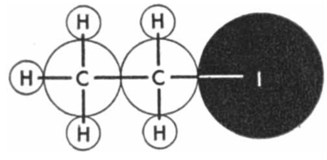
$CH_3CHII^*$



$CH_3I^*$

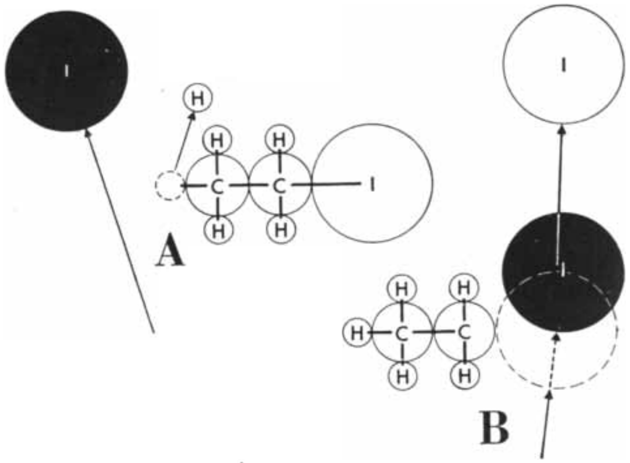


$CH_2II^*$

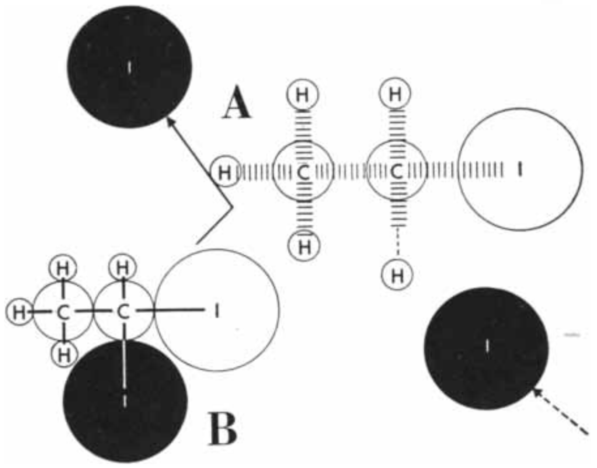


$CH_3CH_2I^*$

**FIVE COMBINATIONS might occur when the recoiling radioactive iodine atom interacts with the molecule of ethyl iodide (*top*). The radioactive atom is represented in black.**




**IODINE ATOM** striking a molecular hydrogen atom proceeds on its way almost unchecked (A). Iodine atom striking another iodine atom is abruptly slowed (B).




Iodine atom striking a whole molecular group may set the molecule to vibrating so that it ejects a hydrogen atom (A *at right*). This is replaced by iodine (B).

normal iodine atom in ethyl iodide by a hot iodine atom. Of the 40 per cent of hot atoms that re-enter ethyl iodide, seven out of eight replace the iodine atom. The eighth, in most cases, knocks out a hydrogen atom and forms $C_2H_4II^*$.

Why is the hot atom more likely to take the place of an iodine atom than of a hydrogen atom? This is easy to explain by ordinary collision theory. The atom in the ethyl-iodide molecule that is closest in mass to the attacking hot iodine atom is of course the molecule's normal iodine atom. When a moving object strikes another of nearly equal mass in an elastic collision, the striking object is virtually stopped in its tracks and the one that is struck is accelerated; in other words, the first object transfers its velocity to the second. This is what would happen if a fast-moving freight train ran into a slow-moving one of the same size. In the atomic case, the high-velocity iodine atom, if it collides head-on with the normal iodine atom in a molecule, knocks out the latter and is itself slowed at once to the thermal speed of the remaining fragment of the molecule. When ethyl iodide is in the liquid state, the closely packed molecules trap the radioactive atom at the collision site, and it is held there long enough to react with the ethyl-iodide fragment to form $C_2H_5I^*$. But when the compound is in the vapor state, there is no surrounding wall of closely packed molecules to hold the radio-iodine atom and the ethyl fragment together. Consequently they escape from each other without reacting.

NOW the case of a collision between a radio-iodine atom and a hydrogen atom is very different. This time the iodine atom, being much heavier than hydrogen, is not perceptibly slowed by the collision; instead of a freight train hitting another freight train, it is more like a freight train hitting a hand car. The iodine atom follows right along after the hydrogen atom it has knocked out; it does not pause in the disrupted molecule long enough to react with the fragment.

The question therefore arises: how is it that a radio-iodine atom does occasionally enter the molecule in place of a hydrogen atom rather than of iodine? This, too, is not hard to explain. If a berserk radio-iodine atom does not happen to make a head-on collision with an iodine atom in the molecule, but rather has a series of glancing collisions with iodine and collisions of all sorts with hydrogen atoms or carbon groups, its energy will eventually be reduced to the point where it is comparable to the energy of the chemical bonds holding an ethyl-iodide molecule together. In that case the flying atom may transfer its energy of momentum to the molecule as a whole. The molecule then would become intensely excited. For example, if the atom struck the $CH_3$ group in a molecule, the collision might stretch the chemical bond to nearly the breaking point. In snapping back, the stretched fragment would transfer energy throughout the molecule, so that all seven bonds in the molecule would begin to vibrate with great energy. This vibration might well eject a hydrogen atom from the system, and the trapped radio-iodine atom could take its place.

It is clear from this explanation that hydrogen replacement must be less probable than iodine replacement, since it can occur only when the iodine atom finds itself in a certain restricted energy range—between the energy of a chemical bond and two or three times this value. Obviously any change in conditions that would increase the chances of hot atoms dropping to this energy range before they can collide with iodine atoms in the molecule would increase the yield of compounds in which the hot atoms substitute for hydrogen. One way of accomplishing this is to dilute the ethyl iodide with a substance that contains no iodine atoms, such as a hydrocarbon like pentane. Now collisions between the hot atoms and iodine become much less probable, and collisions with hydrogen and carbon groups much more probable. Since collisions with these lighter groups remove the energy from the hot atoms in small pieces, nearly every hot atom will have a good chance of passing through the velocity range necessary for the reaction in which it can replace hydrogen. The yield of hydrogen-substituted products will be comparatively high. And indeed experiments show that this is the case. When an extremely dilute solution of ethyl iodide in liquid pentane is irradiated, about 30 per cent of the radio-iodine atoms, instead of less than 10 per cent, appear in products in which they have substituted for hydrogen. They generally replace hydrogen not in the ethyl iodide but in the pentane molecule. The latter compound, $C_5H_{12}$, is thereby converted to amyl iodide, $C_5H_{11}I^*$.

TO what uses can hot atom chemistry be put? One of the obvious uses is the preparation of extremely concentrated sources of radioactivity. For example, the irradiation of a large bottle of ethyl iodide results, after the subsequent extraction, in the concentration of some 60 per cent of the radioactive atoms in a quantity of iodine so small as to be hardly visible. This technique should be of assistance in many purposes for which radioactive material is used, notably in biology. When a radioactive isotope is injected into the body, either as a tracer or in a treatment for disease, it is often essential that the amount of material injected be held to a minimum, in order to avoid disturbance of the normal constitution of the blood or the normal metabolism of the body. Hot atom methods make it possible to concentrate large radioactivity in small amounts of such material.

Another possible use of hot atom

chemistry is the synthesis of radioactive molecules that are difficult to prepare by other methods. Probably one of the most hopeful of these possibilities has to do with the radio-carbon isotope carbon 14. C-14 is produced by irradiating ordinary nitrogen, N-14, with thermal neutrons. Immediately after the nitrogen absorbs a neutron, the atom ejects a high-energy proton to become C-14. As a result, the C-14 atom must recoil with a huge energy, estimated to be some 2,500 electron volts. The importance of carbon is that it is an ingredient of very complex organic molecules, such as proteins, which at the present time are extremely difficult or impossible to synthesize. It seems likely that the irradiation of a protein, which contains nitrogen, will result in the direct synthesis of complex molecules in the radioactive form. The immense recoil energy of the hot carbon atoms will effect chemical reactions that would not ordinarily occur. To be sure, these very high-velocity atoms may wreak such havoc upon the chemical bonds of the ordinary carbon and nitrogen atoms in the material that the resulting radioactive molecules will hardly resemble the original protein. In any case, very heavy and very extraordinarily marked molecules should result. Research in this direction is now in progress.

THIS article has considered one type of nuclear transformation that leads to hot atom reactions. There are, of course, other types. In some of them the nuclear transformation actually changes the chemistry of the atom. For example, the irradiation of a certain atom may result in the emission of a beta ray and the transmutation of the atom to an isotope of the element next higher in the periodic table. Of course this change of the element itself has basically important chemical effects. But in addition the emission of the beta particle results in excitation of the electron structure of the atom, and this endows the new atom or molecule with a very considerable capacity for bizarre reactions. The excited atom may be able to disrupt the most stable kinds of molecules, if they happen to lie in contact with it, and may enter into reactions with them to form inherently less stable molecules.

As already pointed out, the field of hot atom chemistry is still so sketchily explored that any review of it at this point can only illustrate the subject, and not define the scope of the field. As radioactive materials come into greater use, knowledge of hot atom reactions will doubtless become increasingly important.

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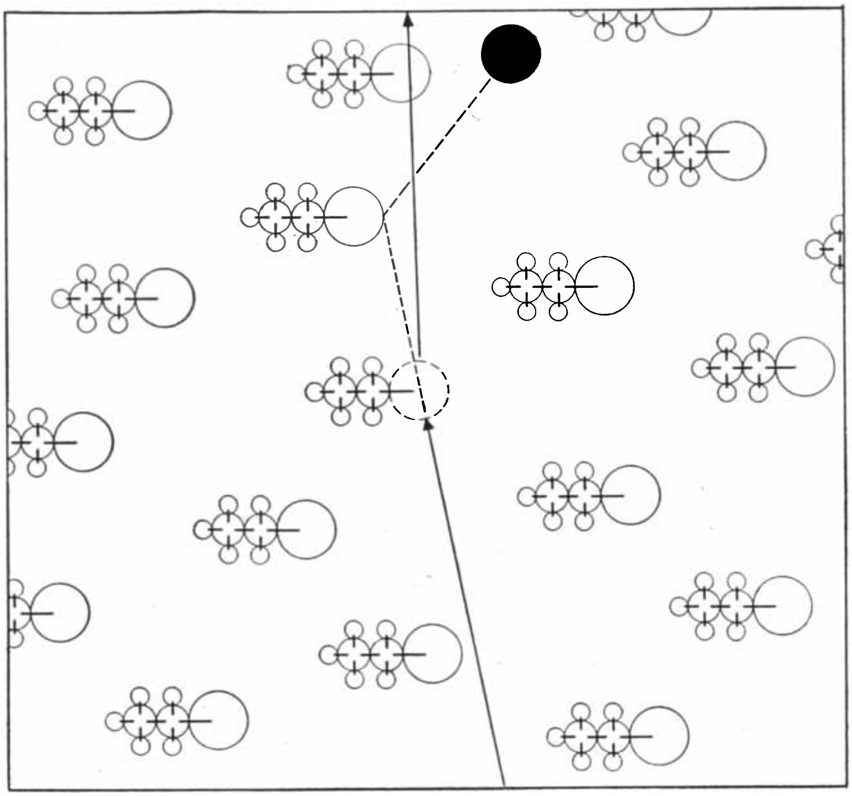
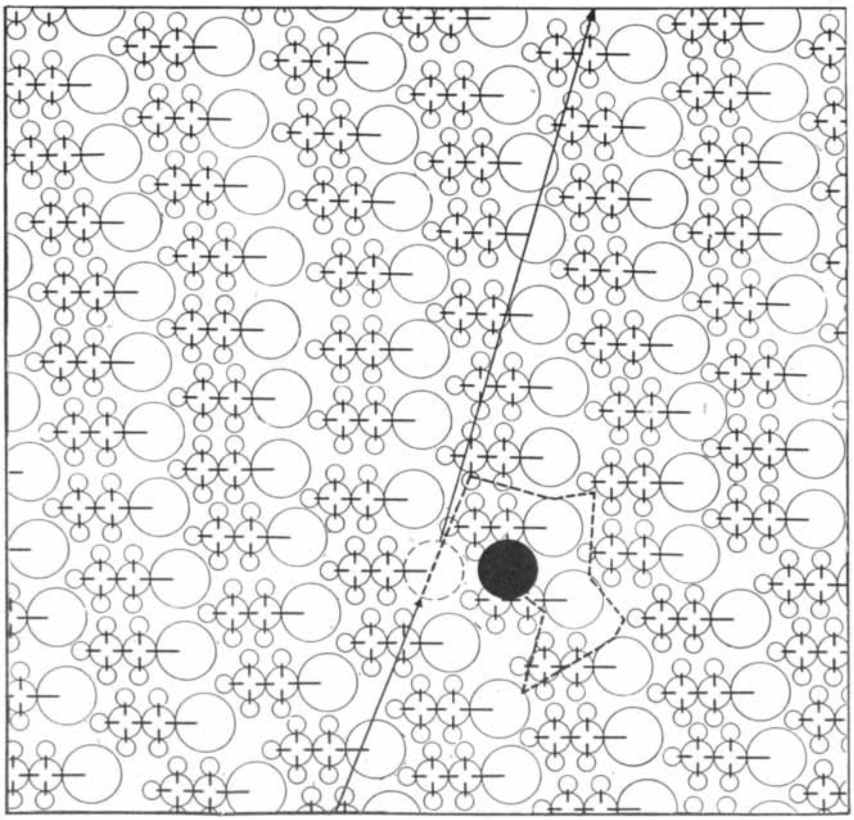
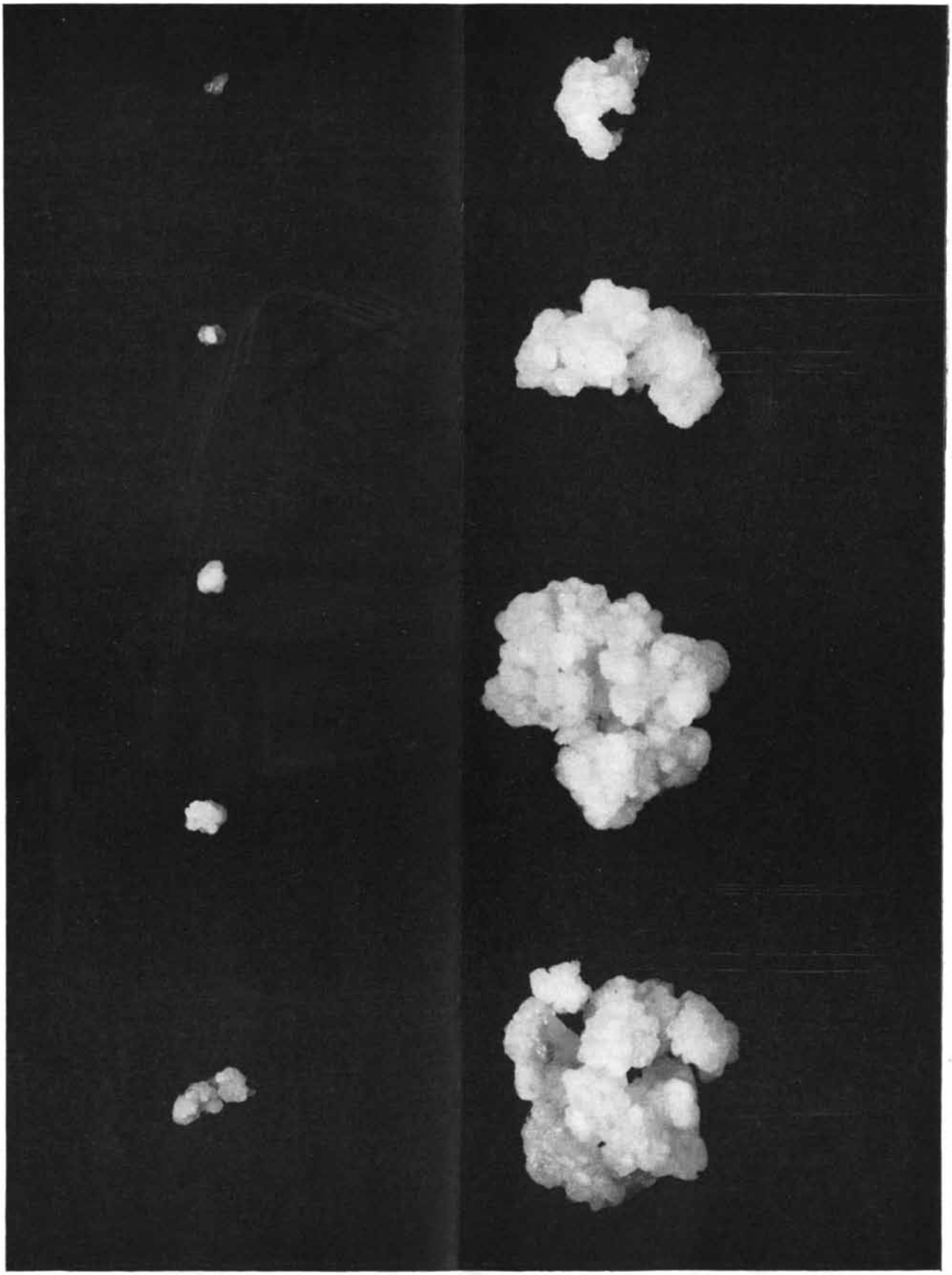


**ETHYL-IODIDE GAS** is composed of molecules that are far apart. When a fast iodine atom collides with one in molecule, the latter departs with the speed of the former. The original fast atom is slowed, but it still wanders away.



**ETHYL-IODIDE LIQUID** is composed of molecules closer together. The struck iodine atom again departs at high speed. The slowed iodine atom is now confined to the vicinity by repeated collisions with packed molecules.



**CULTURES OF TISSUE** from a tumor of the periwinkle are formless masses of cells. The cultures at the upper left are newly isolated. The others range in age up to 20 weeks. The original tumor was produced by bacterial infection. The infection was subsequently "cured" by a heat treatment that destroyed the bacteria but not the tumors.

# Plant Tissue Cultures

*The individuality of cells is obscured by their social organization. The cells of certain plants are therefore isolated and grown in a controlled asocial environment*

by Philip R. White

EVERY cell of the body has a dual character. First there is a fundamental character which arises from the innate qualities of the cell itself; this cannot be altered without destroying the cell. Then there is a more ephemeral character which arises from the fact that the cell is embedded in a complex environment which includes millions of other body cells; this can be changed without necessarily destroying the cell. The first qualities are personal, so to speak, the second social.

So long as a cell remains in its normal place in the body it is difficult or impossible to distinguish between its personal and social qualities. If, however, a cell or group of cells is removed from its usual surroundings and placed in an environment which, though asocial, is sufficient for survival, the social aspects of its character fall away, and we can discover not only what is the real individuality of the cell, but also just how the social factors have affected it. Cells or tissues so isolated are called tissue cultures.

If a piece of willow twig a foot long is stuck into moist sand, it will sprout roots at one end and leaves at the other, finally growing into a new tree. If we divide the one-foot piece into six two-inch pieces, each piece will sprout roots and leaves in the same manner. Some of the tissues that were near the "base" of the longer piece, and would have produced roots there, will in the basal two-inch bit now find themselves at the top of the smaller piece, and will produce leaves instead. In other words, the development these cells have undergone is an expression of their social relationships to the functional whole.

If, however, we take only a very small bit of tissue, either from the interior of the tip of a young stem or from the rapidly growing layer between the wood and bark (the layer that splits when one makes a willow whistle), the requirements for survival and the results will be quite different. On sand alone such a bit would soon die. To nurse the tissue we place it on a nutrient medium that contains all the salts, carbohydrates, vitamins and other substances needed for growth. On such a nutrient the cells will multiply without forming roots, leaves or bark. They develop into an unformed mass which can be kept growing for months or years. This, then, is a tissue culture. By reducing the number and variety of cells that can affect any given cell in the mass, we have removed most of its social environment and permitted the cells to express only their innate characteristics. This mass can be divided into a large number of cultures, all with identical heredity and identical environmental background. We call a group of cultures so derived a clone of tissues. Their personal characters are all exactly alike, and they can be manipulated to determine precisely those variants of nutrient, temperature, acidity and the like that are needed to elicit roots or leaves or woody deposits or what one will.

This sounds very simple, but in practice the problem of establishing the necessary techniques, particularly of defining the nutritional requirements, proved far from simple. Nutrition as a science is relatively new. Forty years of experiments elapsed between the first carefully planned attack on the problem, begun in 1898 by Gottlieb Haberlandt of Germany, and its solution. In 1939 three independent workers—Roger J. Gautheret at the Sorbonne in Paris, Pierre Nobécourt at the University of Grenoble, France, and the author at the Rockefeller Institute for Medical Research in Princeton, N. J.—almost simultaneously published accounts of the first really successful cultures. These three publications laid a firm foundation for the study of plant tissue culture. In the past decade, the results of these studies have blossomed into an important experimental discipline.

What nutrients does a piece of plant tissue need for growth? Let us make the experiment with a thin slice cut through the young stem of a tomato plant. When placed on moist sand or on gelatin saturated with water, this tissue, assuming that it is kept free of molds, will undergo a characteristic series of changes. If it is large enough, it may form roots and stem growing points as did our willow. More likely it will merely swell. The surface cells will take up water and expand into large sacs or vesicles. Some cells below the surface will divide parallel to the direction of the cut, and the new-formed cells will be transformed into cork. The interior cells will become woody and the mass will soon cease to grow. Here it is evident that our substituted environment, which of course is not a nutrient, is far from adequate for anything like normal function.

We know that isolated roots can be made to grow for years on a relatively simple nutrient containing only certain salts, cane sugar, thiamin and one or more other special substances, which differ with the particular root studied. In the case of tomato roots the special supplement required is either glycine, the simplest of all the amino acids, or the two vitamins pyridoxine and niacin. It would be logical to suppose that stem tissues, as well as roots, would grow on one of these nutrients. Unfortunately this has not proved to be the case. Stem tissues require something more. Gautheret and Nobécourt have shown that this something more is the "plant hormone," or auxin, named indole-acetic acid. Indole-acetic acid is extremely poisonous in above-normal amounts; indeed, its near-relative, 2, 4-D, is a deadly weed-killer. But in very low concentrations it possesses important growth-stimulating properties. When added to the nutrient of an isolated bit of tissue in a concentration of about one part in 100 million, it suppresses the formation of cork and wood, promotes cell division and causes the fragment to grow, somewhat irregularly to be sure, but nevertheless continuously. Thus indole-acetic acid permits the establishment of "tissue cultures."

For many plants a related substance, naphthalene-acetic acid, is somewhat more satisfactory. Some tissues may require additional foods, such as biotin, pantothenic acid, inositol or other vitamins. But for the majority of tissues studied to date, indole-acetic acid or its equivalent is the only indispensable supplement to the basic nutrient.

With the establishment of these relatively simple requirements, many different plant materials have been grown and studied during the past few years. The first plant investigated was the carrot. Carrot tissues grown in the dark require thiamin, but when exposed to light they synthesize their own thiamin. Carrot cultures at first possess a distinct polarity, but this is lost after four or five passages, *i.e.,* divisions of the multiplying cells and their transfer to fresh nutrient. They also lose their capacity to form roots. Gautheret found that after long cultivation some carrot tissues even lost their requirement for indole-acetic acid; they acquired the capacity to synthesize their own. Such altered behavior is called "habituation." Not all carrot cultures undergo this change, nor do we know the exact conditions necessary to bring it about, but that such a change does sometimes occur seems to be a fact whose elucidation should be of very great importance for our understanding of tissue growth in general.

ANOTHER tissue that has been very instructive is that of the tubers of the Jerusalem artichoke. Tissues of most plants, when first isolated, contain some residual auxin and will make a little growth on a simple nutrient, though the growth soon stops. But tissues taken from mature artichoke tuber tissues have no residual auxin and make no growth at all. They are therefore especially good material in which to study the precise effects of graded series of auxin concentrations. Tissues of kohlrabi, on the other hand, contain so much residual auxin that in test-tube cultures they poison themselves and cannot undergo cell division; the cells merely explode into enormous blisters.

Tissues of grapevines can be used as a medium on which to study the behavior of the downy mildew *Plasmopara viticola,* a parasitic plant that has not previously been amenable to study in the living condition in the laboratory. This approach will undoubtedly prove to be an important use of the tissue-culture technique. The same approach has permitted the study of tobacco mosaic virus and crown-gall infections in tobacco and tomato plants; the latter study has helped to clarify many points in regard to crown gall, as we shall see. Among other tissues that have been grown in cultures are those of hawthorn, rose, snapdragon, blackberry and Virginia creeper. One of the latest to be successfully established is willow. Though willow was one of the first plants studied, only after 15 years of intermittent investigation has Gautheret at last succeeded in deciphering the particular nutritional problem that this species presents.

The tissues of all these plants vary widely in their requirements and growth habits. Some, like the willow, require several vitamins and other substances; others, like the carrot, need only one, indole-acetic acid; still others, like the "habituated" carrot, are capable of growing without any external supply of vitamins or similar substances. Some possess a marked polarity of growth while others are without evident polarity. Some plants produce solid, firm cultures by a superficial proliferation over the entire surface. In others, proliferation is more deep-seated and in discrete areas, resulting in loose, friable, even powdery masses. Tissue cultures of the Virginia creeper are snowy white, those of the carrot yellow, those of *Scorzonera* almost black. The permutations of behavior patterns and of nutritional and other environmental requirements are almost endless, as are the potentialities for use and study of these cultures.

HERE we come to an aspect of the investigation that was not envisioned at all in the beginning but has a particular cogency now. This is its application to the study of cancer. Tumors and cancers are parts of the body that have escaped from the social restraints characteristic of normal growth. In setting up tissue cultures we have deliberately removed those restraints. We have therefore transformed normal tissues into something possessing certain important resemblances to tumor tissues. These resemblances are artificial and we know how they have arisen. We can thus begin to understand some of the processes by which tumors may arise in nature. Moreover we now have a technique by which the tissues of plant tumors that occur in nature can be studied in the laboratory. Plants develop many different sorts of tumors, representing all the major types of cancers found in animals. They grow hereditary tumors, tumors caused by viruses, chemically induced tumors, tumors caused by organisms such as bacteria, and still others whose causes are not known. The tissues of all of these can be grown in culture. One of the facts learned by this means is that at least two groups of plant tumors are sterile, yet are capable of producing new tumors upon transplantation into healthy plants. Thus they possess qualities analogous to those responsible for the malignancy of cancer cells in man.

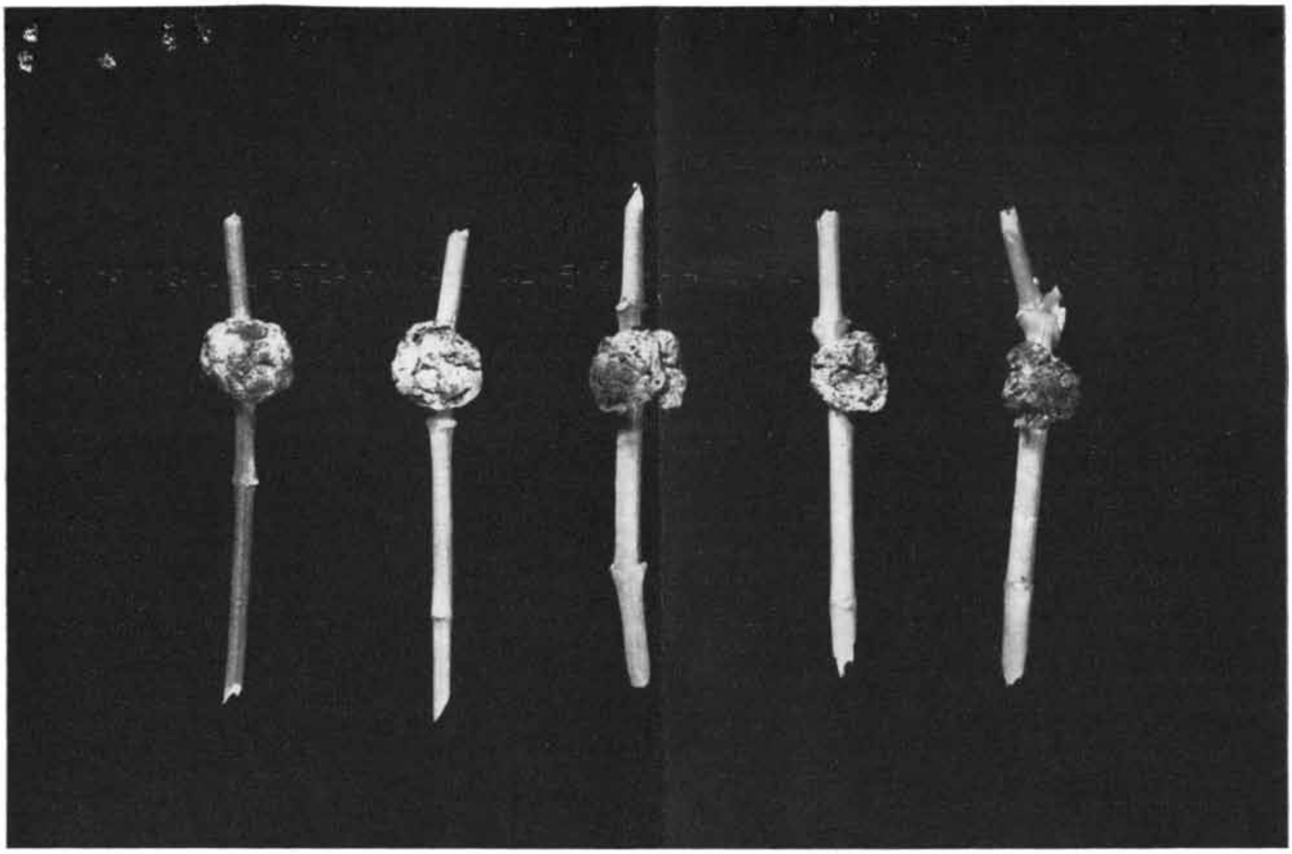
We have been able to learn a great deal about the steps involved in the production of some of these tumors. For example, tumor tissues, unlike normal ones, do not require externally applied auxins. If bits of normal tissue are placed beside bits of tumor tissue, the normal tissue will grow even on a nutrient lacking auxin. This suggests that the tumor tissue excretes auxin in quantities sufficient to permit the growth of the neighboring normal cells. Other experiments confirm this suspicion. Slices of chicory placed on moist sand will ordinarily form buds on the upper surface and roots on the lower, but the production of buds can be suppressed either by applying auxin paste to the upper surface or by grafting bits of tumor tissue into this surface. In other words, the tumor tissues can substitute for the auxin paste. Moreover, tumor tissues do not show the characteristic growth responses to moderate dosages of auxins that normal tissues show. All of these bits of evidence indicate that tumor tissues must produce auxins and that one of the changes a normal plant cell undergoes in becoming a cancer cell is an increase in its ability to manufacture auxins, or at least to make them available. We can study the way in which this change comes about.

One of the unexpected facts uncovered in these studies is the extreme rapidity with which the change from normal cell to tumor cell takes place. Armin C. Braun of the Rockefeller Institute for Medical Research has shown that in crown gall, a plant tumor started by bacteria, the transformation of normal cells into malignant ones is completed in 10 hours, within a critical temperature limited to a range of only three degrees. This is much more precise information than has ever been obtained about the origin of any animal tumor.

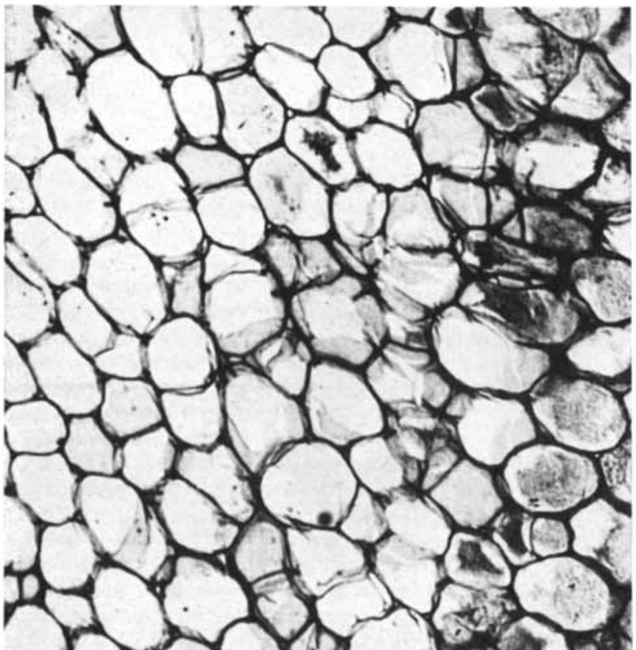
SEVERAL laboratories are investigating intensively the whole range of environmental factors involved in the satisfactory maintenance of cultures of both normal and tumorous plant tissues—nutrient ions, energy sources, specific organic nutrients, nutrilites, vitamins and hormones, temperature, light, acidity, osmotic values and so on. We already know a great deal more about the requirements of plant tissues and what can be accomplished by modifying their environment than we do about the corresponding requirements of animal tissues. In fact, the picture has changed so radically in the past decade that we are now trying to apply to animal tissue cultures some of the methods that have proved so fruitful in studying plants. We hope, for example, that these methods may help to unravel the almost hopeless nutritional tangle in which the classic technique of animal tissue culture, using a nutrient of embryo juice and blood plasma, finds itself.

The chief obstacle in the way of progress in this very promising field today is the lack of sufficient trained personnel to carry on. It is to be fervently hoped that this lack may be corrected in the next few years.

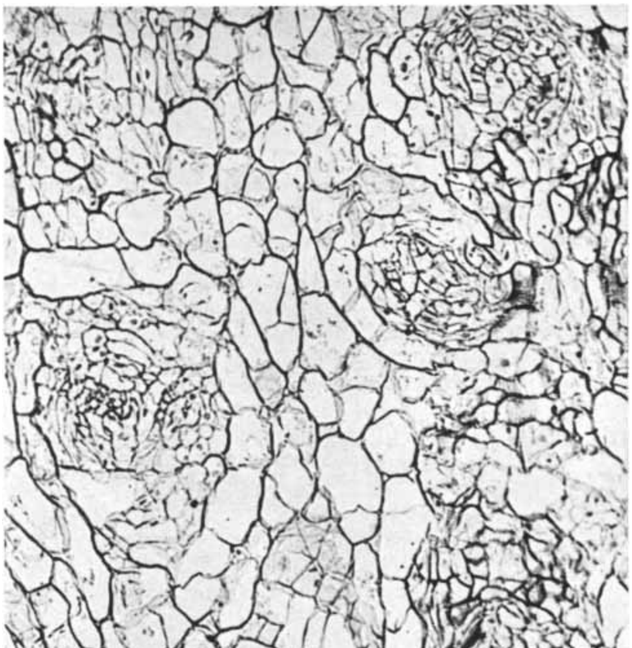
*Philip R. White is a member of the Institute for Cancer Research.*



**TUMOROUS GROWTHS** bulge from parts of the periwinkle. Such growths occur when bits of tumor tissue like those which appear in the photograph on page 48 are grafted beneath the bark of healthy plants. Tissue from these secondary tumors can then be grafted in the same way to produce tumors in other healthy plants.



**TISSUE** from a Jerusalem artichoke is shown in a photomicrograph after it has been placed on a medium containing salts, sugar and agar. The tissue has not grown.



**SAME TISSUE** is shown in another photomicrograph after the growth substance naphthalene-acetic acid was added to medium. Tissue produced 41 daughter cultures.

# OBSTETRICAL LABOR

*The forces that propel an infant into the world have now been measured precisely by a technique largely developed for experimental engineering*

by Samuel R. M. Reynolds

THE birth of babies has been going on for so long and with such frequency that one might suppose we know nearly all there is to know about the process. Moreover, nature has provided so reliable a mechanism for the delivery of babies that it may seem a mere labor of curiosity to try to discover new facts about it. All too often, however, the mechanism does go wrong. The possibilities for complications in labor are legion, and an obstetrician may continue to encounter new ones throughout a lifetime of deliveries. So the study of the basic facts about obstetrical labor is of some importance. And some recent discoveries, made by means of a new technique of investigation, have reopened this old and long-closed subject.

Like the three R's of pedagogy, obstetrical labor has its three elementary P's, which stand for the passenger (the baby), the passage (the cervix, or neck, of the uterus) and the powers of the delivery mechanism. All three must meet certain conditions if the delivery is to be normal. It is with the last of the three P's, the powers of labor, that we are here mainly concerned.

By powers of labor we mean the force employed by the muscles of the uterus and abdomen to effect delivery of the baby. The longest and most important phase of obstetrical labor—known as the first stage—is devoted to enlarging the cervix, or neck, of the uterus so it will permit the passage of the baby. For a normal delivery the cervix must be dilated from about the diameter of a finger tip to an opening nearly four inches across. This is accomplished solely by the force of uterine contractions, without aid from the abdominal muscles.

Nature has provided a most efficient scheme for this purpose. The uterus grows from about two ounces at the beginning of pregnancy to something over two pounds at the time of delivery. During pregnancy it must provide an adequate supply of maternal blood to bathe the tissues in which the embryo is growing, and must expand to accommodate the ever-increasing products of conception. At the same time, the uterine muscles must develop sufficient contractile power to make the birth possible. In short, nature provides a growing force to meet a definite resistance at a definite future time, yet it does not test its strength against that resistance until the moment of conflict has arrived.

What is the magnitude of the forces that the contracting uterus in labor must bring to bear to dilate the cervix for the delivery? The study of this fascinating aspect of obstetrics, which is little known to obstetricians today, can appropriately be called "uterine mathematics." Strangely enough, the first basic investigation of it was made by a 19th-century Anglican priest, the Reverend Samuel Haughton. Haughton, whose scientific interests included geology, mathematics and finally medicine, was primarily responsible for reorganizing the medical school of the University of Dublin, making it during the latter part of the last century one of the leading medical centers of the world. In 1873 Haughton published a book entitled *Principles of Animal Mechanics*. This was the fruit of 10 years of dissection, research and study. In his book he reported measurements of the uterine forces in labor, which still stand as remarkably accurate.

The average uterus, he found, is capable of contracting with a force equivalent to a pressure of about 3.4 pounds for every square inch of its surface. This is ample to rupture the membranes about the fetus, a prelude to birth; on the average it takes only about 1.2 pounds of pressure per square inch to accomplish this. On the other hand, the pregnant uterus itself can withstand a pressure of 18 to 25 pounds per square inch, so it is provided with a fivefold to sevenfold factor of safety against rupture.

An analysis of the factors involved shows, however, that the uterus is incapable of developing enough power to push the fetal head through the pelvis for birth. According to the best evidence, the narrowest part of the pelvic passage forms an elliptical band having an area of a little over 15 square inches. The uterus can develop but 3.4 pounds per square inch. Consequently the uterus forces the baby against this resistance with a total force of some 50 to 55 pounds. Experiments have shown that 80 to 100 pounds or more of total force are necessary to force the average baby through the average pelvic passage. Thus the uterus can supply only a little more than half of the necessary pressure. The rest of the force required for expulsion of the baby is furnished by contractions of the abdominal muscles during the second stage of labor. These movements are called into action by nervous reflex mechanisms associated with distention of the pelvic passage by the baby. If for any reason the abdominal muscles fail to supply sufficient force, artificial methods must be used to extract the baby. Most often the use of forceps or even the hand of the attending physician will serve; occasionally surgery to reduce the resistance in the pelvic passage is necessary.

HAUGHTON'S pioneering measurements were followed by others, but these investigations left obstetricians with little real knowledge of the essential mechanism and pattern of uterine contractions. Then during the 1930s Douglas P. Murphy of the University of Pennsylvania began an intensive study of these contractions, and one of his findings was so startling that it raised a big question which eventually led to an entirely new understanding of the mechanism of labor.

Murphy's provocative observation was that in a few cases women delivered their babies normally without giving any evidence of rhythmical uterine contractions or of uterine pains. This was astounding, if true. In the first place, it is the nature of uterine smooth muscle to contract and relax rhythmically. In the second place, if the uterus contracted continuously and increasingly for the hours necessary for cervical dilation to take place, the flow of maternal blood to the placenta should have been seriously restricted and these labors should have produced a high incidence of fetal distress. Yet the births were normal.

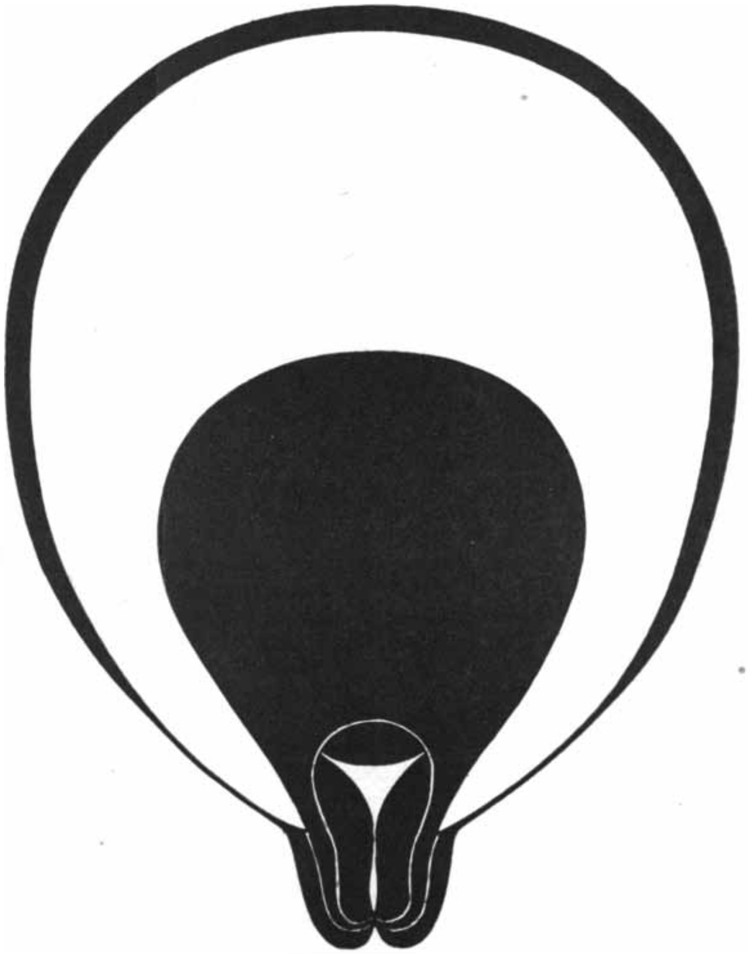
Either the theory of uterine physiology had to be revised or there was something wrong with the observations. It seemed to me that the latter was more likely. To register the contractions, Murphy had used an instrument, strapped to the body, which recorded the movements at a single point on the abdomen. Would the results be different if recordings were made simultaneously at several places on the abdomen instead of only one?

There was no instrument then available to do this. Fortunately, during my wartime duty with the Army Air Forces I saw in wide use an instrument that seemed adaptable to the purpose. This was the strain gauge, an instrument for measuring, usually by electrical means, the force or stress to which a structure is subjected. In the Air Forces strain gauges were used for measuring impacts, stresses in different parts of aircraft, and acceleration forces. In engineering they are used for measuring strains on bridges, beams, axles, boilers, ships' hulls and the like; in ordnance, for recording forces to which gun barrels, mounts and rifles are subjected; in geophysics, for prospecting oil fields. A strain gauge is the heart of a seismograph. And strain gauges of still other types are employed to record various physiological functions such as vascular pressure pulses in the fingers.

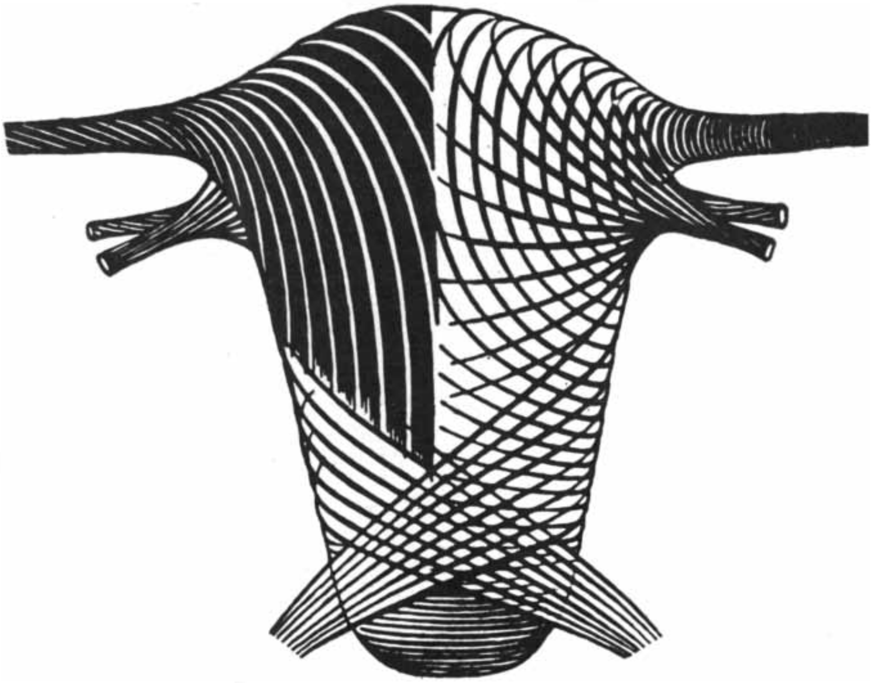
On my return to the laboratory in Baltimore after the war, a strain-gauge instrument was developed, with much effort and the help of many collaborators, to record uterine contractions. It is called a tokodynamometer, or TKD for short; the name means "measurement-of-force-pertaining-to-childbirth."

At Johns Hopkins Hospital the hospital's department of obstetrics and the department of embryology of the Carnegie Institution of Washington joined in an intensive study of uterine contractions by means of the TKD. (There are several other TKDs in use now in other hospitals.) Our instrument takes three simultaneous recordings with three strain gauges mounted with Scotch tape on different parts of the abdomen. One gauge is usually placed over part of the top third of the uterus, one over the middle third, and one in the midline over the lower third just above the bones of the pelvis. The activity of each section is recorded separately on a piece of paper; recordings are made at intervals of one minute. The instrument records the organization, the intensity, the duration and the frequency of uterine contractions in three widely separated parts of the uterus, and makes it possible to study the coordination of these contractions. Not only does the TKD tell an obstetrician when the contractions are out of kilter, but it is useful for observing the effects of uterine stimulants, sedatives, anesthetics, analgesic drugs, "natural childbirth" and other procedures.

WE now have a great deal of data on the pattern of events in the first stage of labor. Under the supervision of Dr. Louis M. Hellman and Dr. Jerome S. Harris of the Hopkins staff, records



**SIZE OF THE UTERUS** varies greatly during pregnancy. The small white outline is the uterus at the onset of pregnancy. The largest outline is the uterus at term; the solid black outline, the uterus immediately after delivery.



**MUSCLES OF THE UTERUS** and the Fallopian tubes (*upper left and right*) are situated to do the work of obstetrical labor. The fibers that branch out at top and bottom are attached to ligaments that support uterus.

**THE STRAIN GAUGE** is used in the author's laboratory to record uterine contractions. It is assembled in a device known as the tokodynamometer. The pickoff of the tokodynamometer (*top*) contains an adjustable strain gauge. The sensitive "finger" of the gauge may be seen in the bottom view of the pickoff (*left center*). In the drawing at bottom strain gauges have been located at three points on the abdomen of a subject in labor.

have been obtained from nearly 300 maternity patients. The intensity of each contraction, the length of time required for each to develop, its duration, the frequency of the contractions—all this has been determined for each of the three levels in the uterus. These facts, along with pertinent clinical data, were coded, entered on punch cards, and analyzed extensively on a sorting machine. The person directly responsible for this operation, Mrs. Jane B. Holt, maintains that she has "spent more hours in labor without a child than anyone else in the world."

We have found that the first general stage of labor, which ends when the cervix is fully dilated, can be divided into three substages. During the first substage the cervix dilates from two centimeters to about three centimeters—an increase of about a third of an inch. During the second, it increases about another centimeter. During the third, it expands by about six centimeters; in other words, more than half of the dilation takes place in the last third of the first stage of labor.

But the most significant observation is that the uterus does not contract in all its parts. Ordinarily the top section contracts most strongly, the mid-portion with intermediate intensity and the lowest section hardly at all! Here, then, is the explanation of how the lowest section, or cervix, is dilated. As the top section contracts and applies pressure, the inactive cervix can hardly help being stretched and molded. But why need the process take so long, even up to six or 12 hours or more? The reason is that the resisting cervix must be softened up before it yields. During the second substage the contractions in the upper and mid-part of the uterus become longer in duration. The prolonged application of pressure tends to weaken the lower section and render it thinner as it dilates slightly. While these changes take place, there is a slight but steady increase in the frequency of the contractions. Only after all this has happened do the contractions become stronger, and then only in the uppermost part of the uterus. How neatly timed this mechanism is, to achieve its destined end!

INDIVIDUAL cases may of course deviate from this normal pattern. A number of factors are known to modify it. Previous pregnancies, for example, alter the configuration of forces, making the contractions more intense and prolonged in the last third of the first stage of labor. We have observed that in women who have borne children previously it often happens that only the top of the uterus contracts; the other sections of the uterus are entirely inactive. This may explain why Murphy's recording instrument, placed at only one point on the abdomen, sometimes failed to record any rhythmic contractions at all.

Some investigators and obstetricians hold to the view that the muscles of the cervix itself, as well as those of the top of the uterus, do the work of the first stage of labor. It is true that the cervix is often contractile before labor, but we have never observed such contractions during true labor. Confirmation of the fact that the pattern of contraction is as we have found it has come from two independent investigations. One is some recent work by Dr. Charles Steer of Columbia University, who has studied this question by an examination of bioelectric currents, an essential feature of biological activity. He has proved that such currents are lacking in the lowest part of the uterus during labor, and therefore that this part is indubitably passive. Dr. Árpád Csapó, formerly of the Kvinno Klinic in Upsala, Sweden, and now working in our laboratory, has obtained another corroborative proof. He has shown by biochemical methods that the muscle tissue of the uppermost part of the uterus is rich in the proteins responsible for muscle contractions; the mid-portion has smaller amounts of these proteins, and the lowest part is poorest in them.

What are the factors that control the period of gestation and the pattern of obstetrical labor that we have described? Everyone knows that hormones play the most important part, but it has been less well appreciated that biophysics also has a large bearing on the matter.

During pregnancy the growth curve of the uterus is very different from that of its contents. The growth of the uterus slows down toward the end of pregnancy, whereas the enlargement of the fetus accelerates rapidly at that time. Clearly the volume of the uterine contents must in time tend to exceed the capacity of the uterus. As a consequence, the uterus is subjected to forces of distention, and it is affected by well-known hydrostatic laws that apply to the distention of elastic membranes. According to these principles the tension, or resistance to expansion, of an enclosing elastic membrane increases as the square of the radius of the membrane's curvature. The Reverend Dr. Haughton was well aware of the implications of these facts for obstetrical labor, and he investigated them quantitatively. He found that the radius of curvature of the top of the uterus exceeded that of the cervical region in the ratio of seven to four. Thus the tension ratio is 49 to 16; that is, the top of the uterus has a tension roughly three times that of the cervix. Since the efficiency of a muscle's contractions is increased, within limits, by increasing the tension to which the muscle is subjected, one can readily see that in the distended uterus at term the top must have considerably greater powers of contraction than the cervix. This physical factor reinforces the physiological mechanisms that bring about a gradient of diminishing intensity of activity from the top to the bottom of the uterus.

The hormonal factors that influence this pattern of uterine activity are exceedingly complex. We know that during pregnancy a neatly coordinated set of developments in the production and metabolism of steroid hormones, particularly estrogens and progesterone, sets the stage for a favorable uterine metabolism for labor. In the first place, these developments increase the proportion of the contractile protein actomyosin in the uterine muscles. This, in the words of my colleague Dr. Csapó, is like increasing the number of hands available to do work. Then, by setting up favorable conditions in the milieu, they improve the speed with which the available hands can work. They enormously increase the output of enzymes that facilitate the interaction of actomyosin with the energy-giving substance adenosine triphosphate. They also raise the production of energy-rich glycogen and change the concentration of inorganic substances, especially calcium, magnesium and potassium, in such a way as to improve the efficiency of the actomyosin contractile system. Actomyosin is most abundant in the fundus, or top section, of the uterus. Thus nature has placed the most "hands" where they will be most effective in developing the uterine forces in labor, and has created favorable biophysical and biochemical conditions whereby these "hands" may work most efficiently.

MUCH remains to be learned about the mechanism. We do not yet know for a certainty what controls the proper production of those hormones that favor the conditions for normal labor. Nor do we know what regulates the withdrawal of opposing hormones which tend to stabilize or at times prolong the duration of pregnancy. We do know that aging of the placenta and alterations in its blood supply are involved, and that certain special hormones may, at a crucial point in the labor process, fortify the contractile mechanism within the uterus.

When all the factors are known, we shall be able to say what determines the span of gestation and what triggers the onset of labor. We may then be able to do something about that misfire of nature known vaguely as "uterine inertia," which is the dread of mothers and obstetricians alike. Meanwhile, we must content ourselves with piecing together the fragments of an extraordinarily complicated puzzle, some pieces of which are not yet in our possession.

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# BOOKS

## *A kindly view of Francis Bacon, a curiously controversial figure in the history of science*

by James R. Newman

FRANCIS BACON, by Benjamin Farrington. Henry Schuman ($3.50).

THERE are men upon whom history never finds itself able to pronounce a verdict. Such a man is Francis Bacon; for more than 300 years his reputation has been the subject of sustained and inconclusive controversy. During his life he was both honored and scorned, the scorn being directed not only to his confessed "corruption and neglect" in public office but to the quality of his contribution to logic and to the advancement of science. A century later Alexander Pope described him as the "wisest, brightest, meanest of mankind." Macaulay, in a famous, gargantuan "book review" (55,000 words) of a new edition of Bacon's works, while spurning the "vulgar" notion that Bacon had invented a new method of arriving at truth, spoke of the "vast benefit" of his intellectual achievements and of his great "common sense" in thinking upon better ways to make men more "comfortable." In the same sense, Karl Marx, in a footnote to *Das Kapital,* lauded Bacon's anticipation of an "alteration in the form of production, and the practical subjugation of nature by man, as a result of the altered mode of thought."

Our period has provided detractors of Bacon as well as defenders. C. D. Broad, the Cambridge philosopher, has dismissed as negligible Bacon's influence on the course of science; certain historians (*e.g.,* R. K. Merton) have placed high value on the social connections of his thought; the late Morris Cohen, writing of the Baconian "myth," sharply challenged his claim to intellectual originality, charging further that he had opposed and obstructed every "great constructive scientific achievement of his day."

Benjamin Farrington, a classicist noted for his writings on the history of ancient science, especially in terms of social circumstance, comes to praise Bacon; to re-examine and, where possible, to reconcile opposing views; to say the best that can be said of him in the light not only of modern scholarship but of the values of liberal social thought. Farrington has not given us a full-fleshed biography. The emphasis is on Bacon as the first "philosopher of industrial science" rather than on his public career or personal life. Discounting the extravagant claims often made for Bacon's philosophical ideas and accepting the validity of some of the criticism uttered by other capable scholars, Professor Farrington remains throughout his study a fervent admirer and, because of the sincerity of his appraisal, perhaps the most persuasive of Bacon's admirers to date. It seems to me, nonetheless, that he has strained his interpretations, too lightly weighed the body of adverse criticism and overstated his case. This is a provocative essay, but it should be read with careful skepticism; the Bacon portrayed by Farrington, one cannot help feeling, is a Bacon who fits better into the author's frame of history than into the frame of demonstrable fact.

Bacon's "great idea" as summarized in Farrington's book is that "knowledge ought to bear fruit in works, that science ought to be applicable to industry, that men ought to organize themselves as a sacred duty to improve and transform the conditions of life." To the elaboration and spread of this idea Bacon devoted a good part of his life. The ambition to "reconstitute man's knowledge of nature in order to apply it to the relief of man's estate" spurred him from adolescence (he was a most precocious child) to old age; his last illness resulted from a chill caught while stuffing a fowl with snow to determine the effects of cold in delaying putrefaction. In the role of philosopher he glimpsed intimations of immortality—and therefore chose Latin, the eternal language, for his more systematic writings. The public positions of honor—and profit—to which he aspired and later rose were dear to him, at least so he said, mainly because they would confer "a larger command of industry and ability to help [him] in [his] work."

Scarcely a modest man (though Farrington has somehow managed to persuade himself to the contrary), Bacon boasted that he was "fitted for nothing so well as for the study of Truth." Though he regarded himself as an apostle of science, the title cannot be allowed if it is taken to mean that he himself was a scientist either in temperament, skill or learning. He was not, as Farrington admits, a pioneer of research, "the revealer of any fresh law of nature, the author of any great new hypothesis." On the occasions when he turned to experiments, he proved himself "a clumsy investigator." The deficiency went even deeper. When his *Novum Organum* appeared in 1620, the scientific discoveries of Copernicus, Kepler, Galileo, Gilbert, Vesalius, Harvey, to mention only some of the leaders, had long been published. Yet Bacon contended, in effect, that before he had appeared on the scene there was no well-established science based on experience—a claim which, as Morris Cohen observed, in any other man would have been characterized as that of a "crank or charlatan." Bacon rejected the Copernican astronomy (Farrington explains this on the curious ground that Bacon was a "practical" man more interested in the geographical than the cosmogonical revolution); he failed to appreciate the greatness of Harvey's discovery of the circulation of the blood; he was careless in his treatment of the unpublished writings of Gilbert that had been entrusted to him, though we learn that he was "enthusiastic about Gilbert's practical work on the magnet."

Voltaire made the claim that Bacon had anticipated Newton in the theory of gravitation. This is nonsense, though it undoubtedly helped to establish Bacon's European reputation. Bacon is also sometimes credited with the modern concept of heat as a form of motion, but this claim is equally unsupported. While admitting that the "Table of Essence and Presence" and other Baconian aphorisms dealing with the subject of heat are a little "peculiar," Farrington asks us to be understanding of Bacon's research because "we must remember that modern science did not yet exist and that Bacon was starting where the Greeks left off." This assertion is so patently untrue that it is hard to understand how so knowledgeable a historian as Professor Farrington could have made it.

As for the advance in method and in the logic of science on which Bacon most prided himself, it was neither original as an advance nor fruitful as a method. The common sense of his proposals—namely that to learn the behavior of nature one had to observe nature—had been current among the ancient Greeks and probably much earlier, while the elegant, but sometimes inflated, terms and phrases in which Bacon clothed the "new logic" too often served only to conceal what was complex and to confuse what was simple.

The kernel of the inductive principle, as expressed in *The Great Instauration*—of which the *Novum Organum* is a part—was to reject all fixed preconceptions ("anticipations") about nature, to approach natural phenomena with a free and unconditioned mind (*tabula rasa, i.e.,* a "blank slate"), to observe and to experiment, and finally, by induction, to draw general conclusions from the facts observed. Not the smallest advantage of these rules was that they provided a formula for the manufacture of scientific discoveries almost by rote; every "industrious plodder" could become a successful scientist. "The course I propose for the discovery of sciences," wrote Bacon, "is such as leaves but little to the acuteness and strength of wits, but places all wits and understanding nearly on a level. For as in the drawing of a straight line or a perfect circle much depends on the steadiness and practice of the hand, if it be done by aim of hand only, but if with the aid of rule and compass, little or nothing; so is it exactly with my plan."

There is no evidence, of course, that a single scientific discovery ever was made by induction as conceived by Bacon. On the contrary it is quite clear that to engage in research without the stimulus and guidance of hypotheses, rules, preconceptions, anticipations, control criteria and the like is a hopeless if not indeed frivolous activity. Abundant support for this conclusion may be found throughout


**THE TITLE PAGE** of Bacon's book *The Great Instauration* was an ornate symbol of the Elizabethan period in which he lived. The book was in Latin.

the literature of science, and proof of the futility of "pure induction" is not lacking in Bacon's own records of research. Farrington attempts at some length to disprove the assertion that Bacon thought his method capable of making every man a scientific discoverer. There is no need to present this defense, if for no other reason than that Bacon did not always mean exactly what he said. It was characteristic of him to exaggerate and to play for effects. He was a person of enormous talent and conceit, pretentious and grandiose in his schemes, self-seeking, a brilliant literary artist and propagandist; he was not a fool. Farrington calls him a philosopher of industrial science but it is more fitting to think of him as publicist and politician. The pretty ways of these professions were certainly well known to him. He knew how to appear modest when modesty was in order; he knew the value of the right hint here and there as to the frailty of his health, and the failure of his hopes for personal advancement. Above all, he knew the temper of his age, the eagerness for golden promises, the impatience with sterile philosophies and with the disputes (as Macaulay wrote) of the "orthodox Lilliputians and the heretical Blefuscudians about the big ends and the little ends of eggs." He surely recognized, and the contradictions in his writings are ample evidence of such recognition, that the methods he proposed were not as effective as he claimed them to be; one must remember, however, that he wrote as publicist rather than philosopher, and exaggeration was necessarily a part of his art.

The publicist, we may concede, is not without his uses. When Bacon lent his enthusiasm and literary genius to a sound cause, the results were impressive. His ideal of organized scientific research, expressed in the *New Atlantis* and elsewhere, undoubtedly "caught the imagination of his contemporaries." The first history of the Royal Society, by Thomas Sprat, acknowledges that "one great man . . . had the true imagination of the whole extent of this enterprise, as it is now set on foot; and that is the Lord Bacon." Robert Boyle and other early members of the Society were equally lavish in their praise of Bacon's contribution. Many of Bacon's aphorisms embody the most trenchant and farseeing comments on science. When he was not out of his depth, not occupied with grand designs, not polemizing for the sake of effect, not disporting himself in the realm of prophecy, not overcome with self-admiration, his words are of extraordinary eloquence and perceptiveness.

A few examples may suffice to show his best side, and how far ahead of his time his conceptions occasionally ranged. In *Valerius Terminus* he wrote: "I find that even those that have sought knowledge for itself, and not for benefit or ostentation, or any practical emblements in the course of their life, have nevertheless propounded to themselves a wrong mark—namely, satisfaction (which men call Truth) and not operation." The crucial test he proposed was that "Science, like religion, must be judged by its fruits." And, again, "It is by the witness of works rather than by logic or even observation that truth is revealed and established. It follows from this that the improvements of man's lot and the improvement of man's mind are one and the same thing." Knowledge, in other words, was valid only when it could be put into practice and when it worked; all else was "babble."

It is a pity he was unable to follow his own advice. He denounced Aristotle (in Farrington's paraphrase) as a "wretched sophist, his logic a manual of madness, his metaphysics a superstructure of cobwebs erected on a small foundation of fact." Plato was indicted as a "deluded theologian," a "sham" and a knave. How faithfully he projected the image of his own foibles onto others! James I, on whom he fawned, had a low opinion of the *Instauration* and observed that the philosophy of Bacon was "like the peace of God, which passes all understanding." Harvey made the celebrated quip: "He writes philosophy like a Lord Chancellor." These judgments we may accept. We can also accept, however, the verdict of Farrington that Bacon "fought to render intelligible and acceptable the opinion that the pursuit of truth in science is inseparable from the improvement of our human lot." For this, if for nothing else, he deserves the immortality he labored so strenuously to achieve.

THEORY OF HEARING, by Ernest Glen Wever. John Wiley & Sons, Inc. ($6.00). A summary and evaluation of theories and of anatomical electrophysiological and psychological evidence concerning auditory function. The theory of hearing has long been a controversial matter, but new research tools, especially electrical devices, have in the past two decades provided critical evidence for purposes of theory evaluation and construction. Dr. Wever shows the deficiencies of the classical theories, such as the Helmholtz place-resonance theory and the Rutherford frequency theory, and, in clear and succinct fashion, formulates a comprehensive theory in the light of modern evidence. Perhaps the theory of hearing has at last reached an approximation of its final form.

SPACE, TIME AND ARCHITECTURE, by S. Giedion. Harvard University Press ($10.00). The eighth edition of this standard, superbly illustrated survey of the roots and growth of modern architecture has additional plates and diagrams, a chapter on Alvar Aalto, the noted Finnish architect and designer who is now a professor at the Massachusetts Institute of Technology, and some other brief, fresh material. A feast for the mind and eye.

COSMOPOLITAN WORLD ATLAS. Rand McNally & Company ($12.50). A completely new reference work, 10 years in the making. More than 110 maps, clearly drawn with unusually legible typography, arranged on a broad regional basis—not country by country but with each regional map "centered around a major country or a significant grouping of countries." There are also useful information tables, a historical gazetteer, glossary and index. While this volume is not designed to compete with various sumptuous British and Continental map compendia, it is by far the best general home and school atlas published in this country in many years.

LENGTH OF LIFE, by Louis I. Dublin, Alfred J. Lotka and Mortimer Spiegelman. The Ronald Press Company ($7.00). A revised reissue of a book that first appeared in 1935. It deals with such matters as the longevity of famous men (*e.g.*, former Cabinet members have, on the average, lived seven years longer than authors of "political poetry" but only five years longer than "authors of words to church hymn tunes"), the gradual extension of the life span, the geographical variations in heredity (*e.g.*, Nebraska offers the highest life expectancy and Arizona the lowest), mortality in relation to heredity, the contribution of medical and other sciences to longevity, the effects of occupation and other factors on length of life (*e.g.*, agricultural labor has the lowest standardized death rate, but "hard work" after 40 is killing). The index to this book, it may be noted, has an entry for atomic energy but only with regard to certain peacetime hazards attendant on its use; from the actuarial standpoint the relation between warfare and longevity is inconsequential, deaths thus incurred being classified as acts of God. Not only a standard work for professional purposes but full of interesting material for the general reader.

PREHISTORIC MAN, by Charles R. Knight. Appleton-Century-Crofts, Inc. ($5.00). A confusing, stilted, poorly arranged, but nevertheless interesting and admirably motivated account of prehistory by the well-known muralist-naturalist whose re-creations of prehistoric creatures, including man, decorate the walls of many leading American museums. How an editor could pass this volume for press is hard to understand: There is no index; the chapters are not numbered; there are grammatical lapses; Mr. Knight frequently repeats himself and does not hesitate to include in this historical study such irrelevant items as reminiscences about the bad soup served to him in the south of France 20 years ago. There is no chronological chart separating the various ages of prehistory and, indeed, the author appears strangely reluctant to impart this essential information anywhere in the text.

A SURVEY OF PRIMITIVE MONEY, by A. Hingston Quiggin. Methuen and Company, Limited, London (45 shillings). This handsomely illustrated volume in Methuen's *Handbooks of Archaeology* series gives a most interesting account of the beginnings of currency and of currency substitutes throughout the world. For the great gold hoard at Fort Knox there were and are many more useful money equivalents: throwing-knives, salt, cowries, cloth, axheads, millstones, tree bark, paper, coconuts, clay, lizard bones. With money of the right kind, if one has enough of it, anything can be bought almost anywhere. In the Solomons, for example, where gold would be spurned, 100 to 200 fathoms of shell strings will get a wife, 20 to 30 a pig, and 100 is the going rate of blood money for murder. Mrs. Quiggin does not believe that the inconveniences of barter were primarily responsible for the development of currency. Early exchanges were along the lines of "present-giving . . . with no ulterior economic purpose"; barter then arises (and still continues) between "areas of contrasted produce." But the use of a conventional medium of exchange, "originally 'full-bodied' but developing into 'token' money, is first noted in the almost universal customs of 'bride-price' and *wergeld* (blood-price)." This soon leads to a system of conventional gifts and payments with a definite scale of values and these are the "first steps in the evolution of money."

THE EPITOME OF ANDREAS VESALIUS. Translated by L. R. Lind. The Macmillan Company ($7.50). In 1542, two weeks after completing his epoch-making treatise on anatomy, *De Humani Corporis Fabrica*, the 28-year-old Vesalius turned out the *Epitome*, an abridged manual of descriptive anatomy or, as he himself described it, a "pathway" to the larger work intended for a wider public. Dr. Lind of the University of Kansas offers the first English translation of the *Epitome* in this publication of the Historical Library of the Yale Medical Library. The style of the *Epitome* is clear and brief and the translator has made every effort to preserve the lucid elegance and the simplicity of this "triumph of condensation." Latin scholars will have to pronounce their own judgment; the general reader with scientific tastes will fully approve Dr. Lind's results. It is good to have this wonderful work made accessible to non-specialists, together with the Latin text and a satisfactory, if undistinguished, series of reproductions of the magnificent anatomical plates designed by Vesalius himself.

# THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

A BRIEF study of Lieut. Col. Alan E. Gee's unconventional telescope, shown in Roger Hayward's drawings on the opposite page, is enough to reveal its simple secret. It would be a conventional refractor if its tube were not "broken" and jointed at the center. At this point it has two cubical box castings connected by a swiveling joint. In each box is an optically flat mirror. The eyepiece half of the tube remains pointed downward, parallel to the earth's axis, but the objective half is free to dip or turn sidewise. When it turns sidewise the eyepiece end rotates in its fixed bearings.

Thus the Gee telescope is an equatorial coudé, or "elbowed," refractor similar in principle to the widely known type devised in 1882 for the Paris Observatory. It differs from that instrument, which is diagrammed in Louis Bell's book *The Telescope*, in a number of excellent practical modifications which are of interest to all planners of small telescopes.

"A refractor of this size on a conventional mounting would be extremely bulky," Colonel Gee points out, "weighing hundreds of pounds if it were to equal this one in stability. Even using the eyepiece on the coudé as a handrest when getting up or down from the observing chair will not disturb the image in the least. The reason is the location of the eyepiece at the highly stable apex of a broad pyramid. The instrument performs beautifully and is well worth the very considerable time and effort it took to build it.

"Without its two removable counterweights the whole telescope, which is made almost entirely of aluminum alloy, weighs only 40 pounds and can be folded nearly flat and carried by one person.

"The tube can be moved at will to a new part of the sky, and the slow motions take over from there. The right-ascension slow motion near the eyepiece is a 360-tooth 18-*pi* diametral-pitch worm gear. I cut this 6.4-inch gear on my Globe miller with a hob that was made from drill rod and hardened. I made the hob for a 14½-degree pressure angle instead of using a standard tap because I have noticed that worm wheels cut with taps are not very satisfactory.

"The declination slow motion at the elbow is a positive-action tangent screw without a spring, working on a floating friction plate in typical Springfield mounting fashion.

"The right-ascension bearings consist of a 3¼-inch bronze sleeve bearing at the eyepiece end and a one-inch brass sleeve bearing in a forked 'mermaid's tail' resting on the ground. The declination bearings consist of a pair of seven-inch-diameter bearing plates that are integral parts of the two boxes containing the diagonal mirrors. The 3½-inch-diameter hollow central stud has a threaded, removable retaining ring.

"The rack-and-pinion focusing tube has a 1¾-inch clear aperture and permits the use of low-power, wide-angle eyepieces. Three eyepieces are used—a 1½-inch wide-angle modified Erfle, a one-inch Erfle and a very good two-thirds-inch Brandon orthoscopic, plus a 2X Barlow lens. These three provide powers from 60X to 260X. The telescope handles the high power nicely.

"The Barlow lens is a Laboratory Optical Company (Plainfield, N. J.) product of minus 4-inch effective focal length, mounted in a tube to provide 2X magnification. Various war-surplus Barlow lenses have appeared on the market in recent years with elaborate claims for impossible optical characteristics. Those I have examined are simply negative achromats of less than minus 2-inch focal length, far too short for optimum performance. Actually, minus 4-inch is on the short end of desirable focal length and minus 6-inch would be better. Barlows I have made for my own use are of minus 6½-inch e.f.l. and leave nothing to be desired in performance.

"The mirrors at the elbows are mounted on push-pull screws for adjustment and can easily be aligned by autocollimation. They are one-tenth wave aluminized optical flats and are highly important to the image quality. They must be mounted completely strain-free, and gave me much trouble until they were given three-point suspension on little cork pads that pinch them between the metal backing and the hold-down lugs. To give satisfactory results they should check within one-tenth wavelength of flat when mounted.

"The finder consists merely of a rear peepsight with an eighth- to a quarter-inch opening (the exact size is unimportant) and a forward stud whose end is coated with luminous paint. Such a finder is very simple to construct, and is superior to the usual optical finder of considerably more complexity. With it an object can easily be placed in the field of view of the telescope.

"I did not make the objective.

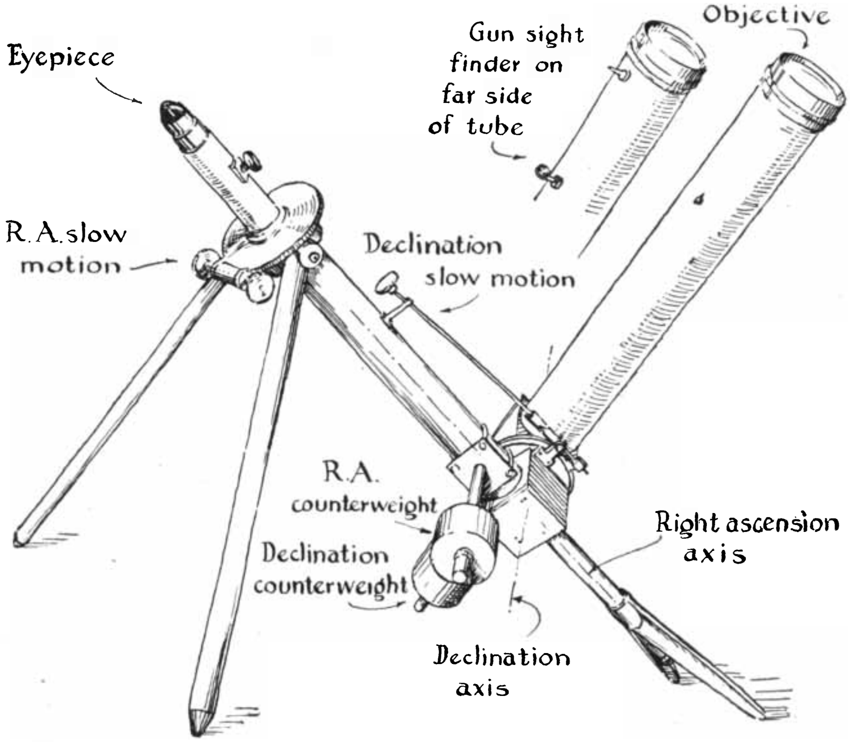
"Were I to build another telescope of this type I would use ball bearings in place of the upper sleeve bearing, whose inevitable play made it very difficult to adjust and maintain the fit of the right-ascension drive gear. Ball bearings would alleviate this. Probably a pair of retainerless 'propeller-type' bearings, or a single 'double-row' bearing, would be best. In any case the two rows of balls would be necessary for stability of the worm seat.

"It is true that there is a loss of light at the two elbow mirrors of this telescope, but the loss is negligible."

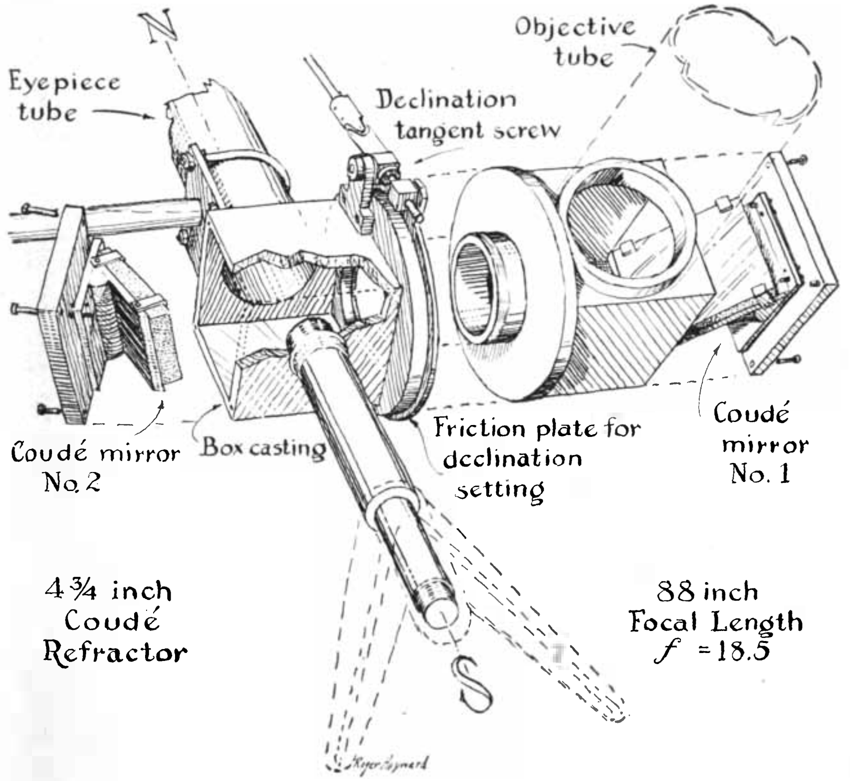
Amateur telescope makers of long standing will recognize Colonel Gee as the co-builder of the 12½-inch reflector shown in *Amateur Telescope Making—Advanced*, pages 319-322, and more recently of a 20½-inch Cassegrainian at Portland, Ore. He also is the proponent of a practical method of testing Cassegrainian secondaries and the author of theoretical studies of that problem. Colonel Gee recently completed two years' study of optical design at the University of Rochester's Institute of Optics, and is now Chief of the Fire Control Division (which includes optics) at the Frankford Arsenal, Philadelphia, Pa., but he remains one of the widespread and enthusiastic fraternity of amateur telescope makers. Wherever his vocation sends him his lathe and other tools, like Mary's lamb, are sure to go. He has made numerous mirrors and flats, and also a dozen identical Barlow lenses of 1⅝-inch diameter and minus 6½-inch e.f.l.

IN THE DRAWING on page 62 Roger Hayward has worked out the effect of a coudé telescope on images of star groups or of the moon in four different attitudes for the four cardinal directions. (The images are represented by capital letters.) If the objective tube of the telescope is shifted to the opposite side of the eyepiece tube, these different attitudes change still further. Thus it all seems to add up to confusion. In practice, however, the user comes to know his star groups well no matter how they are thrown at him—whether inverted, erected, perverted or reverted. In this respect the coudé is closely related to the Springfield, each having two added reflections, but with a difference: in the Springfield these follow a course "up-across-up," in the coudé "down-across-up."

Brandon orthoscopic eyepieces, no longer available from the original Brandon source, are said to be obtainable




*Colonel Gee's "elbowed" refractor*




*Arrangement of flats in the Gee telescope*

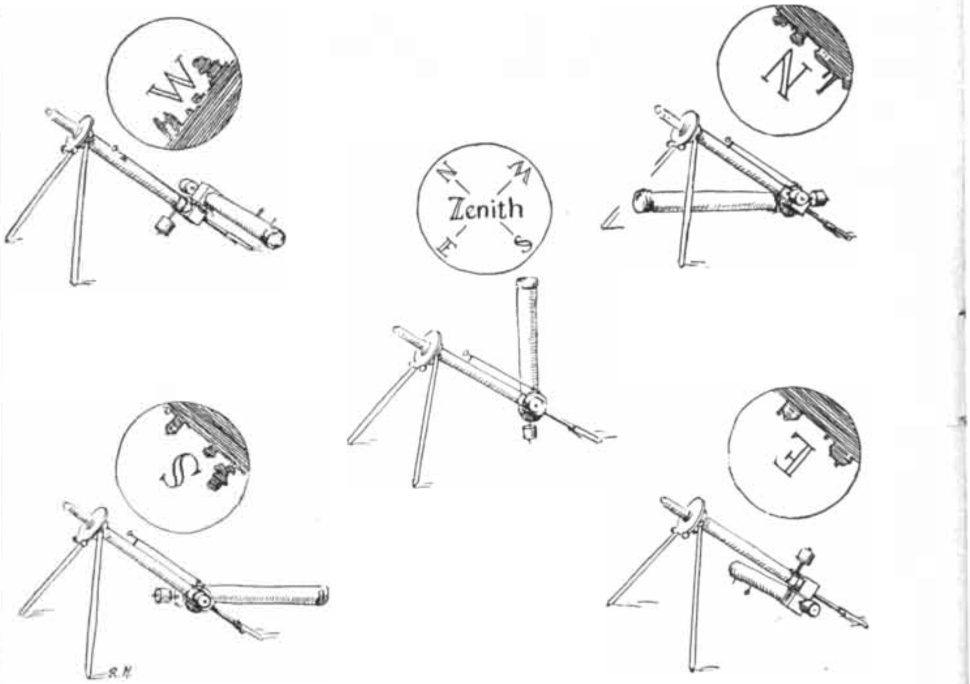



*Image attitudes in the Gee telescope*

through the Valley View Observatory, 106 Van Buren St., Pittsburgh.

USING the grinding strokes described in *Amateur Telescope Making*, the beginner usually can excavate about 95 per cent of the desired concavity of his telescope mirror in less than two hours, preparatory to the much slower remaining stages. A few, however, encounter a baffling, often maddening refusal of the glass to change from flat to concave. In final desperation and before considering suicide, some of them send poignant appeals for help to this department.

These SOS calls are always regarded with sympathy. On his own early mirrors this writer encountered the same total depravity of inanimate objects. The following entry has been found, dated November 7, 1926: "Half hour spell. Increased stroke cadence to 120 full strokes a minute, sweating copiously, but curve still refuses to deepen."

The frenzied speeding up to 120 strokes per minute was intended to force the curve to deepen, but the cause of the failure in this instance was precisely too rapid strokes! A note concerning this source of frustration was later inserted in *Amateur Telescope Making*, page 244.

The following are related problems submitted by other sufferers similarly at their wits' end. No two workers describe identical circumstances, which is an added difficulty in diagnosis and prescription.

From Ralph B. Saunders of Detroit, Mich.: "After 20 hours of hard work with the coarsest abrasive and the use of every known stroke from *Amateur Telescope Making* and *Amateur Telescope Making—Advanced*, the curve on my 6-inch mirror is still only one thirty-second inch deep, but the thickness of the disks is vanishing into thin air. The glass is plate and the tool is Pyrex."

From Abdulazim Aziz, Nicosia, Cyprus: "In grinding an objective lens 4¾ inches in diameter the glass wear was abnormally high, with the result that the disks now are too thin for specifications. I ground dense flint glass on top of medium barium crown 10½ hours. Result: thickness removed was more than 200 per cent of depth of sagitta on the upper disk and 87 per cent on the lower. I also ground white plate on dense flint 20½ hours. Result: thickness removed, 267 per cent of sagitta. Strokes, cross and back, from the center of upper to edge of lower disk, 16 per minute."

Puzzled as a physician would be if called upon to diagnose by mail, the writer sometimes passes such problems around among those in the mirror-making fraternity having more than average experience. In reply, Albert H. Johns of Larchmont, N. Y., an amateur who worked in wartime as a professional precision optician, commented as follows: "In answering the second inquiry I would mix in a little professional dope. The upper disk should be pushed forward until its center is over the *far* edge of the lower, and on return strokes brought back center over center; in the early stages, not so far as that. For a very deep curve the same result is obtained by grinding the center of the upper disk over the edge of the lower at the side, though this tends to hollow the center too deep; it is too local.

"A way to avoid excessive wearing away of glass," amateur-professional-amateur Johns continues, "is to observe the following simple procedure. Suppose we are using coarse Carbo. If the center of the upper disk has been contacted by the farther edge of the lower disk, then those are the only areas that are ground away. Stop grinding with coarse Carbo when the lower disk shows at the center an untouched spot of, say, one-inch diameter, as shown at 1 in the drawing at the bottom of this page, and the upper disk has an untouched rim of, say, one-fourth- to one-half-inch width. This diameter of untouched area works out well on $f/15$, but shallower curves should have a larger untouched diameter. If the worker is a beginner or is roughing out with coarser Carbo than No. 120 (which gives little or no net gain anyway), a 1½-inch untouched spot should be left on the lower disk.

"Proceed with the next size of Carbo, and when the pits left by the coarsest size are removed a central spot of about one-half-inch diameter should remain as shown at 2, with a decrease in width of the untouched ring on the upper disk. The central spot should always be perfectly round and exactly centered. Any departure from this indicates astigmatism, but can be corrected by working on one side to bring the spot to center. Similarly, on a concave surface press on a wide margin while grinding. The use of regular strokes, however, should avoid these difficulties.

"Continue as above through finer grades until No. 600 or equal has been reached. Regular one-third strokes there develop a complete spherical curve, and the entire faces are fine ground, as shown at 3.

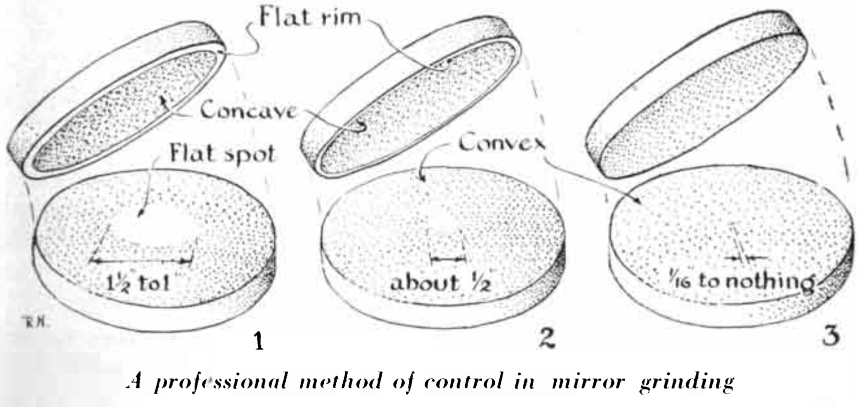
"This method of grinding ensures that a maximum thickness of glass will be left. Professionals use cast-iron tools and high speed—200 to 300 revolutions per minute on spindles—but in grinding down the blanks a spot is left as described, to ensure full thickness at the finish."

The attentive reader may inquire, "In what essential, if any, does the stroke described above differ from a stroke from the center toward the worker?" States Johns, "Theoretically it would be the same. However, pushing forward gives better control of pressure and of general manipulation while turning the disk. Pulling would probably bring it into one's lap. Exerting pressure while pulling the disk toward the near edge would be awkward. Also, for long grinding periods one applies frequent dabs of abrasive to the lower disk without removing the upper disk, but the substitute stroke would require placing dabs on the far side while the disk was being drawn toward the worker. By selecting the proper stance, arm's-length work should bring the center of the upper disk to the far edge of the lower where it can't be pushed off."

Commenting on the case first described, that of Ralph B. Saunders, Johns wrote: "Using a Pyrex tool might lengthen the time consumed." Saunders soon reported: "I have discarded the plate-glass mirror disk for one of Pyrex, grinding it against the same Pyrex tool as before, and it is coming beautifully to curve without complications other than poundings on our door by the occupants of the apartment below us, who complain no less than before about the reverberations that resound from above them. What would Mr. Johns suggest as a remedy for this?"

Many, including the writer, have ground Pyrex *mirrors* on top of plate-glass *tools* with no complications whatever; why then should the reverse create difficulties? In any scientific experiment it is a basic principle that only a single circumstance should be changed at one time: there should be but one variable. A big source of difficulty in the diagnosis of mirror-making ills is the fact that, by the nature of the work, more than one variable is often introduced without the knowledge of the worker. He may then attribute the outcome to the wrong factor and make erroneous deductions as a result. According to his temperament, he regards the baffling situations then produced as either a "headache" or a fascinating contest of wits.

Commenting on the case just described, Colonel Gee wrote: "I suspect too much pressure. The normal roughing action is independent of pressure; the weight of the disks alone will suffice to form the curves. Added pressure serves only to remove glass over-all and thin the disks; it does not speed up curve formation."




*A professional method of control in mirror grinding*

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