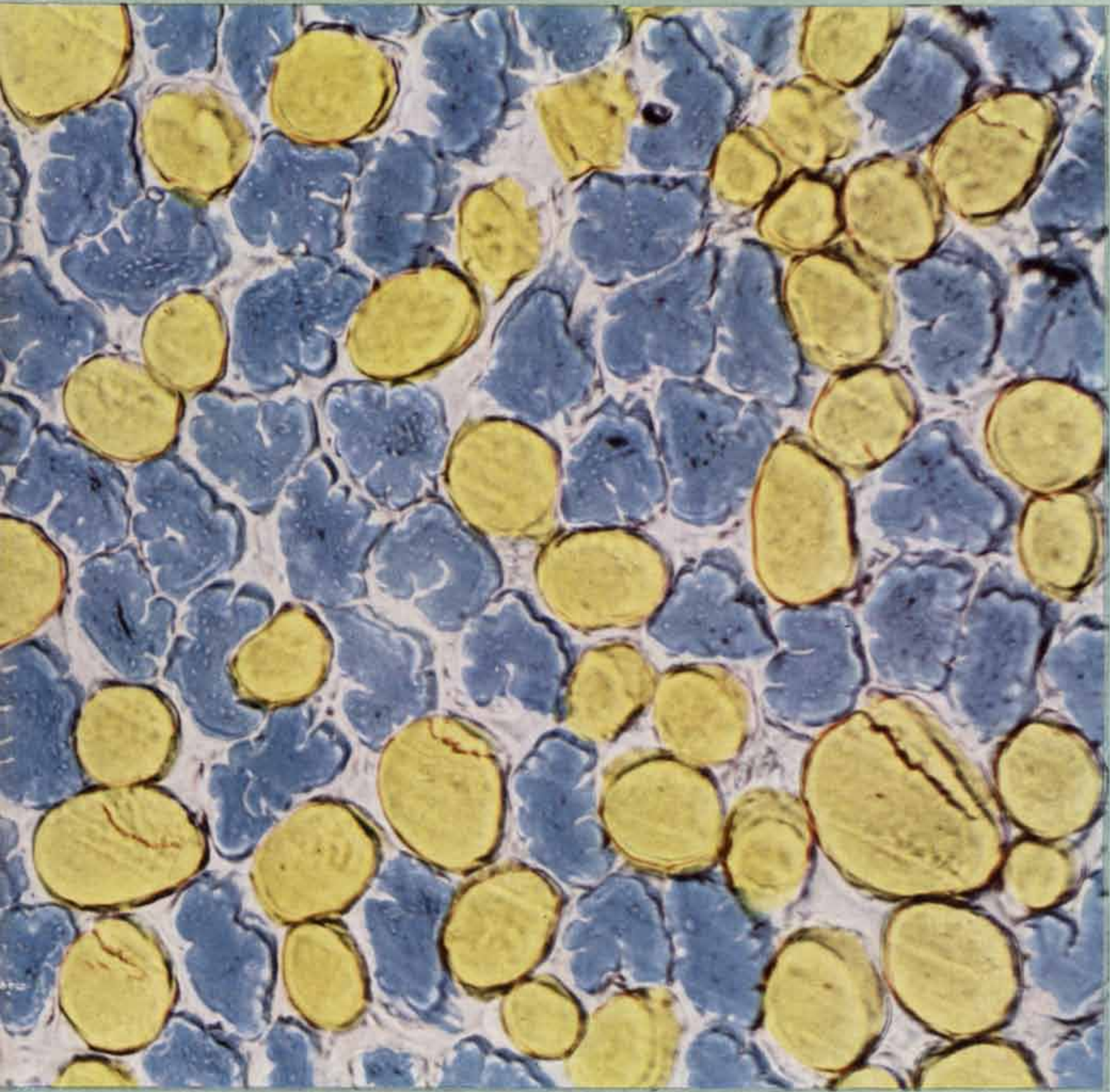
SCIENTIFIC AMERICAN



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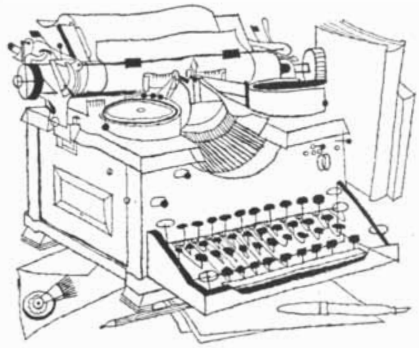
July 1951



LETTERS

Sirs:

Ernest Nagel's review in your May issue of *The Rise of Scientific Philosophy* by Hans Reichenbach moved me to attempt my own considerably less erudite review of Reichenbach's new book. The result was the following bit of nonsense. Perhaps I should add that in "real life" I am quite partisan to the philosophy of Reichenbach.

The Rise of Scientific Philosophy,

by Hans Reichenbach.

A brief review.

I know that this may cause a shock
—Says our author Reichenbach—
But full of nonsense is for me
Traditional philosophy.
I think it's time we start to scuttle
The *form* and *matter* of Aristotle.
And isn't it a little late, O,
For the idealism of Plato?
I must be equally emphatic
About rationalism post-Socratic.
And logically on the bum
Is René Descartes' *ergo sum.*
Then there's nothing quite as gory
As the *synthetic a priori;*
Except that nonsense elephantine
Of metaphysics neo-Kantian.
And full of holes is—like a bagel—
The dialectic law of Hegel
(Not to mention Ernest Nagel).
I must admit I'm more in tune
With such empiricists as Hume,
Provided I'm not too demanding
Concerning "Humean" Understanding.
For even Hume could not make sense
Of the inductive inference.
What caused this grievous *cul-de-sac*?
The *Search for Certainty,* by Locke!
But modern physics teaches us
—Insofar as she reaches us—
That there is sheer futility
In all but probability.
In this task nobly aiding her
Were Heisenberg and Schrödinger.
And now, without apologies,
I'll tell you what all knowledge is
(I could have said "apology"
And rhymed "epistemology"):
You get your axioms in position;
Coordinate your definition;
Then undergo an operation;
Meanwhile make your observation;
Then you have the whole thing licked,
For now you're able to predict.
The method won't get you in Dutch
Provided you don't ask too much.
For surely 'tis heuristical
That everything's statistical,
Though not the least bit mystical.
And so, dear reader, I've made *klar*
The thing *was zu beweisen war:*
How undogmatic one can be,
And still have a philosophy.

HARRY LUSTIG

Department of Physics
University of Illinois
Urbana, Ill.

Sirs:

In the March issue of the *Scientific American* Dr. Alphonse Chapanis has presented an interesting and clearly written discussion of the mythology and facts concerning color blindness. Valuable also is his condemnation of the "training" of color-deficient individuals to pass the tests administered by the armed services. As he correctly states, leading associations both of ophthalmologists and of optometrists have formally expressed disapproval of this practice which enabled the color-blind to become a danger both to themselves and their associates in the armed forces.

However, we believe an injustice has been done to optometry, probably unintentionally and chiefly by implication. Dr. Chapanis states that "Most of these claims [curing of color blindness] were made by optometrists. . . . Most of the people who attempted to cure color

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blindness were sincere but uninformed with respect to the physiological and psychological aspects of color vision. . . . If you think you are color-blind . . . the thing to do is to have yourself tested by a reliable ophthalmologist."

It is unfortunately true that *some* optometrists (doubtless a fraction of one per cent) did engage in color "training." The profession of optometry started later, and is coming to maturity later, than medicine. In consequence there are among the earlier optometrists some whose training is comparable to that of early physicians who attended proprietary medical schools (such as flourished before the Carnegie report of 1910) and received from practicing physicians more of the art and mystery of medicine than its scientific basis. The representative schools of optometry are now on a university basis, have adopted a five-year curriculum, and give a more thorough training in refraction as well as physiological and psychological optics than is offered by the majority of medical schools. (Both writers have taught physiology in a well-known medical school; both are at present teaching at an optometry school where "Physiological and Psychological Optics" is a 12-semester-unit course, extending over two years and including 128 hours of lectures and 128 hours of laboratory experiments, many of these in color vision.) That knowledge of the workings of the eye is not exclusively a medical problem is perhaps best illustrated by the fact that the excellent article under discussion was written by Dr. Chapanis, himself a psychologist. The rather urgent advice to see a "reliable ophthalmologist" seems somewhat odd since all agree that nothing can be done for the color defective. The fact that the color-blind individual is urged to "accept the fact as best you can" might, indeed, suggest a psychologist or psychiatrist.

The article is further proof that its author and the editors of *Scientific American* are interested in educating the public to understand and appreciate intelligent and skilled professional service. We are sure that there was no intention of being unfair to optometrists, who, while functioning within a more limited field, have the same professional ideals as do ophthalmologists or physicians.

MONROE J. HIRSCH, PH.D.

FRANK W. WEYMOUTH, PH.D.

Los Angeles College of Optometry
Los Angeles, Calif.

Sirs:

I quote from the article "People in Groups" in your February issue; page 28:

"The interaction profiles of a number of husband and wife teams . . . brought out . . . particularly interesting points. The first was that during the discussion the husband and wife gave information and facts about the situations rather than opinions and analyses. Apparently the efficiency of communication between them was such that a word or sentence of information was sufficient to make a point clearly, without the need for lengthy analysis."

And now I should like to quote from Tolstoy's *War and Peace*, page 1305, Inner Sanctum Edition:

"Pierre and Natasha, left alone, . . . began to talk as only a husband and wife can talk, that is, with extraordinary clearness and rapidity, understanding and expressing each other's thoughts in ways contrary to all rules of logic, without premises, deductions, or conclusions and in a quite peculiar way . . . from the moment this conversation began, contrary to all laws of logic and contrary to them because quite different subjects were talked about at one and the same time. This simultaneous discussion of many topics did not prevent a clear understanding but on the contrary was the surest sign that they fully understood one another."

Similarly, most of the "findings" of your article have been the common knowledge of intelligent foremen, executives and military men for a good long time. Business, which always seeks efficiency, did not need to hit on the "inverted-Y" system described in the article. And everyone knows that the lower echelons tend to gripe about orders from above.

Proponents of social relations experiments such as those described will say that these facts will become more useful as they are generalized and set into a readily applicable form for use by those who must work with people. There are two fallacies, I believe, to this idea. The first is that the study of behavior in specific, "hermetically sealed" conditions is impossible because of the complexity of human beings—one aspect of human nature cannot be separated from the rest. An original study would lead to the underlying motives of the individual. Second, any person intelligent enough to use the results of a Work Pattern Profile, for instance, should be able to judge a man intuitively, or he shouldn't have the responsibility.

I cannot see how any group or organization can be made to run efficiently and happily without the irrational but very real feeling of harmony in each of the members, instilled by an intuitive brand of leadership that comes with experience and intelligence. Tables and Work Pattern Profiles seem a mighty poor substitute, or even supplement.

THOMAS BLANDY

Harvard College
Cambridge, Mass.

50 AND 100 YEARS AGO

JULY 1901. "The motor-driven balloon of M. Santos-Dumont had a trial on July 12, the voyage being from St. Cloud around the Eiffel Tower at Paris and return. According to cable reports the speed was about 37 miles an hour. The height of the balloon above the ground varied from 320 to 890 feet. The aeronaut descended successfully six times upon foreordained spots."

"It cannot be too strongly urged that the only hope of utilizing the vastly increased powers which photography has given to astronomers lies in the multiplication of astronomical laboratories to measure the star photographs which have been made at the great observatories. Far more photographs have been obtained than can be measured in a reasonable number of years by the astronomers who took them, even if they could afford to lay aside the photographic survey of the heavens on which they were before engaged, and to let their telescopes stand idle, producing no more results."

"One hundred years ago it was generally believed to be impossible for two substances of entirely different properties to have the same composition. This phenomenon of isomerism, so rare at one time, is now very common. We have, for example, 55 substances having the formula $C_9H_{10}O_3$, all having the same elements in the same proportions, or the same kind of atoms and the same number of atoms of each kind. To explain isomerism it was necessary to assume that in these different bodies the atoms are differently arranged or grouped. Since 1888 a great deal of work has been done in the development of the theories of space chemistry or stereochemistry. We are in a position now not only to determine how the atoms are linked to one another, but also how they are actually grouped in space. Stereochemistry is the most attractive field of research in organic chemistry today. Prominent among the men who have contributed to this department of chemistry are van't Hoff, Wislicenus, Baeyer, and Emil Fischer."

"The density of population in foreign countries has recently been computed. Great Britain takes the lead with 132 inhabitants per square kilometer; then comes Japan, 114.4; Italy, 106.6; the German Empire, 104.2; Austria, 87; France, 72.2; Hungary, 59.6; Spain, 35.9; the U. S., 8.4; Russia, 5.9."

"Prof. Dewar, in a recent lecture before the Royal Society, reduced hydrogen to a solid and announced that a temperature had been produced which was eight or ten degrees lower than this, or within nine degrees of absolute zero. He is sanguine of success in the liquefaction of helium."

"On several occasions we have given an account of Count von Zeppelin's balloon and the experiments which he made with it. We regret to note that the machine has been badly injured. Violent storms which swept over central Europe in January nearly demolished the balloon house and ripped open the aerostat for about a third of its length. The inner framing, which was constructed of aluminum, was also badly twisted, and a large part of it was torn away."

"During the past fifteen years the borderland between chemistry and physics has been very successfully cultivated, and a new department of chemistry has resulted. This is the department known as physical chemistry, and it deals with such subjects as thermo- and electrochemistry, with chemical statics and chemical dynamics and with the laws of solution and electrolytic dissociation. A great deal of progress has been made in all these directions. It is especially the new theories of solution and of electrolytic dissociation that have most profoundly changed our ways of looking at chemical action."

"Automobiles for carrying merchandise to various parts of cities are attracting a good deal of attention at the hands of engineers. Recently extended trials of various types were held in Liverpool, and the conditions of competition were exacting. The total distance run was about 50 miles, and the several types came through with credit, accidents being very few."

JULY 1851. "In 1846 Prof. Horsford of Harvard published a paper in which he called attention to the interesting relation between glycocol and the other sweet bodies—grape sugar, sugar of lead, &c. He appended the query, 'is this similar taste dependent upon a similar arrangement of their minutest particles?' He has now published a pamphlet in which are enumerated, with their chemical formulae, a great number of substances to prove that such an arrangement does exist among bodies having a common taste."

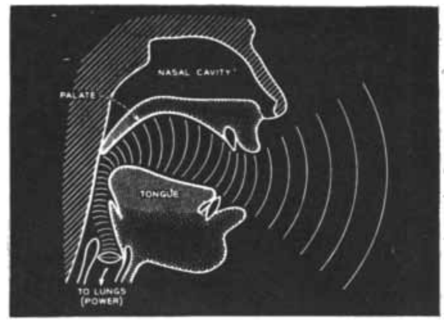
"Mr. Talbot, who is well known for his improvement in the photographic art, has just announced another which enables him to obtain images of objects moving with a certain velocity, a thing found impossible heretofore. Mr. Talbot's experiment overcomes the difficulty by an instantaneous flash of light producing the image."

"At a meeting of the Berlin Academy of Sciences held on May 31 last, the venerable Alexander von Humboldt made an interesting communication upon some observations of singular movements of fixed stars. It seems that at Trieste, January 17, 1851, between 7 and 8 o'clock P.M., before the rising of the moon, when the star Sirius was not far from the horizon, it was seen to perform a remarkable series of eccentric movements. It rose and sank, moved left and right, and sometimes seemed to move in a curved line. It also varied in brilliancy, growing alternately brighter and fainter, and now and then being for moments quite invisible, though the sky was perfectly clear. As far as it is known, this phenomenon has been remarked but twice before, once in 1799 from the Peak of Tenerife by von Humboldt himself."

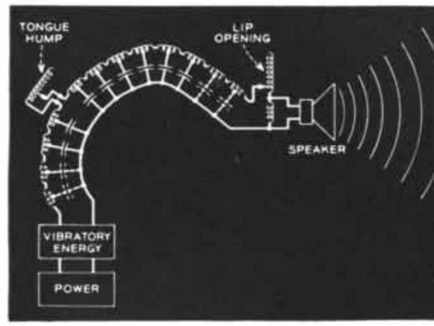
"The progress which medicine has made recently is so great that poisoning by morphine, strychnine, prussic acid and other vegetable substances, hitherto regarded as inaccessible to our means of investigation, may now be detected and recognized in an incontestable manner."

"Among the machinery in the American department at the Great Exhibition in London, the inventions of Capt. J. Ericsson, of New York, are very prominent, especially what is termed a caloric or hot-air engine. Another is his alarm barometer for ships."

"The new asteroid 'Irene,' discovered by Mr. Hind in London, has been observed at the National Observatory by Profs. Keith, Benedict and Major."



It tells how you talk



The machine at the left is saying "Ah!" It's the new electrical vocal system developed at Bell Laboratories. Top sketch shows human vocal system also saying "Ah!" The electrical model is sketched below it. Energy source at bottom of "tract" can emit a buzz sound, like vocal cord tone, or the hiss sound of a whisper.

No one else speaks exactly like you. Each of us uses different tones to say the same words. To study and measure *how* we make speech, acoustic scientists of Bell Telephone Laboratories built a model of the vocal system.

Electric waves copy those of the vocal cords, electric elements simulate the vocal tract, and, by adjustments, vowels and consonants are produced at pitches imitating a man's or woman's voice.

Using this electrical system, telephone scientists will be able the better to measure the properties of people's voices. Knowing more about speech they can find better and cheaper ways to transmit it.

This is another step in the research at Bell Telephone Laboratories which pioneered the exact knowledge of speech. Past work in the field is important in today's fine telephone service. A still deeper understanding of speech is essential in planning for tomorrow.

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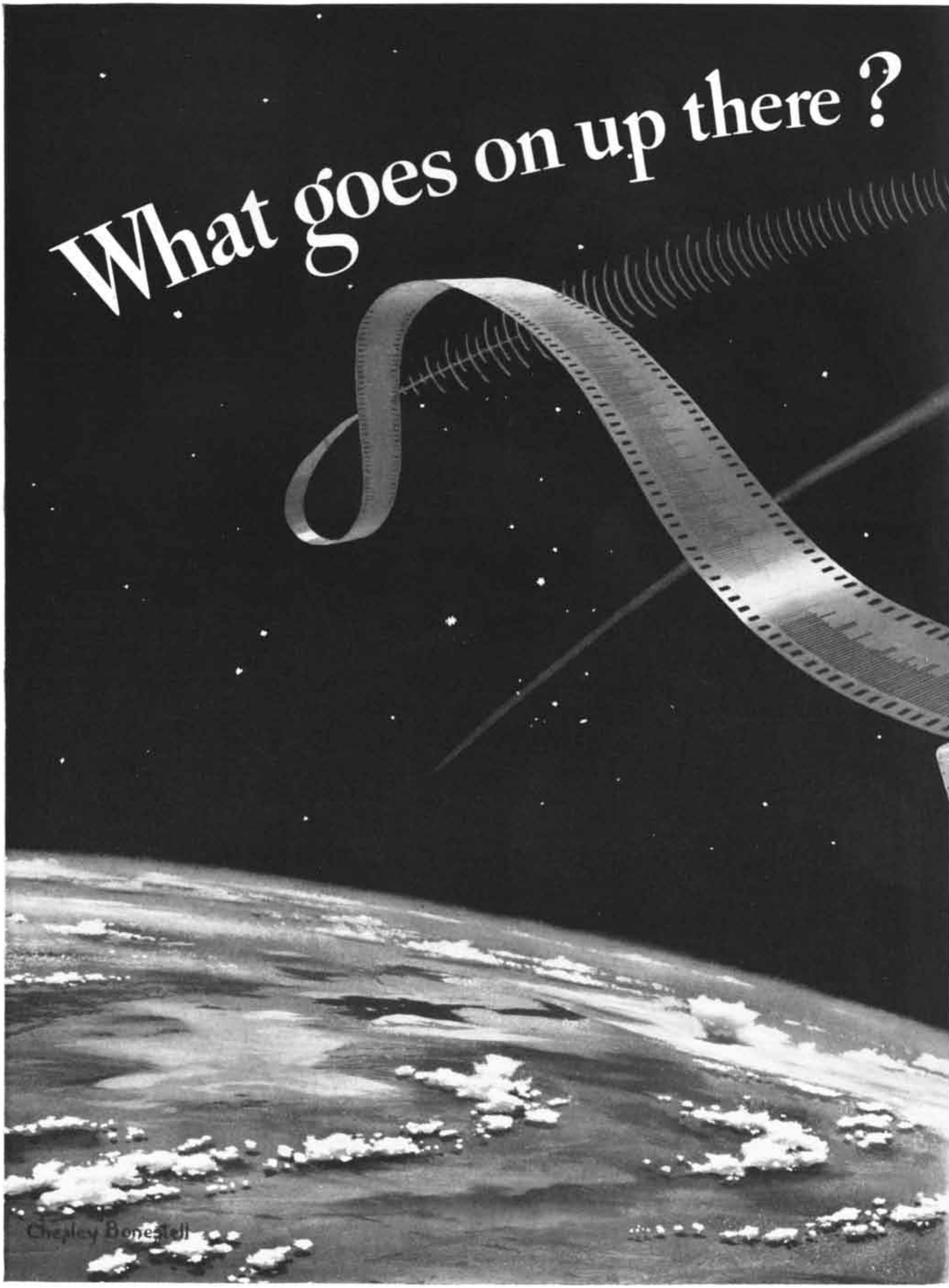
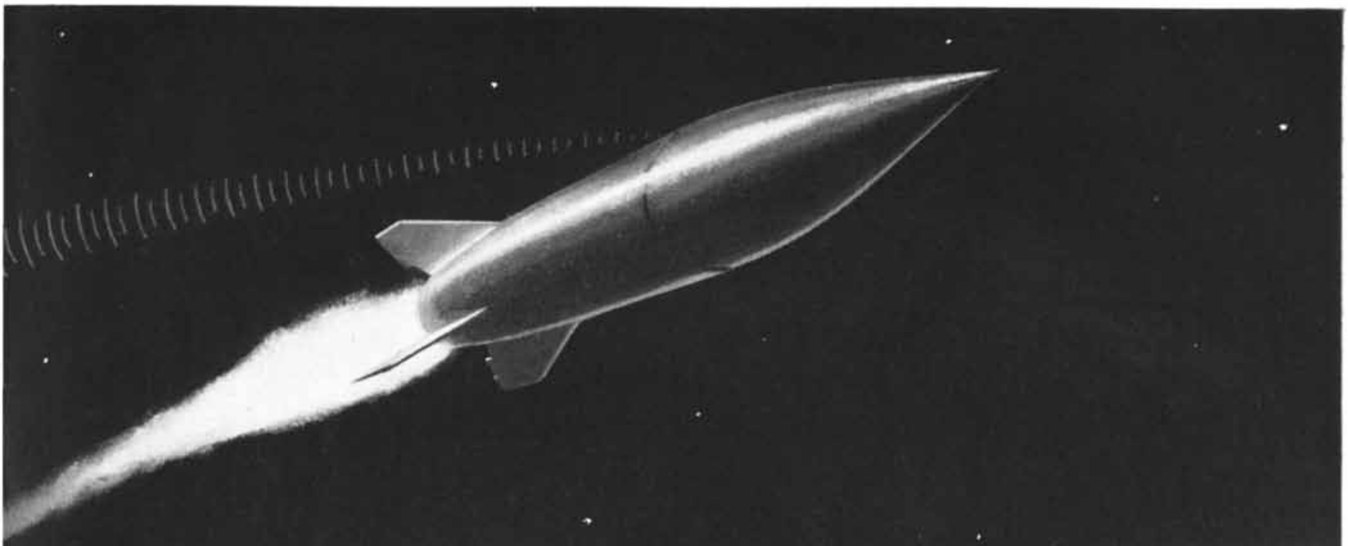
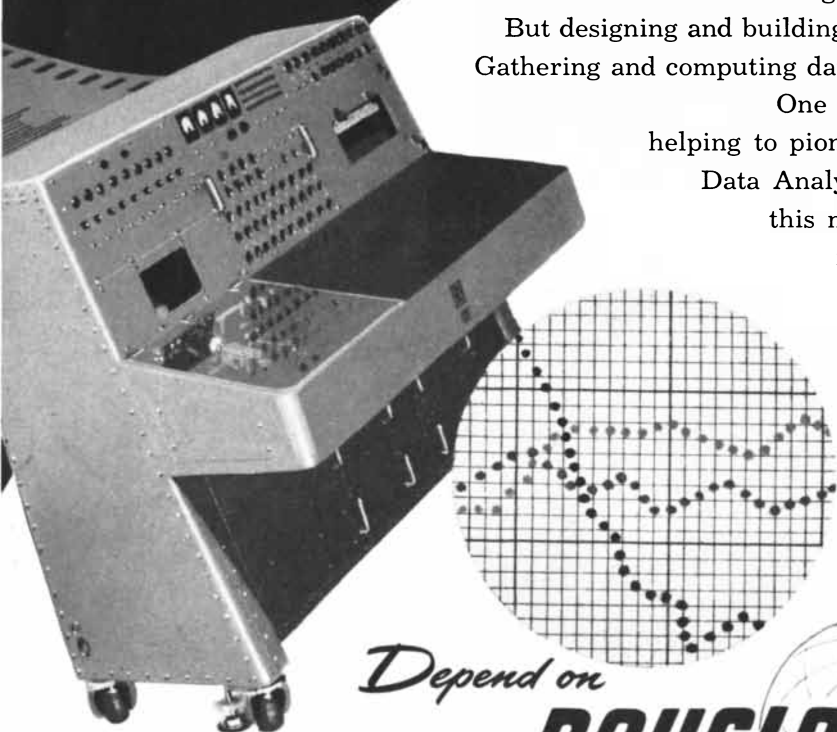

What goes on up there?
Chesley Bonestell



Highest and fastest flight ever attained by any known rocket was that achieved by the "Wac Corporal" on February 25, 1949. The "Wac" was fired from a larger "bumper" rocket miles above the earth's surface. Structural design of the "bumper" and construction of the "Wac" were among the contributions made by Douglas. But designing and building such missiles is only part of the job. Gathering and computing data secured by test flights is also vital. One of many examples of how Douglas is helping to pioneer this work is the new Automatic Data Analyzer. Developed for Army Ordnance, this machine converts coded photographic recordings, such as radio-transmitted missile data, into a flow of interpreted information from instruments to the engineers. In this important field of research analysis and application, as in many other activities in the aircraft and related industries, Douglas continues to make significant advances.

Douglas Aircraft Company, Inc.



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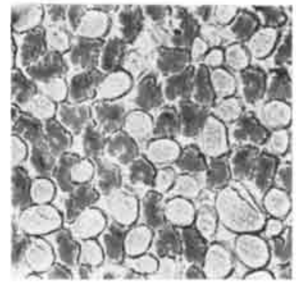

THE COVER

The round objects on the cover are the individual fibers of a textile yarn, seen in cross section. The original photomicrograph from which the cover was made enlarged the fibers 400 diameters; the cover has further increased this to 1,000 diameters. The yarn contains both natural and synthetic fibers, combining their desirable properties (*see page* 37). The rounder yellow objects are the cross sections of yellow-dyed wool. The blue objects with the scalloped edges are the cross sections of viscose rayon, the fiber derived from cellulose which together with acetate accounts for more than 90 per cent of all synthetic-fiber production. The photomicrograph was made in the Microscopical Laboratory of the Calco Chemical Division of the American Cyanamid Company in Bound Brook, N. J. The cross section was prepared by the Hardy technique by Florence Gustafson. It was photographed by Charles Maresh on Ektachrome Type B film.

THE ILLUSTRATIONS

Cover by Charles Maresh

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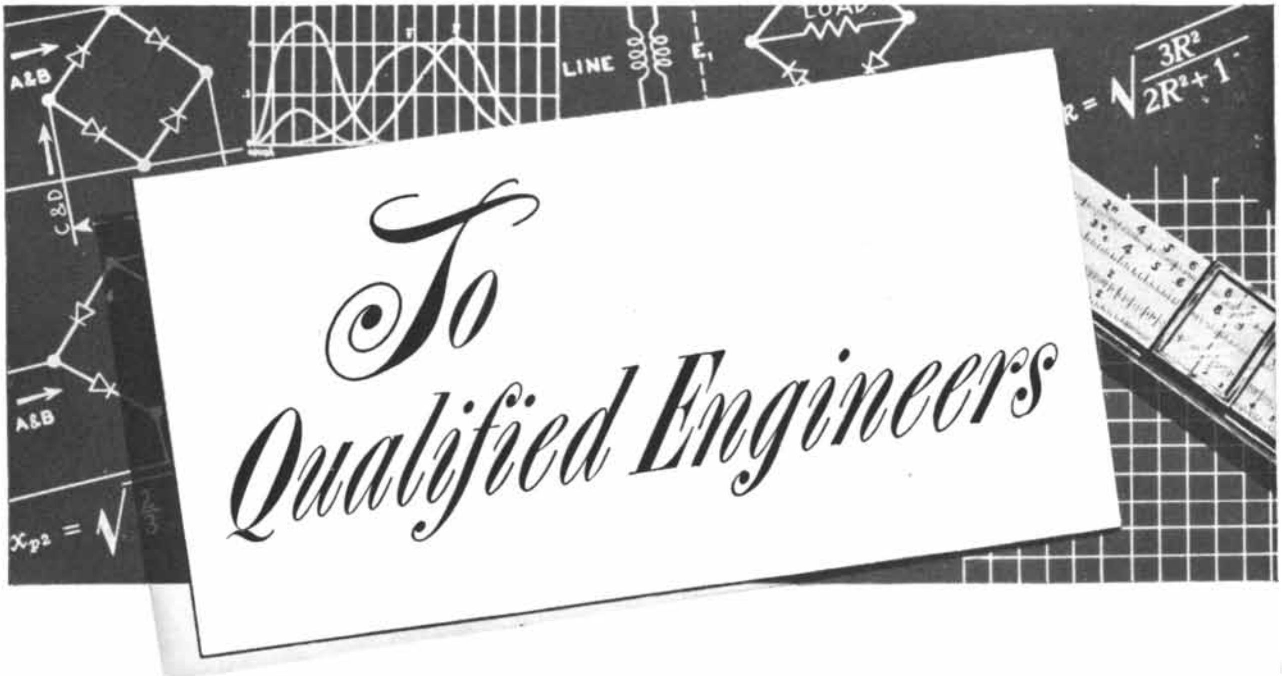

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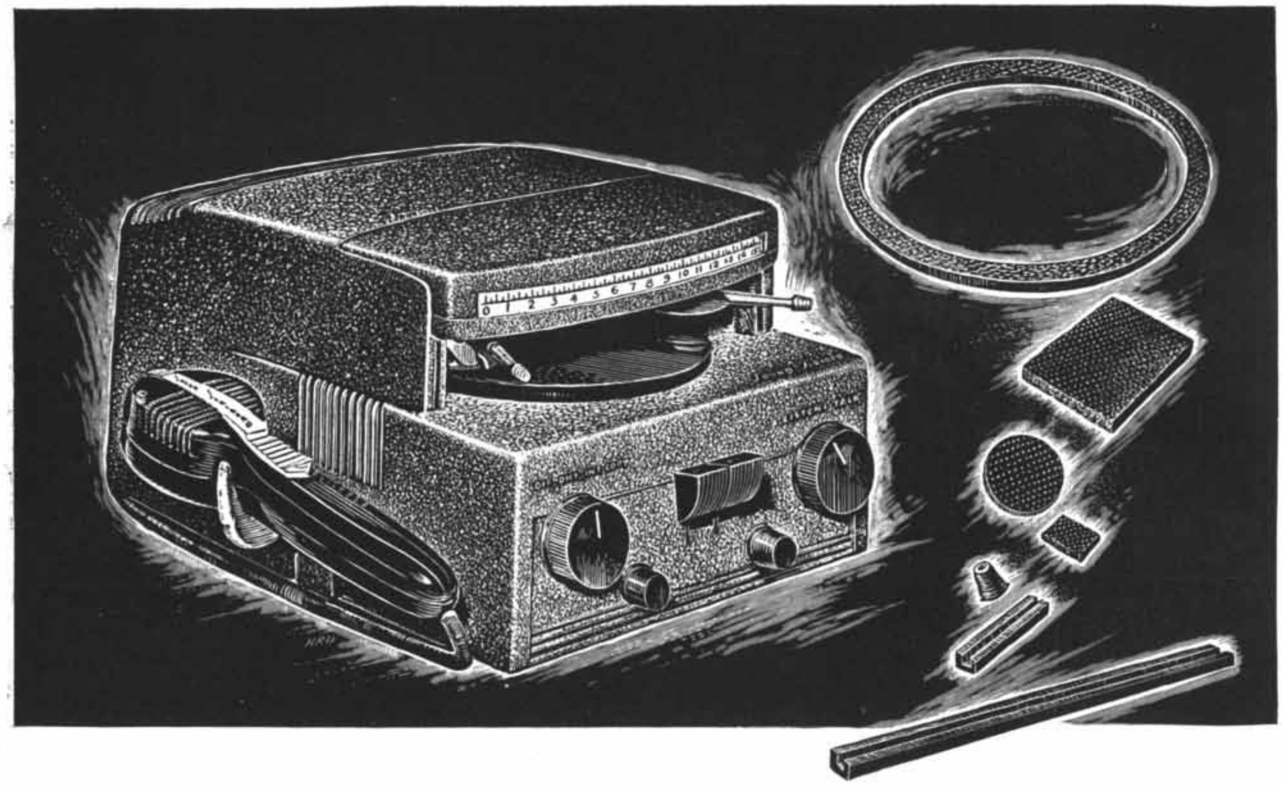

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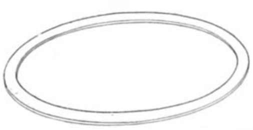
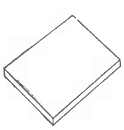
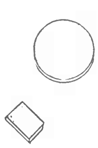


TURNTABLE CUSHION — prevents transmission of motor vibrations to recording disc. Cushion permits clear, noise-free recording. *A custom-molded Spongex part.*



AMPLIFIER INSULATOR — provides wall of insulation between plug-in amplifier and main electrical chassis. *Part is die-cut Spongex sheet stock.*



HAND MICROPHONE SPACERS — microphone element "floats" between rubber spacer cushions. These spacers protect the element from damage, and insulate it against transmitting the sound that would otherwise result from dropping or banging the microphone. *Spacers are die-cut Spongex sheet stock.*

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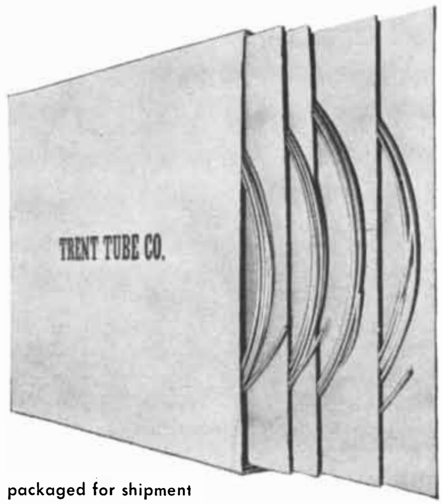
CONTENTS FOR JULY 1951 **VOL. 185, NO. 1**

ARTICLES

DEPARTMENTS

What's New at CRUCIBLE

about Trentweld Beverage Tubing



Beverage tubing packaged for shipment

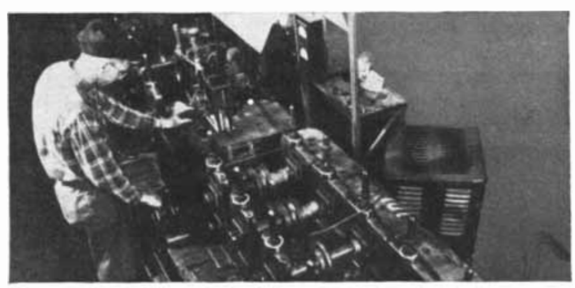
For many years nickel alloys and block tin have been used to make tubing for the soda fountain and beverage industries — applications such as syrup tanks and flavor dispensing lines, carbonated water lines, cooling coils, soda fountain refrigeration coils, beer lines, picnic coolers and tap rods, all requiring corrosion resistant tubing. Due to improvements and changes in processing, nickel alloys have not had satisfactory resistance to withstand the corrosiveness of carbonated water and beverages. This left block tin as the only satisfactory metal from which beverage tubing could be made. Trent Tube, a Crucible subsidiary, was called upon to produce a satisfactory stainless steel tube to meet the demands.

Stainless steel itself is entirely satisfactory from a corrosion standpoint, however, there was much more to the production of a beverage tube than just the metal to withstand corrosion. Second to corrosion, the tubes must be ductile enough to be formed by hand on the job. In order to meet this ductility requirement, Trent made slight changes in the chrome-nickel balance in the analysis and a special annealing practice was developed to obtain maximum ductility for this type of tube. After considerable experimentation on the part of Trent's technical staff, a beverage tube was produced with a Rockwell hardness very near to that of the nickel alloys that had been used in the past.

After the proper analysis and annealing technique had been developed, further experimental work had to be done to insure a bright, clean, sanitary tube on both the inside and outside surfaces. As beverage tubing is usually furnished in 50-ft. lengths, it was difficult to insure a bright oxide-free surface on the inside center of these long lengths. Special bright annealing technique had to be developed to insure absolute absence of oxygen on the inside of the tube during the bright annealing operation.

After a completely bright inside surface was assured, a special passivating technique had to be developed to insure the removal of all free iron on both the outside and inside surfaces of the tube. Free iron on the surface of a tube will result in rusting when placed in service. Rusting of the surface of stainless almost invariably results in setting up a concentration cell, causing a pitting attack which continues until the wall of a tube is penetrated, causing a leak. The special passivating technique developed by Trent insures complete removal of all free iron, and subsequent cleaning operations assure the complete removal of all acids used in these operations. The inside of the tube still remains completely bright.

A unique method of packaging 50-ft. lengths of beverage tubing has found great favor in the beverage industry. The tubing is coiled in compact 30″ diameter coils without appreciably affecting the hardness through cold-working. Four of these coils are placed in cartons, making it very convenient for distributors who sell in small quantities. Five of the small cartons are shipped in a larger carton, making a total of 1,000 ft. per package. These 1,000 ft. packages are convenient for warehouse storage and make it extremely easy to keep inventory records. The small cartons also make it convenient for the ultimate user to store or transport the beverage tubing on the job.



View of Trent machine showing strip as it is formed into tubing

Stainless steel has the characteristic of hardening by cold working which is at a minimum in Trentweld beverage tubing; however, improper handling in making the flares for fittings and in the bending operation may cause trouble. For a detailed brochure on methods of flaring and bending write: TRENT TUBE COMPANY, subsidiary of CRUCIBLE STEEL COMPANY OF AMERICA, General Sales and Operating Offices, East Troy, Wis.

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SCIENTIFIC AMERICAN

JULY 1951 VOL. 185, NO. 1

The Origins of U.S. Scientists

What is the educational background of our doctors of natural science? A survey indicates that liberal arts colleges produce more of them per thousand graduates than large universities do

by H. B. Goodrich, R. H. Knapp and George A. W. Boehm

THE making of a scientist has always been a more or less mysterious affair. The origins of the famous scientists of the past show no particular pattern: some were well educated and some poorly, some trained in science and some untrained, some guided toward science from childhood and some impelled into it fortuitously at a relatively late age. Today science is so complex and formidable a discipline that it might seem there is no room for happenstance or deviation in the development of a scientist; it would almost appear that a candidate must be specially prepared for this esoteric calling from birth, like the Spartans for soldiering. Asked where U. S. scientists come from, the average person would probably say that they flow mainly from the major centers of American intellectual activity and are prepared predominantly in our great universities and special scientific schools.

The facts say otherwise, as a recently completed study makes clear. The survey, a statistical analysis that took some five years, produced several significant surprises. This article will summarize some of our principal findings and conclusions; a detailed report of the survey will shortly be published in book form.

In 1946 a committee of the Wesleyan University science faculty was appointed to study the undergraduate training of U. S. scientists. Supported by the university trustees and subsequently by the Carnegie Foundation, the project rapidly grew in scope. By the time it was completed, it had become a broad survey in cultural anthropology—an examination of the undergraduate ecology of the nation's scientific manpower.

The first step was to define "scientist." For want of a better measure we chose as the subjects of the study all persons who had received doctorates in the natural sciences and were listed in *American Men of Science*. (We had decided, for various reasons, to exclude social scientists.)

The next step was a statistical survey aimed mainly at finding out just what to investigate. Tabulations from the third (1921) and seventh (1944) editions of *American Men of Science* showed that in each decade from 1880 to 1930, the last year for which complete listings were available, the number of scientists roughly doubled. In certain fields the increase was more spectacular than in others: physics and biology closely followed the general rate of increase; geology, mathematics and astronomy suffered a relative decline in numbers; the course of psychology was somewhat erratic; chemistry, from the turn of the century, rose at an accelerating pace, outstripping the growth rate of any other field. In general, the scientific fields that offered the brightest hope of employment and good pay, especially through the opening of industrial applications, attracted the most people.

The preliminary survey also showed that individual undergraduate institutions varied greatly in their output of future scientists. The output of a given institution of course fluctuated from decade to decade with changes in teaching and administrative staffs, but it became clear that some colleges consistently produced a larger proportion of scientists than others, at least since the First World War. Moreover, these institutions were highly productive not just in one field of science but in various fields.

ACCORDINGLY we decided to study the productiveness of the undergraduate colleges in more detail and to determine why some turned out relatively many scientists, others very few. As the index of a college's performance in this respect we used the number of graduates per thousand who subsequently earned a Ph.D. in science. In coeducational schools we considered only male graduates, since relatively few women obtain doctorates in science. We also restricted the study to men who graduated from college between 1924 and 1934, in order to obtain a peacetime picture without the dislocations in education caused by the two world wars. As a check on the validity of our use of the listings in *American Men of Science* we computed a test index based on the list of doctorates in the natural sciences compiled by the National Research Council. This index had a high correlation with the one obtained from *American Men of Science*, confirming the validity of the latter.

What does the index show? The first surprise is that small liberal arts colleges are far and away the most productive sources of future scientists among U. S. institutions. Of the 50 leading institutions in this respect (*i.e.*, those that turn out the largest proportion of graduates who become scientists), 39 are small liberal arts colleges (*see next page*). Only three large universities appear on this list of leaders, and only two technological institutions; the others among the 50 are three state agricultural schools and three small universities that lean toward technology.

For some of the smaller institutions on the list the number of graduates and scientists is too small to make the indexes statistically reliable. But the striking accomplishment of the 39 liberal arts colleges as a group is beyond dispute, as rigorous statistical methods demonstrate.

The second striking fact, which may

surprise some, is that the institutions which lead in the production of scientists are mainly concentrated in the Middle West (*see map on the opposite page*). That this region is particularly productive of scientists is confirmed by a study of all the 500 institutions for which indexes were computed. In that ranking the Middle West and the Pacific coast lead the nation, with the Middle Atlantic States and New England next and the South last.

The significance of this situation is underlined by the fact that in the production of graduates entering some other professions, such as the law, the ranking is quite different. According to a survey made before World War II, the U. S. Northeast is the region most productive of future lawyers; of the 35 undergraduate institutions that led in this respect nearly two-thirds were in New England, New York and Pennsylvania.

OUR next step was to compare groups of institutions, classified according to type, in their output of future scientists. Here the top position was taken by the state-supported agricultural colleges, which as a group had an average index of 19.8 scientists per 1,000 male graduates. The liberal arts colleges came next; the average index of a group made up of 153 privately endowed, non-Catholic colleges graduating from 30 to 200 students a year was 17.8. A group made up of 50 eminent universities stood only in third place, with an average index of 13.8. The leading engineering schools as a group (excluding California Institute of Technology, which occupies a class by itself) produced only 6.4 scientists per 1,000 graduates. The lowest-ranking group was that composed of all the Catholic institutions in the U. S.; their average index was 2.8.

In the case of the agricultural colleges, which achieve top rating here, we must take into account that almost every student in these colleges majors in some kind of scientific work, whereas in the other types of schools on the average only one student in three is a science major. Taking this factor into consideration, it again appears that in proportion to the number of undergraduates studying sciences, the liberal arts colleges are the most productive of scientists.

The low ranking of the technical schools in this hierarchy can be explained by their vocational emphasis; their training is mainly for engineers, not scientists. An engineer receiving a bachelor's or master's degree in a technical school is ready to take a job and does not usually go on to get a Ph.D. On the other hand, a physicist, chemist or mathematician may be severely handicapped in his profession unless he continues his education through the doctoral level.

Probing more deeply by looking into the differences between individual colleges and universities, we found some factors which seemed significant. Besides the factor of geographic location, already mentioned, we discovered that the intellectual quality of the student body in a college and the cost of attending the institution were related to the college's production of future scientists. Colleges that had a high average student intellect, as measured by the American Council on Education psychological tests, tended to show a high production of scientists. As for cost of attendance, the relatively inexpensive and the relatively expensive schools were less productive than those of moderate cost. We believe that the failure of high-cost institutions to achieve distinction in the production of scientists is attributable to the fact that the relatively wealthy students who attend them do not, as a class, turn to science. Evidence which we have assembled indicates that scientists are rarely drawn from homes of wealth. The economic prospects of the scientific profession offer too little inducement to wealthy youngsters; they prefer to maintain their economic standing by going into law, medicine, business management or other work with a greater financial reward than science.

THESE were the major findings of our statistical study. Next we got down to cases. Knapp took a year's leave of absence to visit and study at first hand 22 selected liberal arts colleges, some prominent, others obscure. One of the most rewarding investigations was that of Reed College.

This small college in Oregon with a total enrollment of only about 600 has been far and away more productive of future scientists than any other institution in the U. S. Since its founding in 1911, Reed has had a brilliant record of achievement, though from early days it has labored under financial handicaps. Between 1925 and 1940 it produced 12 Rhodes Scholars. During the 1924-1934 period that we studied, 44 per cent of Reed's students majored in a physical or biological science. The college's claim to distinction is not confined to the natural sciences; it is probably as well known for its graduates who have done outstanding work in the social sciences. Though salaries have been relatively low, many top-notch men have come to Reed to teach and have stayed there, disdaining more lucrative positions. Among the students, most of whom commute from nearby Portland, the campus hero is the scholar. The curriculum is organized to foster maximum individuality of instruction, and teachers and pupils alike carry on a tradition of disputatiousness which in many another institution might be a sign of disorganization and dissatisfaction.

Yet anyone who is tempted to draw generalizations from Reed, as far as productivity of scientists is concerned, should consider Iowa Wesleyan, which stands at the opposite end of the spectrum in almost every way. Iowa Wesleyan, like Reed, has an enviable record in production of scientists. But unlike Reed, it has had little else to recommend it. During the depression it was on the verge of closing its doors, and its regional accreditation was withdrawn for several years. Its student body was of undistinguished quality. Its faculty, which had almost no voice in the administration, was perennially disgruntled and appallingly underpaid; the turnover was so rapid that most of the teachers might almost have been taken for transient guests. The region from which Iowa Wesleyan draws its student body is ground down by an endemic economic depression. But in this setting two men stand out like knights in shining armor. One of them, a competent physics professor and successful inventor, designed equipment for Admiral Byrd's first Antarctic expedition. The other, a chemist, invented a successful process for making patent leather. Consequently to a great many Iowa Wesleyan students a scientif-

1.	Reed	Ore.
2.	California Institute of Technology	Calif.
3.	Kalamazoo	Mich.
4.	Earlham	Ind.
5.	Oberlin	Ohio
6.	Massachusetts State	Mass.
7.	Hope	Mich.
8.	DePauw University	Ind.
9.	Nebraska Wesleyan University	Neb.
10.	Iowa Wesleyan	Iowa
11.	Antioch	Ohio
12.	Marietta	Ohio
13.	Colorado	Colo.
14.	Cornell	Iowa
15.	Central	Mo.
16.	Chicago, University of	Ill.
17.	Haverford	Pa.
18.	Clark University	Mass.
19.	Johns Hopkins University	Md.
20.	Emporia	Kan.
21.	Pomona	Calif.
22.	Wesleyan University	Conn.
23.	St. Olaf	Minn.
24.	Montana State	Mont.
25.	Utah State Agricultural	Utah
26.	Beloit	Wis.
27.	Bluffton	Ohio
28.	Carleton	Minn.
29.	Charleston	S. C.
30.	Wooster	Ohio
31.	Willamette University	Ore.
32.	Brigham Young University	Utah
33.	Swarthmore	Pa.
34.	Southwestern	Kan.
35.	Lawrence	Wis.
36.	Wabash	Ind.
37.	West Virginia Wesleyan	W. Va.
38.	Rochester, University of	N. Y.
39.	Westminster	Mo.
40.	Simpson	Iowa
41.	Hiram	Ohio
42.	Grinnell	Iowa
43.	Drury	Mo.
44.	Miami University	Ohio
45.	Wisconsin, University of	Wis.
46.	Muskingum	Ohio
47.	Butler University	Ind.
48.	Eureka	Ill.
49.	Lebanon Valley	Pa.
50.	South Dakota School of Mines	S. D.

FIFTY BEST PRODUCERS of natural scientists are listed on the left ic career seems to hold out great opportunities, and they try to emulate their local heroes.

In addition to investigating individual institutions, we examined the records of approximately 200 professors and attempted to determine what factors, personal and pedagogical, influence students to take up careers in science. This was done by direct investigation and by questionnaires sent to former pupils.

Statistical examination of the ratings assigned by students and by the investigator indicated first that a successful teacher of science usually is not especially distinguished for his mastery of superficial pedagogic skills. Rather, the successful teachers are marked by three cardinal traits: masterfulness, warmth and professional dignity. It would appear that the success of such teachers rests mainly upon their capacity to assume a father role to their students, in the best sense, and to inspire them to an emulation of the teacher's achievements.

In the light of our studies, what environments are most conducive to the production of American men of science? Our evidence points to the fact that the most productive type of institution is a small liberal arts college, especially at a certain stage of its evolution. The typical U. S. liberal arts college was originally founded by a Protestant sect to train clergy and teachers. It drew most of its student body from the surrounding area and the economic middle and lower-middle class. In the second stage it becomes secularized but continues to draw its students mainly from the same population as before. Eventually such a college may develop into a heavily endowed institution of high reputation, attracting a wealthier class of students. But our statistical and case studies show that those liberal arts colleges that are in the second stage of this evolution are most productive of scientists. Among U. S. colleges those in the East and South are generally older than those in the West. Thus many of the Eastern and Southern schools have passed through the highly productive second stage, while the Western colleges are now in the midst of it. Then, too, the frontier traditions of the West, based on intimate association with the natural universe, seem conducive to the development of scientific interest. One might say that as frontier regions enter the first stages of intellectual development, they turn with particular enthusiasm to the pursuit of science, even though their largely agrarian way of life offers few local prospects of professional employment.

Though some of our conclusions may be tentative and others clearly speculative, our survey has established certain facts that are pertinent to the present manpower emergency. Certainly the clear demonstration of the contributions of smaller liberal arts colleges to the scientific profession should be of considerable interest to those formulating our national policies.

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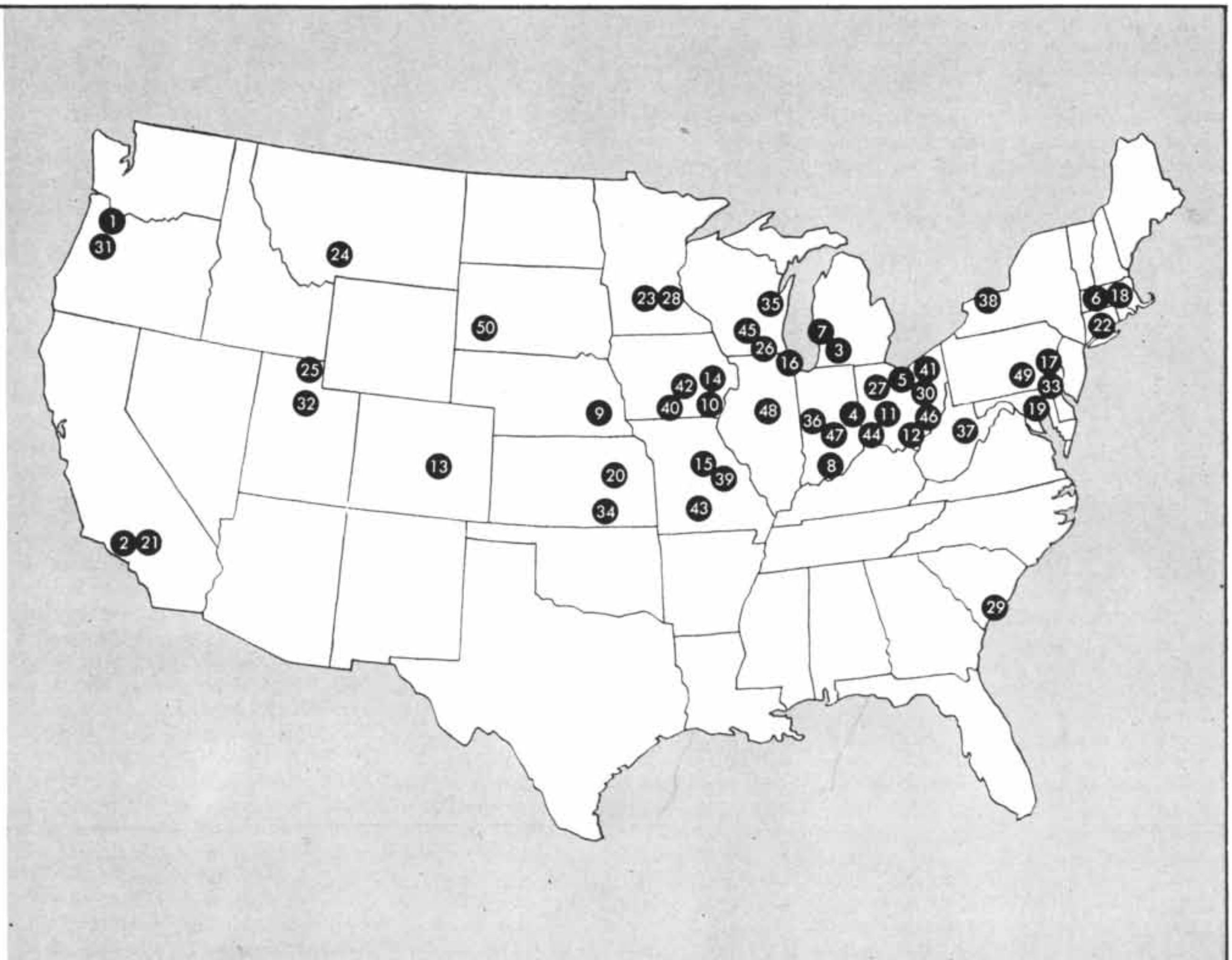


side of this illustration. In the third column from the left is the number of graduates per thousand who went on to take a doctor's degree in a natural science. Each institution is located by a number on the map.

Artificial Respiration

A man apparently dead of electric shock or drowning can live a surprisingly long time. A study of the phenomenon indicates that the common method of resuscitation is inferior to another

by Stefan Jellinek

THE fact that victims of electric shock or drowning can often be saved by artificial respiration has been known for decades, but remarkably little progress has been made in the effective application of this knowledge. Although the past half-century has brought prodigious advances in almost all other fields of medicine, in this particular field we have been standing still. The rate of success in resuscitation of people who meet with such accidents is no better today than it was 50 years ago. In the opinion of this writer there are two main reasons for this: artificial respiration as generally practiced is often a menace rather than a help, and there still exists among many physicians a lamentable confusion as to when a person is really dead.

Many cases could be cited to illustrate the latter point. One particularly dramatic case is recorded in a memorandum of the British Home Office. A laborer in a Scottish factory was struck by 400 volts direct current and fell apparently lifeless. A physician who examined him issued a certificate of death. But the laborer's fellow workers, refusing to give up, went on applying artificial respiration and eventually revived the "corpse."

Many years ago we were called to a power station in Vienna where a worker had received a severe electric shock: 10,000 volts alternating current. When we arrived, a doctor told us that he had found no pulse or respiration in the patient and had certified death. When we remonstrated with him for putting a stop to resuscitation efforts, he declared that the voltage the man had received was certainly fatal. Because of our remonstrance we received an official reprimand for unprofessional interference from the Vienna Medical Council. But a post-mortem examination of the victim showed that certain vital processes had taken place in his body after the shock, proving that he was not killed instantaneously.

In pronouncing these victims dead the two physicians were influenced not only by the fact that failure of the pulse and of respiration was (and still is) generally considered to be conclusive evidence of death, but also by a medical tradition that there was no possibility of recovery from electric shock. This belief had apparently received experimental support from certain studies made during the latter half of the 19th century, when the use of electric current was becoming widespread. Two Swiss investigators, J.-L. Prévost and F. Battelli, observed that when a dog was electrocuted, its heart went into ventricular fibrillation—a state of incoordinate twitching of the cardiac muscle fibers. In such cases the heart apparently never recovered its normal rhythm and always failed. They concluded that ventricular fibrillation was irreversible. All authorities agreed that an electric shock of sufficient size produced instantaneous and inevitable death in any animal.

ACTUALLY Prévost's and Battelli's experiments did not justify any such theory for man. In 1929 we repeated the experiment on anesthetized monkeys. The electrocardiograph showed that after the heart went into ventricular fibrillation it often recovered normal rhythm quite spontaneously. In other words, the condition definitely is reversible, at least in the primates, including man.

Furthermore, we now know that a victim of this kind of accident may be alive even though his pulse and breathing have stopped. There is a definite period after the obvious signs of life have disappeared when active processes still go on in the body. During this period, or at least the early part of it, the victim may be saved by proper methods of resuscitation. Opinions still differ as to how long that period may be: at the last International Life-Saving Congress in Copenhagen in 1934 various delegates argued in favor of one, two, three or four hours, respectively. The answer surely is that resuscitation should be continued, regardless of the clock, until the victim revives or there are incontrovertible signs of death. The patient should be given the benefit of the doubt until death is irrefutable.

What are the final and unanswerable signs of death? There are just a few, and they have been known for a long time. One is the gravitational effusion of blood from the relaxed blood vessels in the parts of the body that lie lowermost, usually the back, into the tissues. About half an hour after death many bluish spots appear under the skin, gradually increasing in size. This produces the characteristic lividity of death. Another sure sign of death is rigor mortis, a tightening of the muscles which manifests itself as stiffness of the joints and springiness in the ankles. The time of appearance of rigor mortis after death is very variable.

Everyone who applies artificial respiration to a drowned or electrocuted person should understand these conclusive indications of death and accept nothing less as a sign that no more can be done. In 1905 the author was led to the conclusion that before these signs appear the victim of an electric shock or drowning may be in a state of suspended animation. The chief basis of this idea was the autopsy findings, which in many cases were really quite incompatible with immediate death.

Careful post-mortem examinations showed that many victims of such accidents bore the changes associated by pathologists with the slow extinction of life through lack of oxygen in asphyxiation. There were many small internal hemorrhages, especially in the so-called serous membranes of the body such as the heart sac, or pericardium. The lung and brain especially were engorged with tissue fluid, and the air passages were sometimes full of the frothy fluid of edema of the lungs. A careful microscopic examination sometimes revealed an accumulation of cells in the spaces around the blood vessels in the brain tissue, such as is found in patients dying a few days after the onset of illness from some forms of cerebral inflammation. We were particularly impressed by the finding that a few victims who had received unsuccessful artificial respiration treatments showed unmistakable bruises of the manipulated muscles and bones—bruises that could not have been produced if bodily processes had not been functioning. All these and other changes indicated a gradual devitalization, rather than a sudden extinction, of the victims.

In these moments or minutes of suspended animation when life seems to be ebbing away, the organism exhibits complex and sometimes mystifying behavior. Occasionally a kind of "intermittent death" occurs. There was, for example, the case of a 35-year-old foreman in a power station who received an electric discharge of 5,000 volts while turning on an elevated platform to give instructions to the other men. He collapsed and lay for a few moments without movement. Then, before his workmates could get near him, he got up, said that he had had a near miss and walked down the three steps from the platform, apparently quite well. When he got to the bottom, however, he collapsed lifeless a second time and could not be revived.

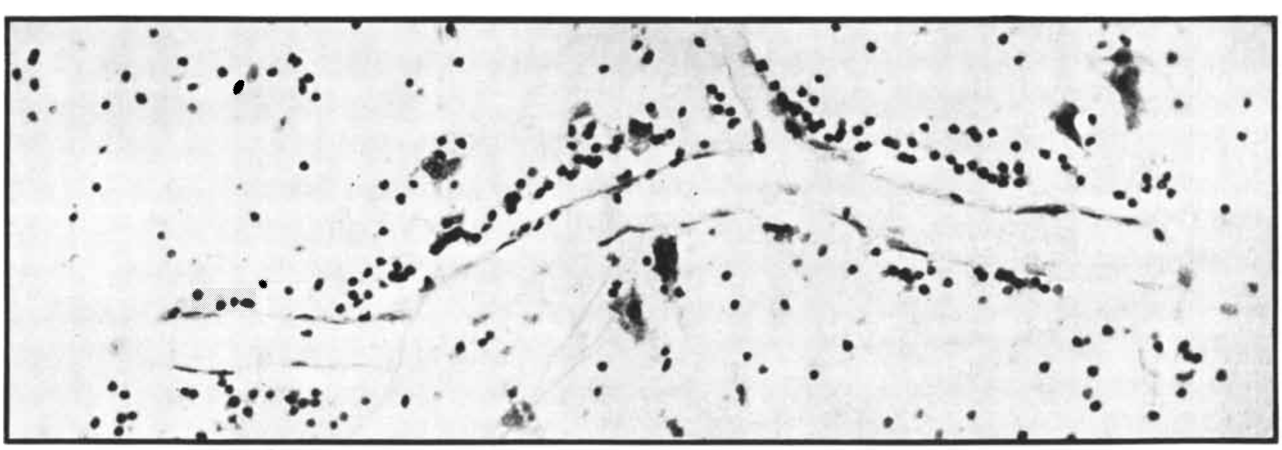
The most extreme instance of clinging to life after electric shock was a phenomenon we observed some years back at the Vienna slaughterhouse for pigs. It was the practice then to stun the animals by momentarily applying a direct electric current of 60 volts to the back of the head. After the electric shock the great vessels in the neck of the animals were severed and the pigs were "bled white." Then the carcasses (and no doctor or biologist would call the exsanguinated objects with absent reflexes anything else) were thrown into vats containing hot water at 60 degrees Centigrade. The animals started violent and apparently coordinated swimming movements. These lasted about six or eight seconds, and the animals then subsided into the previous flaccid and lifeless state. Their coordinated behavior was very different from the familiar muscle twitches and other isolated reflex activity that one often sees in newly killed animals. We regard this phenomenon as specially significant because it occurred only in those pigs that had been stunned by an electric shock; those stunned by the traditional hammer blow on the head showed no such behavior.

There is another sign of life that occurs during this period of suspended animation before final death—the act of swallowing. We noticed that very often after a patient dying of disease has drawn his last breath, a swallowing movement takes place a short time later, as evidenced by motions of the Adam's apple and occasionally by an associated gulping noise. We confirmed this phenomenon experimentally in the course of a study of the effects of carbon-monoxide poisoning in monkeys. These monkeys showed the same signs of swallowing after their breathing had stopped. When they received a sublethal dose of the gas, sufficient only to halt their breathing temporarily, a swallowing movement was the first signal of returning spontaneous respiration.

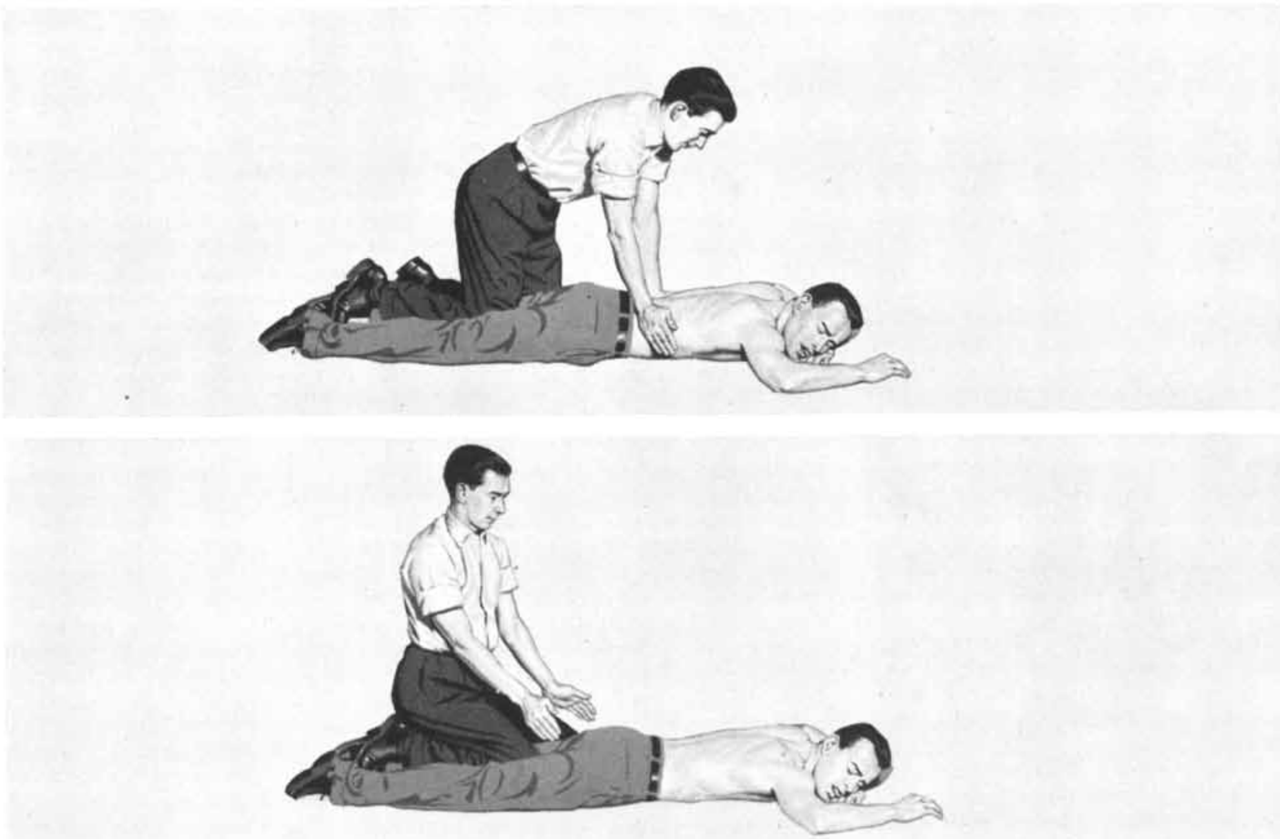
In 1919 a most dramatic case of this kind was reported in Berlin. A 23-year-old nursing sister attempted suicide by taking an overdose of Veronal in a park on a winter evening. She was found the following evening with faint signs of life, but she "expired" in the ambulance and was taken to the mortuary at Grünewald cemetery, where a physician pronounced her dead. She was put in a coffin and left in the cold mortuary. Fourteen hours later the police opened the coffin to identify the girl, and an attendant noticed a slight swallowing movement of the larynx. The physician, recalled, could feel no pulse or see any sign of respiration, but he heard faint heart sounds. The girl was taken to a hospital and given artificial respiration, stimulants, warmth, and so on. After a few hours of treatment she revived! Apparently the cold, which lowered the metabolic requirements, was responsible for her unusually long survival in a state of suspended animation.

It is important, therefore, to watch for signs of swallowing when administering artificial respiration to a shock victim. A swallowing movement may be the first sign of returning life. When it occurs, the artificial respiration treatment should be stopped for a moment to see whether spontaneous respiration has returned, for continuance of artificial respiration against spontaneous breathing may kill the patient.

The condition of suspended animation and the possibility of revival are present only in cases of violent, accidental "death"; when a patient dies of disease, there need be no fear of premature burial. From the processes that take place in death from disease we may, however, gain clues to the explanation of suspended animation. In a patient dying of long-drawn-out disease there is usually a slow dissolution or relaxation of the mind and body. In most cases the patient finally lapses into a deepening coma from which he never revives. Yet occasionally we have come across a case in which such a patient has awakened suddenly from his coma into a brief burst of consciousness during which he was mentally quite clear and capable of fair motor activity. We remember particularly the case of a dying man who had been an assistant hangman and had participated in a number of executions. He was dying of pulmonary tuberculosis, and had been comatose for several days. Suddenly he awoke, sat up, called for the doctor and declared that he could not die because of fear of the life hereafter. He felt guilty and full of remorse for his participation in the executions. When we gave him the obvious reassurance that it was not his but the State's responsibility and that he need not wor-



BRAIN TISSUE of a man killed by electric shock is shown in a microscopic cross section. Along the edges of the empty blood vessel running across the center are cells that have migrated out of it. The migration is associated with slow death processes, indicating that this victim of shock could not have died instantaneously.



SCHAEFER METHOD of artificial respiration involves pressing down on the lower ribs (*top*) and releasing them (*bottom*). By this means air is first squeezed out of chest and then inhaled when the chest expands.

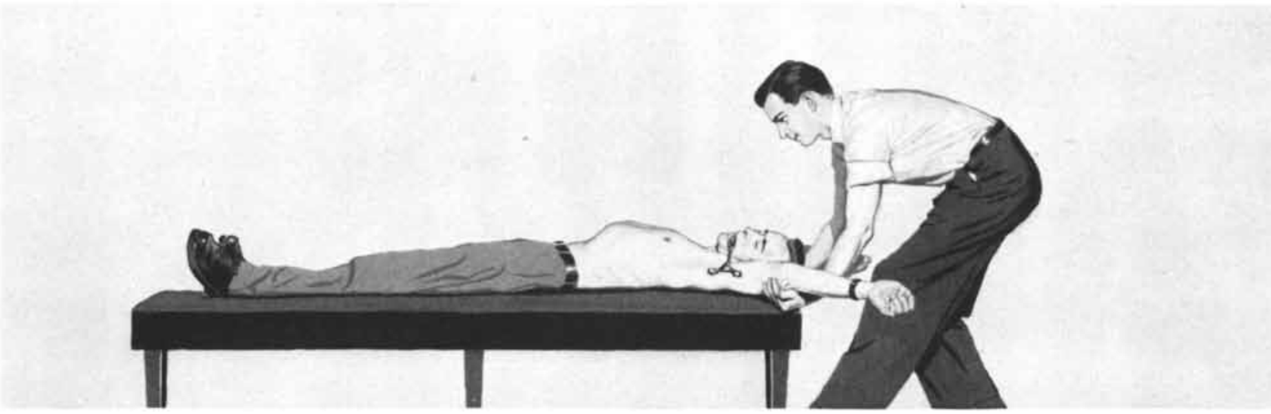
ry about his salvation on this account, he seemed quite satisfied, fell back on his bed and died a few minutes later.

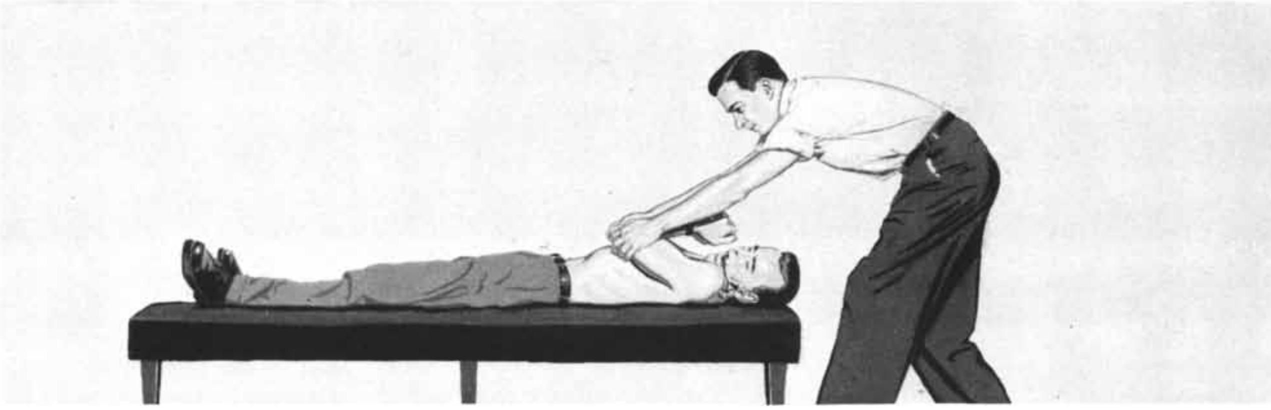
We cannot escape the conclusion that mental factors play a major part, not only in such astounding last-minute reintegrations of mind and body but also in the effects of violent shocks. The importance of the mental factors was impressed upon us many years ago by certain experiments in which we investigated the question of how large a voltage of electricity would be fatal. The fatal dose, of course, is not absolute; susceptibility to electric shock varies enormously in different species of animals and in different people. Individuals have been known to be killed by as little as 42 volts direct current. We started our investigation with animals and eventually experimented on ourselves. We began by touching bare wires of lighting installations under tension of 110 volts D.C. and gradually worked up to 440 volts. Although this range of voltages commonly kills people, we felt no apparent ill effect except the momentary sensation of the shock. Many engineers at the Siemens Works in Vienna repeated the experiments without suffering any harm, and it is now a commonplace experience of electricians. The reason why shocks which had proved to be fatal in many accident cases did not affect us could only lie in the fact that we were prepared for the shocks. The Viennese meteorologist Heinz von Ficker, who knew of our observations, once put them to the test when he was caught in a thunderstorm on the Matterhorn. He consciously braced himself for the lightning, and although he was struck three times, had his equipment torn and received considerable skin injuries, he did not lose consciousness or suffer any serious bodily damage.

We have not, so far, found an explanation of this entrancing fact. Why should preparedness so profoundly alter the effect of an electric shock? When we discussed the question with the distinguished French physiologist Charles Richet, he suggested that anticipation of the shock might release special defensive reflexes. But this could hardly explain a case such as that of the man, mentioned earlier in this article, who collapsed after a shock, recovered spontaneously and then succumbed to a second collapse after about a minute of normal mental and physical activity. This complex behavior is surely beyond the scope of a system of reflexes. Sigmund Freud, disagreeing with Richet, thought that the essence of the experiments lay in the psychic aspect. In bracing oneself against the shock, he suggested, one braces himself against the damaging effects of fear and somehow musters psychic defenses to intercept and overcome the shock effects. We objected that the potentially fatal stimulus was not fear but a measurable physical force. Freud replied that one could not escape the conclusion that electric energy and the psyche were equivalent factors.

BE that as it may, our chief concern here is the bearing that all these observations have on the treatment of victims of such shocks. Certain principles emerge clearly. In the first place, every apparently lifeless victim of an electrical or drowning accident must be regarded and treated as capable of resuscitation, however hopeless the case may seem even to experienced physicians. Secondly, resuscitation must be immediate, without waste of time in carrying the victim about or trying to listen for heart sounds. It will usually have to be attempted by laymen, who should indeed be quite as capable of doing the needful as a physician. The prime need is to ensure a supply of oxygen to the lungs and its transport to the tissues to keep them viable, which means that steps must be taken to help the patient's respiration and circulation.

At the scene of an accident a giver of first aid cannot do much directly to help the circulation. (In an operating theater a surgeon can stimulate circulation by direct manual massage of the heart.) But he can give it considerable





SYLVESTER METHOD of artificial respiration involves pulling the arms outward (*top*) and allowing them to fall back on the chest (*bottom*). The tongue is fastened to prevent it from falling into the throat.

indirect aid by a proper application of artificial respiration. This treatment, provided it is administered correctly, is the major and indispensable agent in resuscitation. But it is an art that must be learned by practical exercise.

Any method of artificial respiration, if carried out properly, can serve the purpose of providing adequate lung ventilation, but in the hands of overenthusiastic lifesavers some methods are more dangerous than others. The dangers arise chiefly from misguided efforts to pump the maximum amount of air in and out of the lungs. This consideration has tended to obscure some of the physiological requirements in normal respiration and circulation.

In normal breathing the active phase, as far as the muscles involved are concerned, is inspiration, *i.e.*, expansion of the chest. Expiration is largely passive, a matter of elastic rebound. Hence in artificial respiration we must devote our active effort to expanding the chest rather than compressing it. Besides the desirability of emulating the normal breathing process, there is another important reason for not compressing the chest. Inside the thorax there exists a precariously balanced system of varying pressures, any upset of which will affect the functioning of the heart and the lungs. To put it more precisely, any active compression of the chest will be transmitted to the great veins leading to the heart and will impair the return of blood to the heart. On the other hand, anything that expands the chest will lower pressure inside and assist the return of blood to the heart as well as the vital coronary circulation itself.

THIS method of artificial respiration, which we believe is the method of choice, is the one originated by the London physician Henry Robert Sylvester in 1858. In it the patient lies on his back and the person administering the treatment briskly and rhythmically stretches the arms and shoulders outward and then allows them to fall back beside the chest. The only disadvantage of this method is that of all supine positions: the tongue tends to slip back and to block the upper respiratory passages. The tongue must therefore be kept pulled forward by some contraption: *e.g.*, a safety pin stuck through the tongue and tied with string to the victim's neck. On the other hand, the supine position allows free inspection of the face and neck for signs of returning respiration, such as a swallowing movement. It is to be preferred to all techniques that involve compression of the chest, including the famous and widely used Schaefer method, invented at the beginning of this century by the British physiologist Sir Edward A. Sharpey-Schaefer.

We have shown quite clearly in experiments that the dangers of bad artificial respiration are very real. It is easy to kill an animal in one or two minutes by excessive compression of the chest. Death is much more rapid than from ordinary asphyxia; it is accompanied by signs of cerebral irritation, by very acute edema of the lungs and brain and by blood clots, which at autopsy are found attached to the inner walls of the heart and the blood vessels. These experimental post-mortem findings are only too reminiscent of the actual changes sometimes found in human victims of faulty or unnecessary artificial respiration—not to speak of fractured ribs and ruptured spleens, livers and diaphragms.

The principles learned during the last 50 years would suffice, if they were properly used, to save hundreds, perhaps thousands, of lives each year. Only their general application—and that means a campaign for reform at the highest levels—can change the present lamentable fate of the great majority of victims of drowning and electric shock.

Stefan Jellinek, professor of electropathology at the University of Vienna, is presently working in association with Queen's College, Oxford. He is author of the recent book Dying, Apparent-Death and Resuscitation.

COMETS

Astronomers have recently constructed some plausible theories about the composition and origin of these periodic visitors to the center of the solar system

by Fred L. Whipple

THE "hairy" comet has long defied detailed scientific explanation and even today maintains some of its ancient mystery. Perhaps one of the reasons why comets remain so mysterious is that they have not received much general attention during the past 40 years. No really bright comet has displayed itself in Northern skies since the last appearance of Halley's in 1910. The constant discovery of faint new comets has, however, kept interest in the subject alive among a few astronomers, and progress has been made in explaining some of the puzzling features of the phenomenon. What are comets made of? Where do they come from? Why are they visible only when they are relatively close to the sun? I shall concentrate mainly on the attempts to answer these central questions.

The problem that has occasioned the most heated controversy is whether comets originate within the solar system or outside it. The problem arises from the eccentricity of the comets' orbits. Unlike the planets, which move about the sun in orderly and nearly circular orbits, all in nearly the same plane, comets have very erratic motions. They move in all possible directions, their paths forming a hodgepodge across the sky. And their orbits are extremely elongated instead of circular. The idea that comets might come from outside the solar system rested on the fact that some of their orbits are slightly hyperbolic, that is, open curves whose ends can never meet. But George van Biesbroeck of the Yerkes Observatory and E. Stromgren of Denmark and his collaborators have recently completed investigations which apparently settle the question. They traced back the paths of some 22 comets that were observed to be moving in hyperbolic or practically parabolic orbits. They were able to prove that in every case these comets were traveling in elliptical orbits when they entered the central planetary region of the solar system. Those comets that acquired slightly hyperbolic orbits were thrown into such orbits by the gravitational attractions of the major planets, particularly Jupiter. Some of these comets, having gone off on a hyperbolic path, are now lost to the solar system forever, but we know that they *were* members of the solar system before the planetary perturbations disturbed their orbits.

These would not exclude the possibility that comets originally came from interstellar space and were captured by the planets and forced into elliptical orbits around the sun. But nearly 30 years ago the Princeton University astronomer Henry Norris Russell showed that this was unlikely to have taken place within the last 10 million years or so. He reasoned that if such captures had occurred recently and were still going on, we should observe many comets in hyperbolic orbits and should not observe such a high concentration of comets with almost parabolic orbits—comets having periods of millions of years. This conclusion has recently been verified in a more detailed research by J. J. van Woerkom at Leyden in the Netherlands.

Hence we may rule out the hypothesis that comets are now being captured or have recently been captured from a comet factory in interstellar space. They are truly members of the solar system, not interlopers. This conclusion immediately raises new questions. We know that comets must be relatively short-lived; a number of them have disappeared even in the brief period that astronomers have been observing them. How, then, is the supply maintained? Have they been formed recently, or are they still being formed, in the solar system? If not, how could these frail phenomena have persisted through the three billion years of the solar system's lifetime?

THE answer seems to be that the solar system has an enormous population of comets extending very far into space. Nearly 20 years ago the Estonian astronomer E. Opik calculated that the sun's gravitational attraction could maintain a family of comets extending out as far as the nearest stars, some four light-years away, without the loss of a large fraction of these comets even during three billion years. To the objection that stars passing through this cloud of comets would rapidly destroy them he had an ingenious answer. A star passing through such a cloud is analogous to a bullet fired through a swarm of gnats. The bullet will eliminate only a small fraction of the gnats, without much disrupting the swarm. For comets the situation would be dangerous only if the passing star came close enough to the sun to attract the sun away from the comets. The likelihood of such a close approach is extremely small, even over such a long period of time.

Opik's important concept of a huge cometary swarm extending to the nearest stars escaped the notice of many astronomers until it was recently rediscovered by J. Oort of Leyden. Oort extended this line of reasoning to provide a clear picture not only of the manner by which the storehouse of comets is maintained

but also of the process by which withdrawals can be made. He called attention to the well-known fact that most comets disappear when they are twice the Earth's distance from the sun; very few have been visible as far away as Jupiter. Oort accepted the assumption that when comets are far from the sun they become completely inactive; that is, the particles and gases of which they are composed cease to vaporize or radiate energy. This inactivity in the "deep freeze" of space outside the planetary orbits is what enables comets to persist indefinitely in a state of hibernation.

Oort postulated that the cometary cloud may contain as many as 100 billion comets, very few of which come as close to the sun as the planets. Occasionally, however, the random passage of a star disturbs the motions of some comets sufficiently to make them swing into the sphere of gravitational attraction of Jupiter or another major planet. In this way comets are taken one by one from the "deep freeze" of the solar swarm and are pulled into relatively short-period orbits. Their hibernation period over, they become active and disintegrate into gas and meteoric particles during a few hundred or few thousand revolutions around the sun. The total supply of comets is so large, however, that despite these captures and losses into interstellar space, the comet cloud has persisted without serious depletion during the long lifetime of the solar system.

HAVING settled the problem of the storehouse and withdrawal system for comets, we may now turn to the problem of their physical nature. The most generally accepted theory is that comets are great flying "gravel banks"—masses of small solid particles held together loosely by gravity. As a comet moves around the sun the gravel bank is supposed to be slowly broken up by forces such as the sun's heat, radiation pressure, tidal disruption, rotation, and so on. This produces the streams of meteoritic material that are observed as meteor showers when the Earth crosses the orbits of certain comets ("Meteors," by Fletcher G. Watson; SCIENTIFIC AMERICAN, June). As the comet approaches the sun, the sun's heat is assumed to drive gases from the surfaces of the particles, producing the gaseous spectra observed in comets.

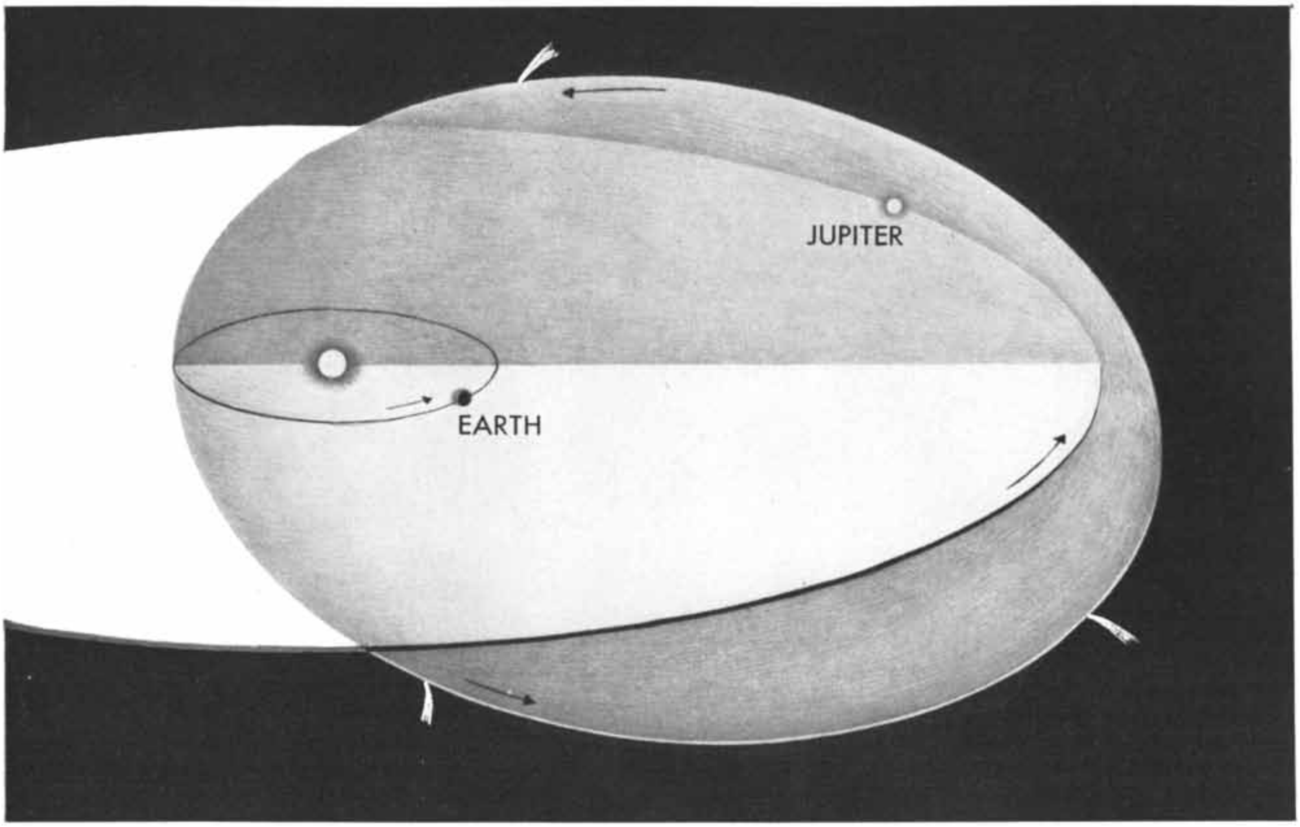
This gravel-bank theory is rather effective in explaining many of the observed qualitative characteristics of comets. Not only does it explain meteor streams, cometary dust, cometary gases and increased activity near the sun, but it also explains how a comet may split in two, disintegrate and exhibit various observed irregularities in behavior. The theory is unsatisfactory, however, in most quantitative aspects. The postulated forces are generally too small to produce the observed disintegration, and it is difficult to see how the particles could carry enough gases, even if they replenished the supply by picking up gas molecules in interplanetary space, to account for the observed gaseous radiations.

These difficulties, along with other quantitative weaknesses in the theory, led me to search for a more adequate comet model. It occurred to me that a deep-freeze process might account for the formation of comets, just as it did for their storage in space. Why not assume that comets were made in the cold of space from the solid particles floating there—the interstellar dust?

What solids would one expect to find in space? In the observable universe as a whole hydrogen is known to be by far the most abundant element, with helium second. Hydrogen and helium alone cannot freeze into solid particles, even in the cold of outer space, and helium does not combine with other elements. Hence we should expect to find that the solid particles in space are predominantly compounds of hydrogen with heavier elements, particularly carbon, nitrogen and oxygen, which are the next most abundant elements after hydrogen and helium. These compounds might be methane (CH_4), ammonia (NH_3) and water (H_2O). In the depths of space all three of these substances should be frozen solid as icy particles. I suggest that perhaps 70 to 80 per cent of the mass of a comet is composed of such ices. As the comet emerges from the deep freeze and approaches the sun, the ices vaporize. On the other hand, the remaining 20 to 30 per cent of the comet's mass, consisting of compounds of the heavier elements in space, do not vaporize appreciably even at rather high temperatures. These would be the particles that produce meteor showers.

Thus according to this model the nucleus of a comet would be a conglomerate of ices and solids—a dirty-looking ice including fine dust or even single molecules of a large number of compounds. In hundreds of millions of years the slight but continuous gravitational pressure within the nucleus would un-

HALLEY'S COMET was photographed from the Chilean station of the Lick Observatory on May 11, 1910.



ORBIT OF A COMET is usually in a plane tilted with respect to that of the Earth and most of the other planets (*lighter disk*). Shown in this drawing is the orbit of Comet Giacobini-Zinner (*darker disk*), which intersects the orbit of the Earth and comes close to that of Jupiter. The comet's orbit is tilted at an angle of 31 degrees.

doubtedly consolidate the particles somewhat; this process may perhaps account for the sizable pieces of homogeneous material that occur in comets.

NOW at great distances from the sun, as we have suggested, the comet would be inactive. But as it approached the sun the solar heat would vaporize the material on the surface of the nucleus from the solid state. The escaping gases would carry meteoritic material with them to form a meteor stream along the tail and orbit of the comet. The gases themselves would then be acted upon by the radiation of the sun. Its ultraviolet light would break down the molecules of CH_4, NH_3 and H_2O into simpler forms. In this way we can account for the fact that the spectra of comets do not indicate the presence of CH_4, NH_3 or H_2O but do show the *radicals* of these compounds, such as CH, CH_2, NH, NH_2 and OH. Such radicals, which cannot be isolated in a terrestrial laboratory, probably are created by the rapid breakdown of the parent compounds by the ultraviolet sunlight.

The icy conglomerate model allows for the presence of certain other molecules that are found in comets. The carbon molecule C_2, so conspicuous in the tail of a comet, may well have been frozen directly in the comet's nucleus. Another conspicuous radical in comets is CN, often called cyanogen in analogy with the true cyanogen, C_2N_2. This radical probably arises not from C_2N_2 but from hydrocyanic acid, HCN. The theory could also explain the puzzling circumstance that the spectra of comets show the presence of free metals, including sodium, iron, nickel and chromium. These could either be frozen molecules imbedded in the conglomerate or products of the dissociation of compounds by ultraviolet sunlight.

Almost all comets show peculiar random fluctuations in brightness during their flight and a very rapid brightening as they come near the sun. Halley's and some of the other large comets erupt strong jets of gas. The model here proposed can easily explain this. We can assume that a porous crust of meteoritic material covers much of the surface of the icy nucleus, providing an insulating layer. As it approaches the intense heat of the sun, the heated nucleus tends to blow out gas and break holes through this crust or remove large sections of it. The underlying ices would then be exposed to direct solar heat and would produce a strong jet activity. The insulating layer may also account for the relatively long survival of comets after their capture by the inner solar system. By retarding the loss of their ices, the insulation may permit comets even as small as one mile or less in diameter to make hundreds or thousands of revolutions around the sun before they are completely dissipated.

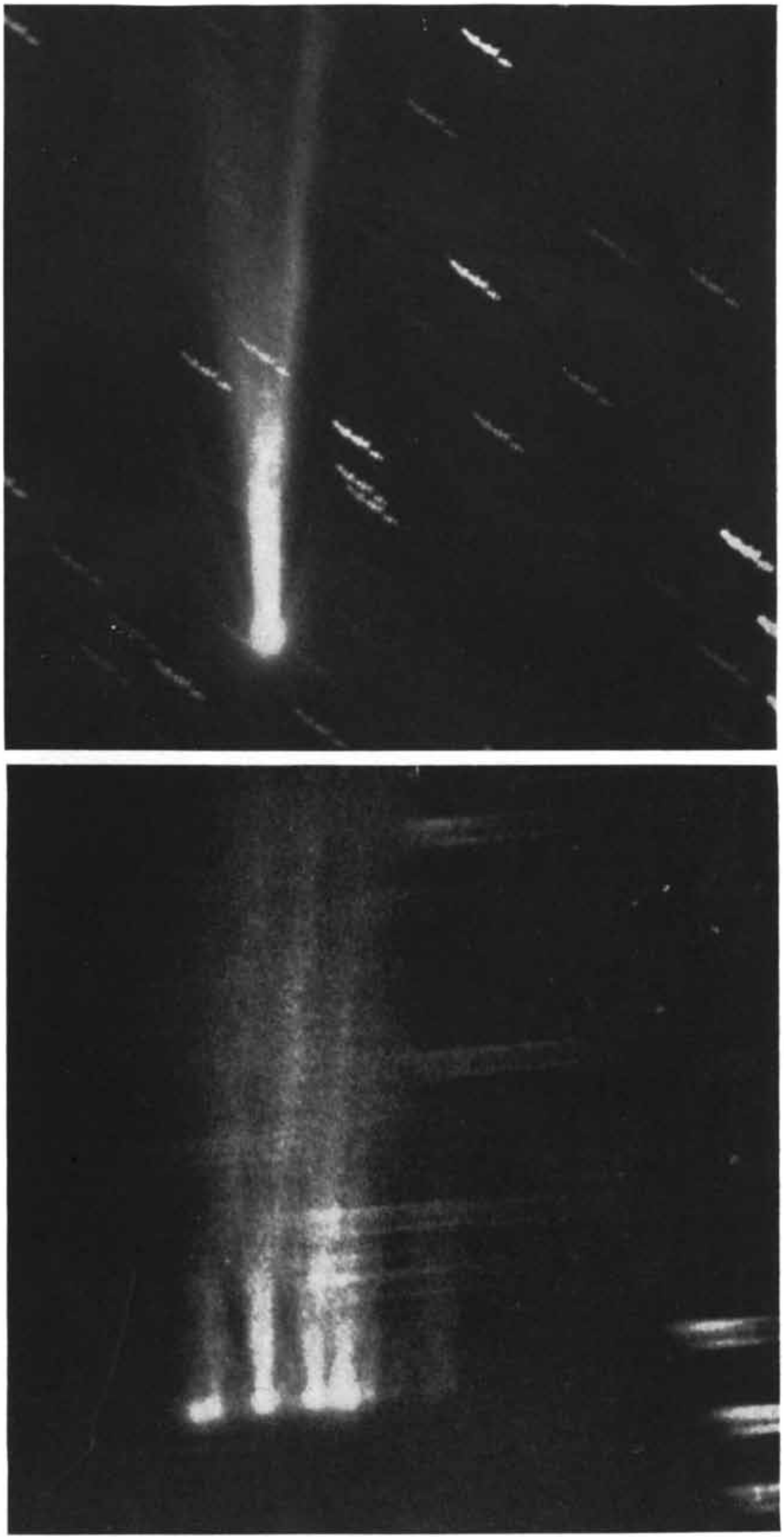
A CERTAIN few comets show a most baffling departure from their timetables which astronomers have been at a loss to explain. An example is Encke's Comet, which revolves around the sun in three and one-third years, the shortest known period of a comet. In each revolution until about 1865 this comet arrived at its closest point to the sun about two and a half hours earlier than it was expected, and since then it has been, on the average, about one hour early. Such a deviation may seem too small to be taken seriously, but the astronomical observations are precise enough to assure that it cannot be due to errors in measurement. Another comet that behaved in similarly erratic fashion was Biela's Comet, which arrived late three times, mysteriously returned in two pieces in 1845 and thereafter was never seen again. It used to be supposed that the reason for the shortening of comets' periods was a resisting medium in space which slowed their motions and caused them to spiral in toward the sun in smaller and smaller orbits. But this notion had to be abandoned when it was discovered that some comets arrive behind schedule instead of ahead of time.

The icy conglomerate model suggests

a mechanism that may explain these strange phenomena. Besides revolving around the sun the nucleus of a comet may rotate on its own axis. Suppose that an erratic comet rotates on an axis that is not in the plane of its orbit. It continually turns a new face to the sun, as the Earth does. When the sun "rises" on a given face of the comet, it will take some time for the sun's heat to penetrate the insulating meteoritic layer and reach the underlying ices. It may be "afternoon" on the comet before the ices are heated sufficiently to vaporize and send out a stream of gas. At this late hour the outgoing vapor stream will be directed not toward the sun but at an angle from it. The stream of course has a jet-propulsion effect on the comet itself, giving it a push in a specific direction. Depending on the sense of the comet's rotation, this push will retard or accelerate the motion of the comet along its orbit. Thus the comet's period will be changed and it will arrive earlier or later than expected. Probably the jet propulsion of outgoing gases affects the motions of all comets to some extent. Halley's Comet, for example, returned in 1910 nearly three days behind schedule.

Calculations show that the loss of mass necessary to account for the jet-propulsion effects is very small; it would not materially reduce the lifetime of comets. Other quantitative checks on the icy-comet theory are possible. One of these concerns the zodiacal light, a sky glow which is conspicuous at the latitude of the northern U. S. during autumn evenings and contributes to the brightness of the solar corona seen at eclipses of the sun. The zodiacal light is produced by the scattering of sunlight by a cloud of small particles near the Earth's orbit. These particles must be slowly spiraling into the sun, because of a momentum effect of scattered sunlight known as the Poynting-Robertson effect. I find that about a ton of such particles should fall into the sun each second. This means that the zodiacal cloud must constantly be replenished by about this amount from some steady source of small particles. The comets, if the icy model is correct, release a total of some 30 tons of meteoritic material per second. Of this material only a part is in the form of particles of the necessary size and only a small fraction of them would survive the gravitational disturbances of Jupiter to contribute to the zodiacal cloud. Hence this check on the icy-comet theory seems satisfactory.

THE nucleus of a comet, to which the discussion has been confined so far, is not the principal part that one observes. In many comets the nucleus is too faint to be seen at all; only the hazy escaping envelope around it reflects or re-emits enough sunlight to be visible. The nuclei of the smaller comets are only



SPECTRUM OF A COMET tells something of its composition but little of its structure. These Yerkes Observatory photographs show Comet Morehouse in 1908. At the top is a direct photograph of the comet; at the bottom is the series of spectral images that are produced by photographing it through an objective prism. The spectra of comets show strong molecular radical lines.


TAIL OF A COMET sometimes changes over a relatively short period. These Yerkes Observatory photographs show Comet Morehouse in 1908. The photograph at the left was made three hours before the one at the right.

a mile or so in diameter, but the visible head, or coma, may extend for thousands of miles beyond it. The nucleus of Halley's Comet is probably not over 10 to 20 miles in diameter; its tail, when last seen, was many millions of miles long.

The theory about the nucleus presented here does not help much to explain how the tails of comets are formed. It does, however, suggest a source for the large quantity of gas and exceedingly fine dust that constitute the tail. Much more theoretical and observational work is needed to explain with precision the processes in a comet's tail, particularly the high velocities of motion away from the sun. In general the pressure of sunlight on the fine dust and gas is clearly the basis of activity in the tail.

WE are still left quite in the dark as to the ultimate origin of comets. Where was the factory in which they were made located, and when did the sun acquire this magnificent assemblage of quite trivial bodies, whose combined total mass, in spite of their vast extent, is probably less than that of the Earth?

One possibility is that the solar system captured the comets from an interstellar cloud many millions of years ago, but we have no idea whether there are clouds in space with a concentration of material sufficient for the formation of comets. Another possibility is that the comets were formed along with the sun and planets from a great cloud of dust and gas that produced the solar system; this would follow naturally from the dust cloud hypothesis I once had the temerity to suggest (SCIENTIFIC AMERICAN, May, 1948). A third possibility is that they came from a disk of condensing gas about the sun which, according to one theory, gave rise to the planets. If so, the comets must have formed in the outer regions of the planetary cloud and may have been thrown into their helter-skelter orbits, as G. P. Kuiper of the University of Chicago suggests, by the perturbations of the outermost planets.

Of one thing we can be certain: comets could not have been formed in the solar planetary system by the mechanism proposed by the British theoreticians R. A. Lyttleton and Fred Hoyle. Lyttleton suggests that whenever the solar system passes through an interstellar dust cloud, the attraction of the sun causes particles from the cloud to concentrate along the line of motion behind the sun. Such a concentration must certainly occur under ideal circumstances, but it is easy to show that planetary perturbations would appreciably disturb the motions of the particles. Thus their convergence upon this line would be so haphazard as to prevent the capture of appreciable aggregates of cometary matter by the solar system.

Be that as it may, we are at least somewhat in advance of Aristotle, who thought that comets dwelt in the upper atmosphere and gave off "hot exhalations" that dried the atmosphere and seared crops. Yet two thousand years ago Seneca, the Roman philosopher and historian, made a wise and prophetic comment about comets that could almost be written today. He said: "Why should we be surprised . . . that comets, so rare a sight in the universe, are not embraced under definite laws, or that their beginnings and ends are not known, seeing that their return is at long intervals? . . . The day will yet come when the progress of research through long ages will reveal to sight the mysteries of nature that are now concealed. The day will yet come when posterity will be amazed that we remained ignorant of things that will to them seem so plain."

Fred L. Whipple is professor of astronomy at Harvard University.

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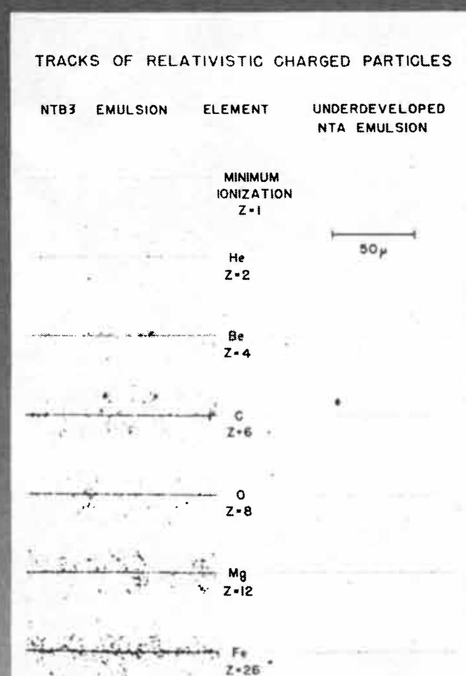

Courtesy of Dr. Bernard Peters, University of Rochester

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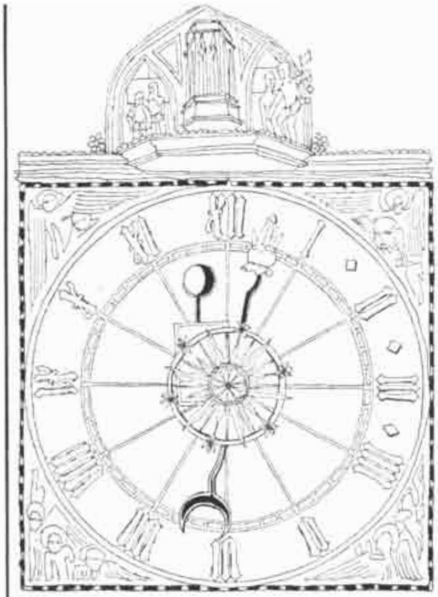


Wanted: Engineers

THE U. S. needs at least 30,000 new engineers a year but only 19,000 will be graduated this year, according to the Engineering Manpower Commission. The Commission is a 19-man body representing six engineering societies. Last month it made a survey of the draft status of the 38,000 graduates from U. S. engineering colleges this year. It received replies from the deans of 86 of the 135 colleges. They reported that 11 per cent of the graduates were to be commissioned through R.O.T.C., 16 per cent were in the reserves or the National Guard and 36 per cent became draft-eligible on graduating. This gives a total of 63 per cent available to the armed forces. After allowing for the normal percentage of 4Fs, the Commission estimated that 50 per cent of the 38,000 would be in the armed forces soon after graduating. The Commission noted that the armed forces would also drain part of the nation's existing supply of engineers, for 25 per cent of the engineers now employed in industry are enrolled in the reserves.

Color TV

THE color-television controversy has had its day in court and is back in the laps of the industry and the Federal Communications Commission. The U. S. Supreme Court last month declined to overrule the FCC's decision approving the Columbia Broadcasting System's color-TV method as the standard. The Court held that while the wisdom of the FCC decision was arguable, the Commission had not acted capriciously and its administrative ruling should stand.

With the legal question settled, CBS announced that it would start regular program broadcasts in color within a few weeks. The only major set manufacturer that plans to make color receivers is Air King International Corporation, a recently purchased subsidiary of CBS. Its sets are expected to cost $400 to $500 and will give a 12½-inch picture. Several small companies will manufacture adapters and converters for existing television sets to enable them to receive CBS color broadcasts in black-and-white or in color.

The issue is still far from settled, however. The Radio Corporation of America and other major set makers announced that they intended to continue to work on improvement of their systems, and the FCC indicated that it would give consideration to new developments in the field. The chief new development since the Court decision was an announcement by CBS' rivals that they had united on a single color-TV method which they believed superior to that of CBS. The group backing it consists of RCA, the Philco Corporation, the Allen B. Du Mont Laboratories, the Hazeltine Electronics Corporation and the General Electric Company. It is described as "a new composite system combining the best elements of the furthest advances of the existing systems." Unlike the systems shown to the FCC last fall, this one is not sequential but simultaneous. Instead of sending red, blue and green signals separately, the transmitter sends the full color combination simultaneously. RCA demonstrated a simultaneous system several years ago, but later dropped it in favor of the dot-sequential system which the FCC rejected in favor of CBS' field-sequential system. Since then GE has done more work on a simultaneous system. The new group, called the National Television System Committee, hopes to have final standards for its simultaneous system ready by the end of the year.

Meanwhile RCA announced that it would make its three-color electronic tube available to CBS. This would make unnecessary the color wheel that CBS has been using, but it would not overcome the incompatibility of the CBS system. At all events, members of the FCC and the industry agree that black-and-white television will predominate for some years to come.

Three-Dimensional Movies

TO the many systems of three-dimensional movies that have been developed experimentally in recent years a new one was added last month. It has the advantages of relative simplicity and moderate cost. The system, invented by Major Robert V. Bernier of the Air Force, simply presents alternate frames

THE CITIZEN

from different angles, relying on the eyes' persistence of vision to integrate the frames.

Bernier's method uses the stereoscopic effect, showing the same scene from the slightly different angles of the two eyes. But instead of employing two projectors to put the two images on the screen simultaneously, Bernier alternates the images on a single roll of film. In the shooting of the film a revolving shutter and a system of viewing mirrors attached to the movie camera photograph alternate frames on the reel from two different angles. The projector then reproduces the film through a revolving Polaroid cylinder which polarizes the light from the alternate frames in two different directions. The viewer wears Polaroid spectacles which transmit the alternate images first through the right lens and then through the left. Because the image persists in the eye longer than it takes the frames to change, the two images merge to give a three-dimensional illusion.

A Threat to the Wheat

THE U. S. wheat crop this year is threatened by the most virulent race of stem rust ever found in North America. The new fungus, called Race 15-B, suddenly appeared late last year on wheat in 15 states throughout the Midwest and destroyed 10 million bushels of durum wheat—a fifth of the crop.

The commercial wheats now grown in North America have been bred for resistance to stem rust, but all have proved vulnerable to 15-B. A peculiarity of stem rust is that in most of the U. S. it must spend part of the year on barberry shrubs, from which it spreads to the grain. While living on barberries, strains of the fungus hybridize and produce new races. Thus to stop the spread of the disease and to avoid the constant creation of new races, the eradication of barberries is as necessary as the development of a resistant wheat.

H. A. Rodenhiser and E. G. Moore of the U. S. Agricultural Research Administration wrote in *Science*: "There is little reason to doubt that we shall be able to develop wheats resistant to 15-B with all the other qualities necessary for commercial production. The only question is how long it will take. With good luck, we may be able to do this in the relatively near future."

Factoring the Supreme Court

L. L. THURSTONE, the University of Chicago psychologist who developed the factorial analysis method to resolve intelligence and personality into their primary components, has applied the same technique to analyze the voting records of Justices of the Supreme Court. Thurstone calls his study, which he made jointly with J. W. Degan at the Psychometric Laboratory at Chicago, "an exploration in scientific method on the problem of identifying the blocs within a legislature, council or court."

The two psychologists took as their raw material 115 decisions handed down by the Supreme Court during the period from 1943 to 1945, when the Court was composed of Justices Stone, Black, Douglas, Roberts, Frankfurter, Rutledge, Murphy, Reed and Jackson. In each of the 115 selected cases there were at least two dissenting votes. By the factorial method Thurstone and Degan analyzed the correlations among the votes of the Justices to determine whether there were consistent agreements or disagreements in point of view among members of the Court.

They concluded that the Court divided into two generally opposed groups, one consisting of Reed, Stone, Frankfurter and Roberts and the other of Black, Douglas, Rutledge and Murphy, with Jackson occupying an indeterminate position. Further, a detailed analysis of certain factors indicated that there were "five distinct attitudes or points of view" among the Justices, each represented by two Justices: 1) Reed and Stone, 2) Murphy and Rutledge, 3) Black and Douglas, 4) Frankfurter and Roberts, and 5) Jackson and Frankfurter. They noted that "Judges Black and Douglas have something in common in their points of view which is quite the opposite to whatever is common to Judges Frankfurter and Roberts."

What that something is Thurstone and Degan leave to political scientists and lawyers to determine. They found political scientists of differing opinions as to the meaning of their results. The reactions of lawyers surprised them.

"We had expected to find," said Thurstone and Degan, "that the factors would represent attitudes towards some general issues that might be called, for example, economic liberalism, or the rights of the individual. When the results were discussed by some of our legal friends we had expected to find the factors interpreted in terms of some legalistic points of view. On the contrary, we found the lawyers discussing the factors in terms of the personalities of the judges. As psychologists, we had refrained from even considering the possibility that factors of personality and temperament would enter into any discussion by lawyers on this problem."

Rice with Fish

HAITIANS live largely on rice and need more proteins in their diet. Experts assigned to the problem by the

United Nations Food and Agriculture Organization thought of an ingenious answer: Why not raise fish, as well as rice, in the flooded rice paddies of Haiti?

Two Haitian officials accordingly visited the Orient, where the technique of growing fish in rice paddies is already well known, and an FAO staff member was assigned to help find a suitable fish for the project. A promising candidate is a fish from Thailand called the Sepat Siam, which can live in mud if its gills are moist. The technique itself is simple. Before draining his rice paddy, the farmer digs a hole. The fish swim into it and have a place to live when the field is drained. The farmer can take as many fish as he wants out of the hole, leaving enough behind to restock the rice field when it is flooded once more. The Sepat Siam is a fast breeder and grower, and is also supposed to help the rice by stirring up the mud and aerating the roots.

Cortisone

A MAJOR advance has been made by chemists of Merck & Company in the effort to find a method to produce cortisone more cheaply and abundantly. They have developed a scheme which promises to make it practical to manufacture the hormone from natural steroids that are plentiful.

One of the main problems in synthesizing cortisone is to attach a key oxygen atom to the carbon atom at the number 11 position in its basic steroid nucleus. The reason why cortisone has been made from desoxycholic acid, a scarce, expensive animal product, is that this compound has an oxygen atom attached at position 12, and it is possible to shift this atom to position 11 by a number of chemical steps. What Merck has now done is to discover a way to add an oxygen atom at position 12 on four cheap, plentiful steroids. These are ergosterol, which can be extracted from yeast; stigmasterol, an ingredient of soy beans; diosgenin, a component of the Mexican yam, and cholesterol, which is available from wool fat, egg yolk and other sources. With this accomplished, it should become possible to use these materials as the starting point for the cortisone synthesis. The Harvard University chemist Louis F. Fieser and collaborators have developed a process similar to Merck's. Whether this will be a better road toward mass production than the total synthesis in which Robert B. Woodward of Harvard University has recently made progress is still an open question.

Bioelectricity

FOR 200 years biologists have known that electricity is associated with life. But what is the source of electric potentials and currents in living cells? Nerve physiologists and others interested in bioelectricity have sometimes assumed that it is due to chemical reactions involving the exchange of electrons, *i.e.*, oxidation-reduction reactions. They have believed that the reactions which generate electricity in the living cell are essentially the same as those which generate it in an electrochemical cell, or battery.

Theodore Shedlovsky, a physical chemist at the Rockefeller Institute for Medical Research, now suggests in *Science* that the electrical energy of cells may derive not from the exchange of electrons but from the exchange of protons, which like electrons are fundamental particles of matter. He points out that a battery requires two electrodes, usually metallic, which conduct electrons and are separated in such a way as to permit oxidation to occur at one and reduction at the other. Obviously, Shedlovsky adds, there are no metallic electrodes in a living cell. He reasons that in living cells acids, bases and water may act as electrodes. Even as metals conduct electrons, acids, bases and water conduct protons. And just as energy is liberated by oxidation-reduction reactions, which involve the exchange of electrons, so energy is liberated by acid-base reactions, which involve the exchange of protons. Insoluble acids or bases, suitably arranged in the living cell, may comprise the electrodes of an electrochemical cell, or, more properly, the protodes of a protochemical cell.

Shedlovsky tested his hypothesis by actually making a protochemical cell. One protode was water bound into a thin membrane of glass; the other was lauric acid. The cell successfully generates electrical energy. Says Shedlovsky: "Protochemical reactions may play an important part in bioelectric phenomena, while it is difficult to see how electrochemical reactions can do so. However, oxidation-reduction reactions can alter and restore the protodes. Thus proton exchange may play a direct electrical role and electron exchange an indirect one. That is, the former pays the electric bill with funds obtained from the latter."

Artificial Muscle

EVERY time a heart beats or a fist closes, the contraction of actomyosin is turning chemical energy into work. This protein has now for the first time been made to do work outside of a living muscle. Teru Hayashi of Columbia University reports that he has found a way to create actomyosin fibers which can lift 100 times their own weight.

Actomyosin is obtained as an extract from rabbit muscle. Years ago Nobelist Albert Szent-Gyorgyi made it into fibers by extruding it through a hypodermic needle to form a stream which later hardened to a solid filament. This filament could be made to contract, but it could not do work. Hayashi employs another method to form the fibers. He spreads actomyosin out as a film on the surface of a trough of water. Then, by pushing a rod along the surface, he squeezes it into a single strand. When immersed in a solution of adenosine triphosphate, the trigger chemical that makes actomyosin contract in living muscle, Hayashi's fiber also contracts.

A one-inch fiber loaded with 100 times its own weight contracts 15 to 20 per cent in 15 minutes. This result is an advance over Szent-Gyorgyi's work, but is still a long way from the performance of natural muscle, which can contract hundreds of times a second.

"Noble" Compounds

THE inert gases argon, krypton and xenon are called "noble" because they refuse to combine with each other or with any other element. It has always been considered impossible to bind them into any kind of compound. Now a revolutionary process whereby they can be fixed in stable crystalline combinations with other atoms has been reported by H. M. Powell of Oxford University.

The pseudo "compound" is formed by dissolving the gas under pressure in a saturated solution of quinol, the photographic developing material. The solution is then cooled, and the quinol crystallizes out. In doing so it traps atoms of the inert gas. The crystals contain one gas atom for every three quinol molecules. The result is a substance of a definite composition which holds 70 times its own volume of gas. It is very stable unless melted or dissolved. It has been named a "clathrate compound," from the Welsh "clathratus," meaning closed by a trellis.

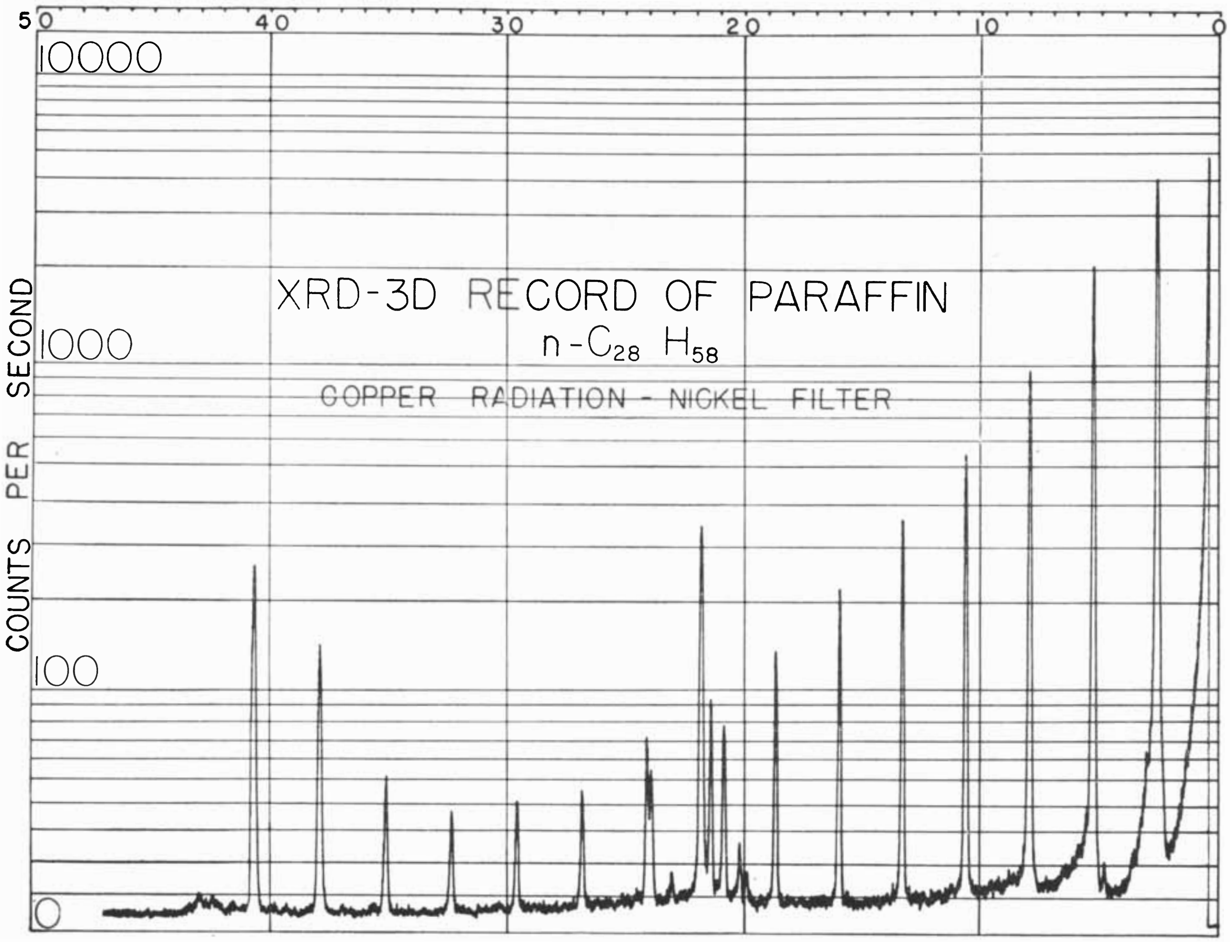
Quinol is able to hold the inert gas atoms because the latter, about four Angstroms in diameter, just fit the spaces in the quinol crystal. Quinol can also trap sulfur dioxide, hydrocyanic acid, methyl alcohol and acetylene, all of which are about four Angstroms wide. Crystalline nickel cyanide ammonia, it has been found, can trap benzene, aniline or phenol. The process may have a practical value as a means of separating chemically similar but physically different molecules. In a single operation nickel cyanide ammonia can separate benzene from other hydrocarbons to 99.992 per cent purity.

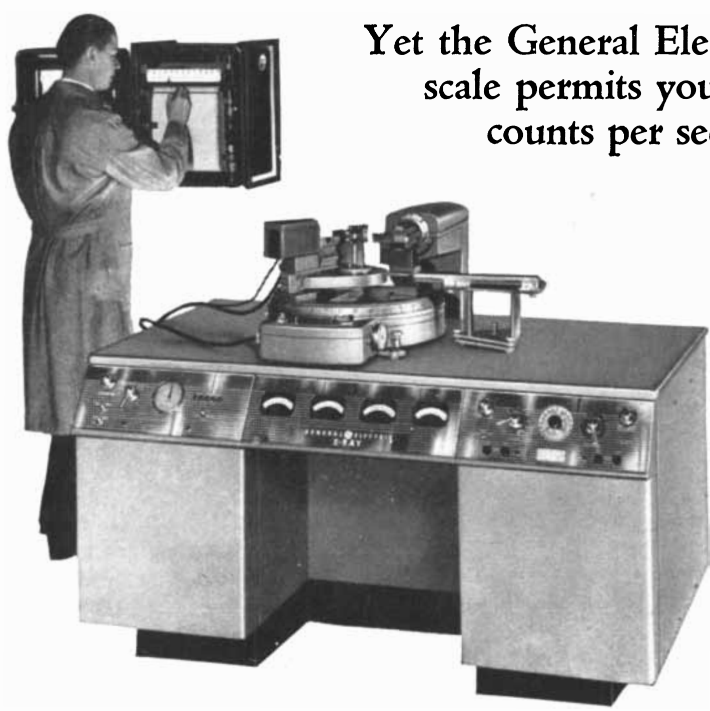
Child Chimp

CHIMPANZEES sometimes seem almost human. What if a chimp were brought up with the same advantages as a human child—would it be possible to distinguish his behavior from ours?

Catherine and Keith J. Hayes, psychologists at the Yerkes Laboratories of Primate Biology in Florida, performed exactly that experiment. They took a female chimpanzee baby into their home and raised her like a member of the fam-

It would take a chart 13 feet high to give you this range of reading on a liner scale...





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GENERAL ELECTRIC

ily. "Our subject, Viki," they reported to startled listeners at a meeting of the American Philosophical Society, "was adopted a few days after birth, and has now spent the first three years of her life in our home. She has been treated as nearly as possible like a human child.

"In general, Viki's development has closely paralleled that of a normal human child, her interests and abilities having appeared in roughly the same sequence, and at about the same rate. Her social behavior is that of an extrovert; she is very friendly, though somewhat aggressive with those who allow her to dominate them. Viki's play is much more athletic than a child's—she spends a larger part of the day running, climbing and jumping.

"She scribbles, cuts with shears and builds with blocks, with about the same skill and enthusiasm as most three-year-old humans. She seems to have as much preference for social play as people do. She leads us about by the hand, coaxes us to tickle her and begs for pickaback rides. When new acquaintances are available, she usually plays with them rather than with members of the family. Just as a human child copies its parents' routine chores, so Viki dusts, washes dishes, sharpens pencils, saws, hammers and sandpapers furniture, paints woodwork and presses photographs in books. Viki's general intelligence has developed at about the same rate as that of a human child and is now at about the normal three-year-old level.

"Language is the one field of behavior in which we have thus far been able to find a large, clear-cut and important superiority of man over chimpanzee. As an infant Viki babbled much less than human babies do, and even this disappeared by five months of age. By manipulating Viki's lips as she vocalized, we were able to make her say 'mama.' By the time she was two-and-one-half years old she had learned to pronounce satisfactory approximations of the whispered words 'papa' and 'cup.' She sometimes confuses them, however."

The psychologists concluded that the human and chimpanzee species "are much more alike psychologically than has heretofore been supposed. Man's superior ability to use language may be his only important genetic advantage. This one genetic advantage makes further advantages possible, however, since language is a means of sharing knowledge.

"If an individual man could grow up in complete isolation from culture, and with only such knowledge as he could gain directly from his environment, we suspect that his behavior would be very different from that of the men we know, and would probably be quite apelike. We suspect that the species chimpanzee closely resembles our hypothetical, cultureless man, with much the same individual capacities—except for language ability."

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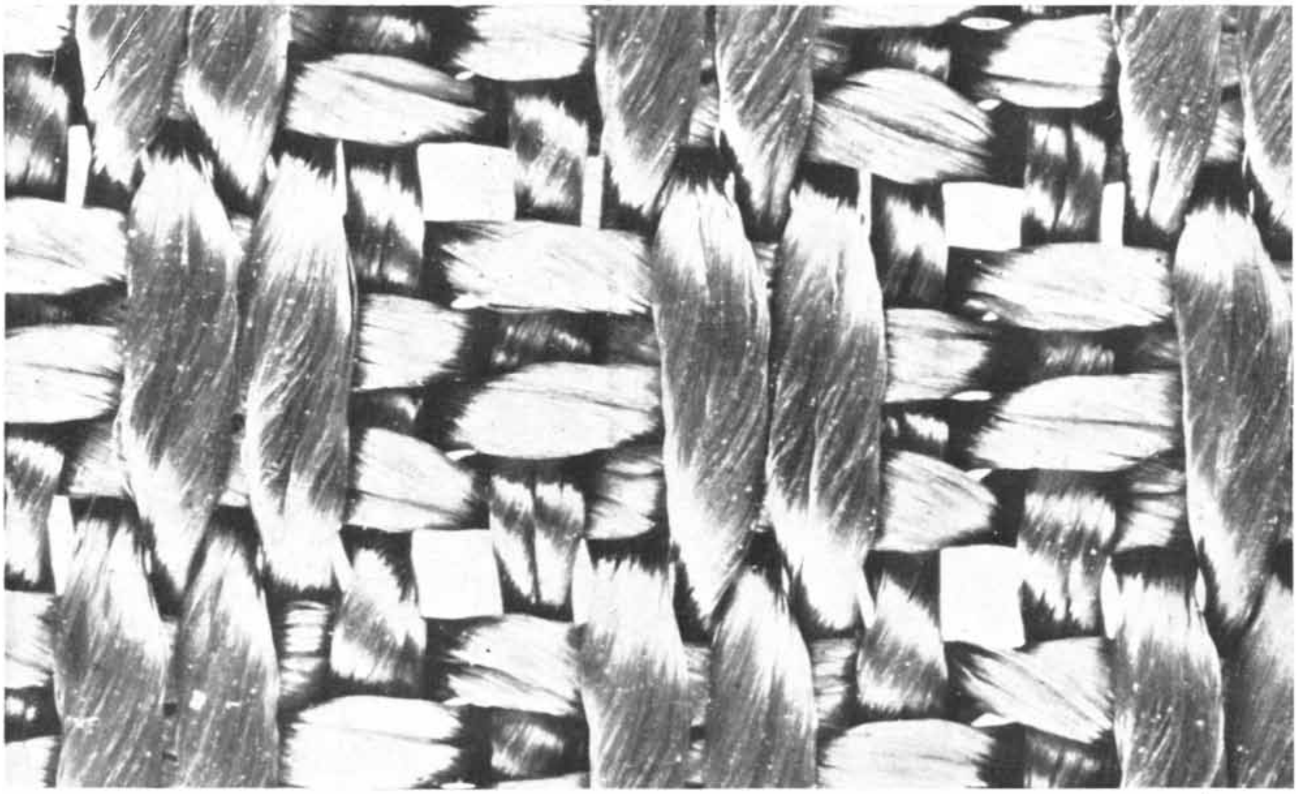
SYNTHETIC FIBERS

The production of the euphoniously named new textile substances has now outstripped that of wool. What is the physical basis of this technological development?

by Simon Williams

FEW developments in modern technology have had so rapid and so profound an impact on mankind as the synthetic fibers. This revolution started only 60 years ago, when the first "artificial silk" filaments began to be manufactured in Besançon, France, and many of its most important products—nylon, azlon, glass fiber, Vinyon, Orlon and others—have cascaded into the textile scene only within the past 15 years. The man-made fibers have met with remarkable public acceptance. Rayon, acetate and nylon have penetrated every wardrobe in the U.S., and the technological and military uses to which these and other synthetics have been adapted are legion. It is estimated that this year the world production of synthetic fibers will total more than three and one-half billion pounds, which means that they have outstripped wool and now stand second only to cotton and jute in the hierarchy of textile raw materials.

Although the artificial fibers still represent only about 10 per cent of all textile fiber consumed in the world, they have already produced startling and far-reaching effects on the world's econ-



TYPICAL FABRIC is composed of yarns, and each yarn is composed of filaments. Natural filaments come in relatively short lengths; synthetic filaments are chopped into such lengths or spun into yarns in continuous form.

omy. They have had a marked influence on the agricultural patterns of the great centers of natural-fiber production, scattered over the four corners of the world. Within the textile industry itself virtually every new mill or modernized old mill today is built so that it can handle artificial fibers in some form. The shift to the manufacture of synthetic fibers is particularly tempting in the rebuilding of war-torn areas and in the design of new industrial empires in backward countries, because it offers such nations the opportunity to free themselves from dependence upon their climate, which may be unfavorable for growing natural fibers, or upon remote sources of fiber supply.

Why have the artificial fibers become so important in so short a time? Why, after centuries of practice in the use of cotton, wool, silk and flax, were the man-made fibers able to storm the textile ramparts with so little resistance?

Part of the answer lies in the name, "artificial silk," that was first given to the fibers now known as rayon and acetate. They were a relatively cheap substitute for silk, the fabulous fiber which throughout human history has been the inspiration for epics of commerce and brigandage. As early as 1664 Robert Hooke, the brilliant and restless English physicist and naturalist, had suggested "that probably there might be a way found out, to make an artificial glutinous composition, much resembling, if not fully as good, nay better, than that Excrement, or whatever other substance it be made of which, the Silk-worm wire-draws his clew. . . . I need not mention the use of such an invention, nor the benefit that is likely to accrue to finder, they being sufficiently obvious."

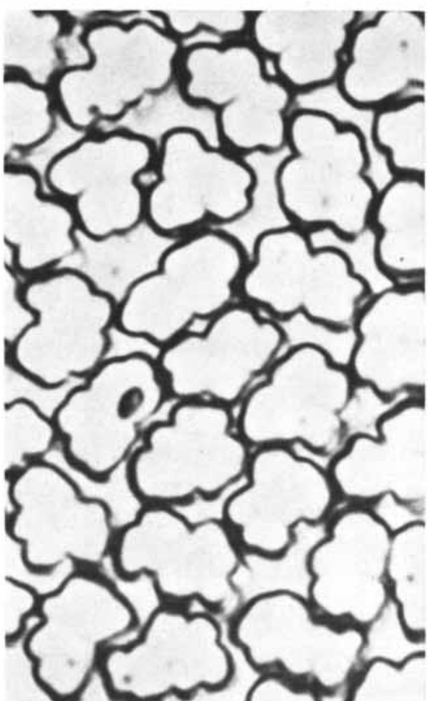
For many years the appeal of the new synthetics was based largely on their rich, lustrous resemblance to silk. But by the late 1930s and early 1940s textile physicists had discovered that artificial fibers offered much more important advantages. They could greatly broaden the spectrum of physical and chemical properties available among the fibers and thereby meet the expanding needs for new types of textiles. Furthermore, man-made fibers could be produced under better control and to more precise specifications than natural fibers. The new understanding of textile performance catalyzed the most productive and creative period in the history of the textile industry. Natural fibers, as well as artificial ones, have benefited from this research, and today the consumer has an almost endless variety of products from which to choose.

Meanwhile the war and certain economic factors helped to accelerate the growth of the synthetic-fiber industry. By cutting off the supplies of silk World War II speeded up the use of nylon at a rate beyond calculation. Rayon was given a vital competitive boost in the civilian-apparel markets by the disappearance of silk and shortages of cotton and wool, due to huge military allocations. The introduction of rayon cord in the tires of combat vehicles doubled the production of rayon during the war years. Glass fibers were given tremendous impetus by their use for electrical insulation and as reinforcement in plastic laminates. The Government's support of agricultural prices, which kept the price of natural fibers like cotton high, also worked in favor of the synthetics, and so did the pressure on the land for food, causing drastic changes in the quality, quantity and price of wool. On top of all this, advertising and vigorous merchandising kindled public interest in the new synthetic fibers.

No fewer than 25 different kinds of synthetic fibers have been invented and produced in at least pilot-plant quantities. Viscose rayon and acetate still account for over 90 per cent of all artificial-fiber production. Among the others the most important so far are nylon and cuprammonium rayon (Bemberg rayon), which together represent roughly six per cent of production, and glass fiber, Vinyon, vicara, Orlon, lanital, ardil and "Fiber V," called terylene in England and Dacron in the U. S. These are only estimates, however; it is difficult to obtain accurate statistics on the production of the lesser-known fibers, particularly those produced abroad.

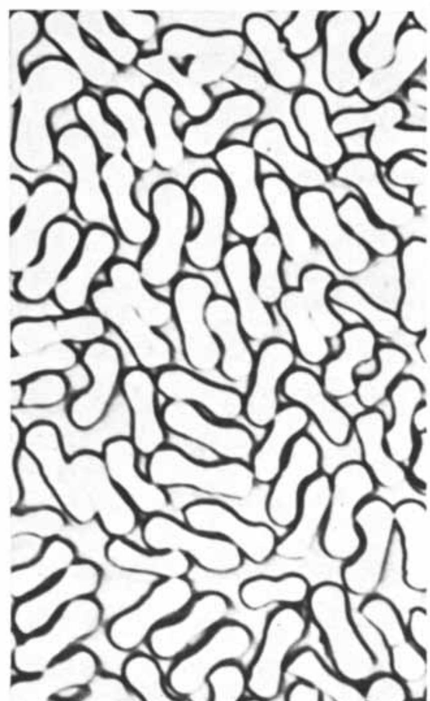
Physics of a Fiber

What is a synthetic fiber? What special properties can be built into such



Estron (photomicrograph)

Viscose rayon



Vinyon N

fibers? Without going into the details of their chemistry or manufacture, we can obtain light on the answers to these questions by first considering briefly the nature of fibers in general.

A textile fiber, or filament, is the basic physical unit from which the textile is made. The fibers are formed into yarn, and the yarn, in turn, is woven to make the textile. A natural-fiber yarn is always composed of a large number of fibers, partially twisted around one another into a coherent structure. To give the textile its necessary properties of suppleness and elasticity, a yarn must be free to move during flexing or other distortion and yet return to its original position in the fabric when the force is removed. In natural-fiber yarns the individual fibers readily yield to a distorting force, and the integrity of the structure is maintained by frictional forces imposed by the twist and the proper elastic reaction of the fibers.

Now it has been found that synthetic-fiber yarns similarly must be composed of large numbers of fibers or filaments. (There are single-filament synthetic "yarns" made of metal, Saran, polyethylene and other materials, which can be woven into textile-like products such as screening, but these are not textile yarns in the sense used here.) Since only large molecules can be manipulated into the long, tough, supple structure required in a fiber, the raw material for a synthetic fiber must be in high polymeric form; that is, it must be composed of large molecules which can be molded into a threadlike shape.

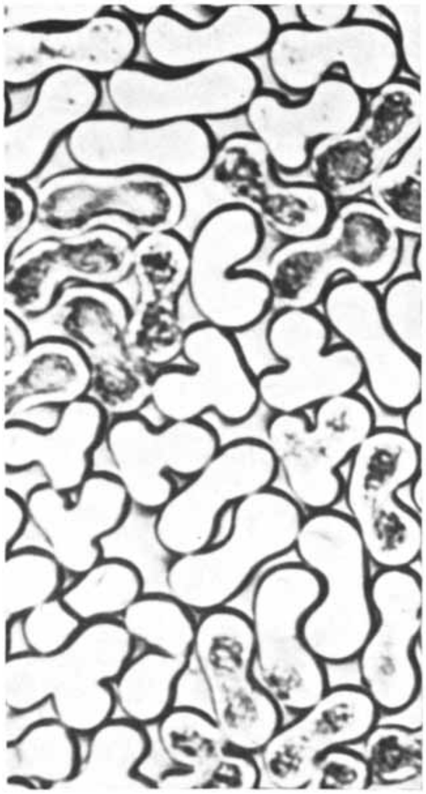
Once such a polymer has been synthesized and put into a suitably fluid condition, the fundamental problem facing the manufacturer is the conversion of the bulk polymer into the form of continuous, extremely fine filaments. The mechanical shaping of the polymer is accomplished by extruding the viscous fluid through minute orifices in a spinneret—named after the organ through which the silkworm ejects its double filament of silk. As the fluid comes out, it is instantaneously and continuously solidified into a filament. There are two ways of doing this. In one method, used to make nylon, acetate, Dacron, Vinyon and glass fiber, the fiber solidifies as it comes in contact with the atmosphere; this is called dry-spinning. In the other, called wet-spinning, the fiber forms in a coagulating bath; the synthetics made in this way include rayon, azlon and some types of Orlon and Vinyon.

One of the major differences between synthetic and natural yarns is that the synthetic, instead of being formed of single filaments twisted together, is itself a continuous multifilament structure. Synthetic fibers are available in two forms. One is the continuous multifilament formed directly by the spinneret. This is ready to be handled as a yarn without the usual spinning. The other form consists of short lengths cut from the continuous filament material. This product, called staple, is analogous to the form in which natural fibers come, and it is spun into textile yarns on the same machinery used for cotton or wool. Most of the synthetic yarn now manufactured (*e.g.*, two thirds of all rayon production) is of the continuous multifilament type. But an increasing percentage of rayon, acetate, nylon and Vinyon (as Dynel) is being made in staple form. In this form the fiber can be spun into cotton-like or wool-like yarns and blended with natural fibers.

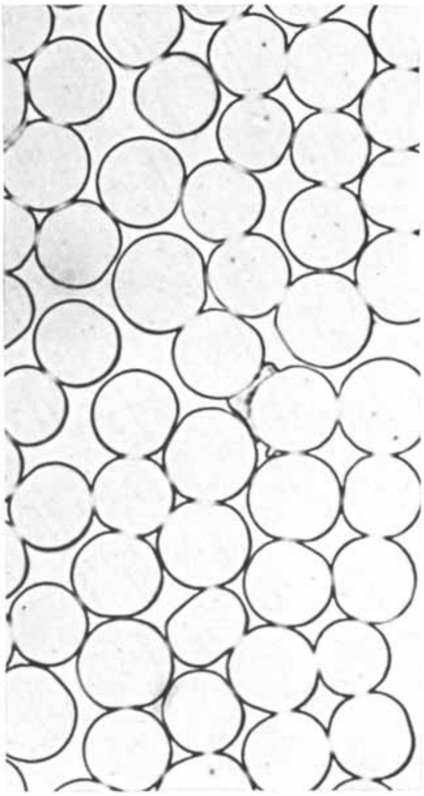
Test of Strength

In evaluating any yarn the first thing in which a textile physicist is interested of course is its tensile properties. Fibers vary greatly in thickness and weight; for example, rayon is nearly one and a half times as heavy as nylon per unit of volume. To make a useful comparison of the tenacity of various fibers we must reduce it to a common denominator: namely, the strength per unit of mass. The criterion of strength is called the denier; one denier means that a 9,000-meter length of the yarn weighs one gram; two denier, that 9,000 meters weighs two grams, and so on. In general, the higher the denier of a yarn, the stronger it is; the rule does not work out exactly, but it is reliable enough to give an extremely useful basis for rating textile strength.

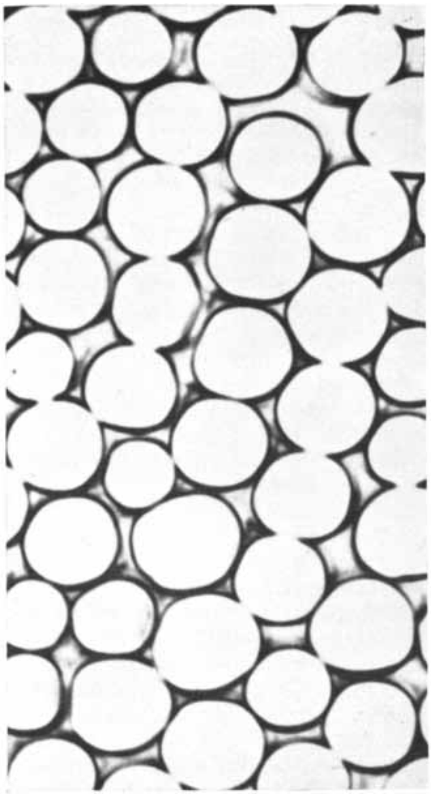
One test of a fiber's utility is to observe how it responds to an increasing load. The load is called the stress, and



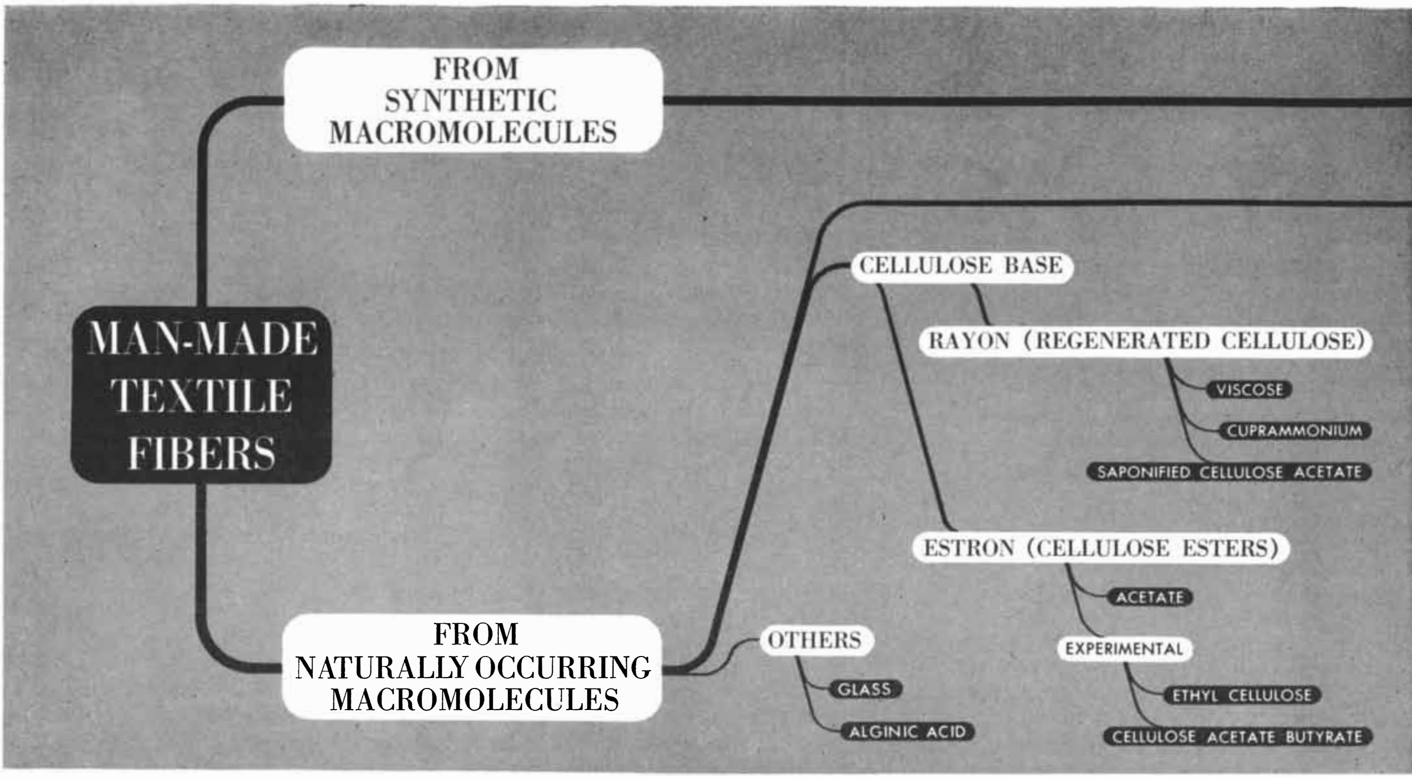
Orlon



Nylon



Terylene



THE DOMAIN OF SYNTHETIC FIBERS is divided into two principal parts: the fibers made from large molecules occurring in nature (*left*) and the fibers made from large synthetic molecules (*right*). Polulan and

the distance the fiber is stretched is called the strain. The two quantities, plotted against each other on a graph, give a "stress-strain" curve (*see diagrams on page 42*). Such curves can serve as powerful tools for analyzing textile performance.

Now in a perfectly elastic material the strain would always be proportional to the stress over the whole range of loads. But in most textile fibers (a notable exception is glass fiber) the response is not uniform; after the material has been stretched a certain amount, it reaches a region where it takes much less force than before to lengthen it a given distance. This suggests that a flow of molecules or some other deforming process has begun to take place and the material is losing its elasticity, so that it will be permanently lengthened. Since the success of a textile depends on its ability to return to its original form after mechanical stress, the fiber is presumably irreparably damaged after it has been subjected to this amount of strain.

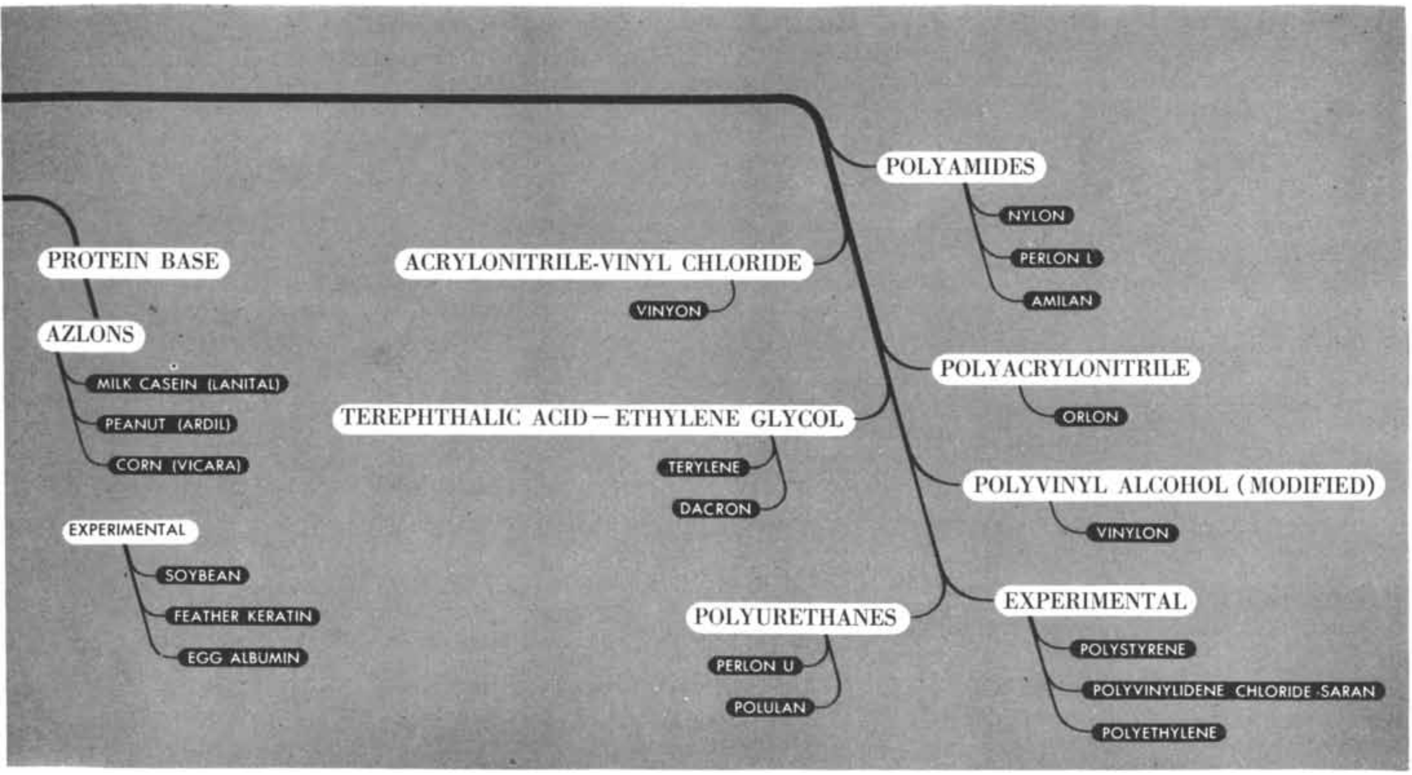
Yet we know that textiles can withstand considerable stress, much greater than the loading test would suggest, without losing their ability to return to their original shape. Why is this so? The answer is not completely known, but it appears to be related to the "visco-elastic" properties of the fibers, whose crystalline structure is not rigid, as typical crystals are, but has a certain amount of flexibility. When a stress is applied, the long chain molecules may straighten somewhat and glide over one another. But the cross-linking bonds that hold the chains together seem able to exert their influence over a considerable distance. Given time, they will help the forces of immediate elastic recovery to restore the fiber to its original structure after the stress is removed. But if the stress is too great and slippage goes too far, the bonds are ruptured and the chains become cross-linked by new bonds at new points; the fiber is then permanently deformed. In other words, so long as the slippage, or "creep," does not proceed beyond the breaking point of the original bonding forces, the fibers can recover their form, though it may take time. This explains why textiles are more adaptable to severe stresses than the stress-strain curves might indicate.

Fiber Energy

Today measurements of the energy-absorbing capacity of fibers have replaced the simple tests for tensile strength and stretching in the evaluation of fibers and textiles. In the last analysis the value of a textile depends on its ability to do work. It is characteristic of most textile use, whether buried in the rubber of a V-belt or exposed on the seat of your pants, that forces of a relatively low order of magnitude are applied with great frequency, and the ability of the material to absorb the energy so imposed is a measure of its quality. The energy-absorbing capacity of a fiber depends on both its tensile strength and its elasticity. Stress is a force and strain a distance: force × distance = work. Wool has low tensile strength, but it has a large capacity for absorbing energy, and this accounts for its great utility. On the other hand, glass fiber, though it has high tensile strength, cannot be stretched much, and its low energy-absorption capacity limits its uses. Nylon combines both high tensile strength and high elasticity; it has the greatest energy-absorption capacity of any fiber, natural or synthetic, and consequently it is an unusually versatile material.

There is another factor governing the performance of a fabric, and that is the form in which the fibers are combined. In the manufacture of yarns and fabrics extremely large numbers of individual fibers are manipulated into complex geometric structures. Their form greatly influences the degree to which desirable fiber properties express themselves in the finished textile. Such "form factors" as the twist in the yarn, the diameter of the yarn, the kind of weave, the number of yarns per square inch of fabric affect the properties of the fabric in important ways.

An illuminating demonstration of this developed during World War II. For many years U. S. Army field uniforms were made of a cotton fabric of twill weave. This weave, of which gabardine is an example, is characterized by ribs running the length of the material. During the war it was found that the twill



amilan are made only in Japan; the perlons, only in Germany; lanital, only in Italy. Terylene, which is made only in England, is identical with the U. S. fiber Dacron, which until recently was called Fiber V.

field uniforms wore out at a discouragingly rapid rate. The U. S. Army Quartermaster assigned the problem to the Fabric Research Laboratories in Boston. The first step was to examine field practice by watching soldiers testing clothing on the model combat course at Camp Lee, Va. It was clear that the predominant abrading force exerted on the uniform by a soldier crawling along the ground or climbing walls and fences was along the length of the body. The twill ribs in the uniform also ran the length of the body and were exposed to the ground. Hence the yarns were exposed simultaneously to abrasion and tension, the latter resulting from the dragging action of the soldier's body. Obviously this could only accelerate the breakdown of the fabric. It was plain that a flatter, smoother fabric, with the threads on the outside face of the cloth running predominantly crosswise rather than lengthwise, would improve resistance to wear. A satin type of fabric was designed in which each warp yarn (running lengthwise) passed under one filling yarn (the crosswise part of a weave), then floated over the top of several filling yarns, and so on. The uniform was then made so that the warp yarns were mainly against the body and the filling yarns on the outside. The filling yarns, lying at right angles to the direction of the soldier's main line of movement, were exposed to most of the abrasive action and a minimum of tension. The warp yarns, largely buried under the filling, were subjected to a minimum of abrasion. This design produced uniforms with more than double the life of any previously tested.

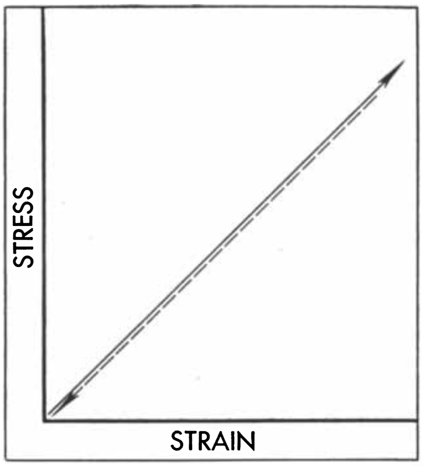
Wear

Let us now apply all this to a few problems with which every textile consumer is concerned. The first thing we shall consider is abrasion-resistance, which is practically the same thing as wear, or durability. The chief factor in a fiber's resistance to abrasion is its energy-absorption capacity. Wool, though a weak fiber, is able to absorb a great deal of energy as a result of its elastic properties, and the wearing qualities of fine wool fabrics are well known. Of the synthetic fibers, nylon is by far the most resistant to abrasion, and glass the least. The other artificial fibers in general have about the same abrasion-resistance as the natural fibers.

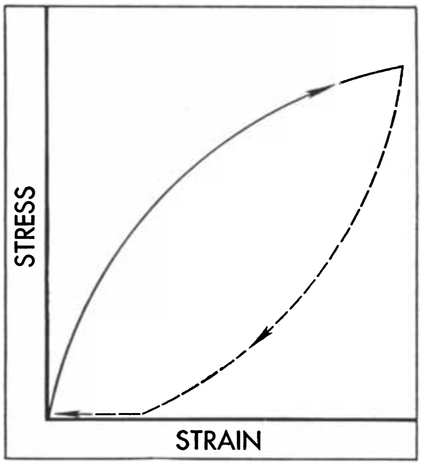
Why should abrasion-resistance be correlated with energy absorption? The answer to this question goes back to the fiber properties we have analyzed. Let us illustrate with an example. From the stress-strain curves it might appear that wool and acetate should be equally good in abrasion-resistance. Yet wool is plainly superior, as any person who has owned a fine worsted suit for many years will testify. This evidence of experience is supported by several theoretical considerations.

We have noted that the fibers in a textile product usually are subjected to loads of a low order of magnitude but high order of frequency. We have also observed that fiber performance under these conditions depends upon the continued ability of a fiber to do work, which in turn depends upon both strength and elongation properties.

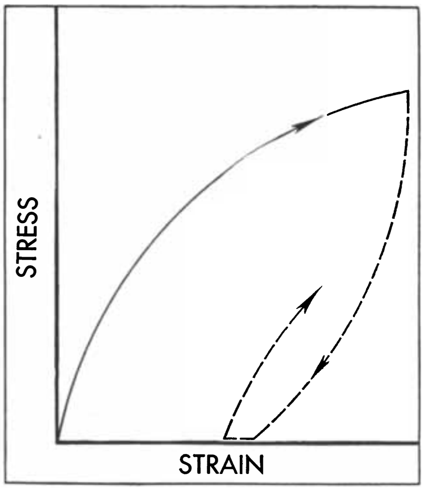
Now acetate is a more plastic fiber than wool. Under the impact of repeated loadings, therefore, it loses energy-absorption capacity more than wool does. In other words, acetate has a much higher percentage of nonrecoverable creep at low elongations. After a strain, or stretching, of two per cent, wool recovers its previous form to the extent of 99 per cent, whereas acetate recovers only 94 per cent; after five per cent strain wool recovers 89 per cent and acetate 73 per cent; after 10 per cent strain wool's recovery is 74 per cent and acetate's only 39 per cent. In the second place, wool is generally made from fibers ranging in length up to eight inches, whereas acetate is largely produced in multifilament yarns, where each filament runs the full length of the yarn. The form-factor influence here is obvious. The wool yarn is never as compact or as smooth as the acetate yarn, and the surface presented to the abrasive material is markedly different. Furthermore, the bulkier, fuzzier form of wool yarn permits it to make use of another property, not heretofore mentioned, namely compliance. Wool is the more readily compressible fiber; at low loads it will re-



PERFECT ELASTICITY in a fiber is shown by curves on this diagram. Fiber is stretched (*solid line*) and returns to same length (*broken line*).



GOOD ELASTICITY in a fiber is expressed by these curves. Stress is not proportional to strain, but fiber returns to original length in time.



POOR ELASTICITY in a fiber is expressed by these curves. Stress is not proportional to strain, and fiber never returns to its original length.

cover quickly and more completely from the compressed state. This ability of wool to "roll with the punch" undoubtedly works to its advantage in wear-resistance.

Within limits it is possible to improve the abrasion-resistance of almost any fabric. Besides changes in the design of the cloth, such as were made in the Army uniforms, there are two other devices. One is to treat the fabric with a resin, usually of the vinyl type, which forms a coating over the fibers. The coating shields the fibers from abrasion (while it lasts) and extends the life of the fabric. The drawback is that a coating thick enough to be effective stiffens the fabric and changes its feel; hence this method is useful only for a limited number of types of material. The other stratagem for improving wear is to mix the given fiber with an abrasion-resistant fiber like nylon. Up to 20 per cent of nylon staple may be blended with cotton, wool or rayon in socks, suitings and a host of other goods without seriously changing the tactile properties of the dominant fiber to which the consumer is drawn.

Shrinkage

Next let us consider dimensional stability, particularly resistance to shrinkage, which like durability is one of the major factors in evaluating any textile. The man-made fibers have made a very significant contribution to the solution of the problem of shrinkage. All the synthetics except rayon and certain types of azlon are hydrophobic, therefore are not shrunk by water. Fabrics of nylon, glass, Vinyon, Orlon, acetate and terylene tend to keep their form when washed, rained on or subjected to other normal conditions of wetting.

The shrinking action of water on a yarn takes two forms. In one, known as swelling shrinkage, water is absorbed into the spaces between the long chain molecules of the fiber walls and the fiber swells laterally, that is, becomes thicker. As it does so, it also decreases in length. This causes the yarn to become shorter and the fabric shrinks. The second kind of shrinkage is called relaxation shrinkage. During the many processes to which yarns are submitted in textile manufacturing they are under constant tension. In the final product the twisted fibers in the yarns may be in a strained condition which will relieve itself at the slightest opportunity. Wetting or heat gives them this opportunity. The fibers relax as in the release of a spring and recover their original form. The entire fabric shrinks accordingly. All fibers except glass are subject to relaxation shrinkage, particularly in hot water.

Nylon, Vinyon and Orlon exhibit another kind of shrinkage under heat, wet or dry. Nylon evidences what has been called a "heat memory." Once it has been shrunk by heat at a given temperature, it will not shrink again unless it is exposed to heat above that level. This property is exploited in the shaping of nylon stockings to women's legs and the production of permanent pleats in dresses: the nylon is shrunk to the desired condition at a temperature higher than any it is likely to encounter later in normal consumer use. Heat shrinkage also makes it possible to introduce a larger number of threads to the square inch than is possible by weaving into certain types of filter cloth and sail cloth which require extremely close yarn packing.

There are, of course, various ways to control shrinking. The most widely known is "Sanforizing," applied mainly to cotton and linen. Sanforizing simply means that the material is preshrunk under mechanically controlled conditions; no chemical treatment is involved. An analogous type of preshrinking by mechanical relaxation, known as "Redmanizing," is applied to knitted fabrics. For wool and rayon there are chemical methods of controlling shrinking. The material is impregnated with certain melamine-formaldehyde or methylol-urea resins and then treated with heat to complete the polymerization of the resin, primarily inside the fiber. If properly applied, these treatments change the characteristic feel of rayon or wool only slightly, and the resins resist removal during laundering or dry cleaning.

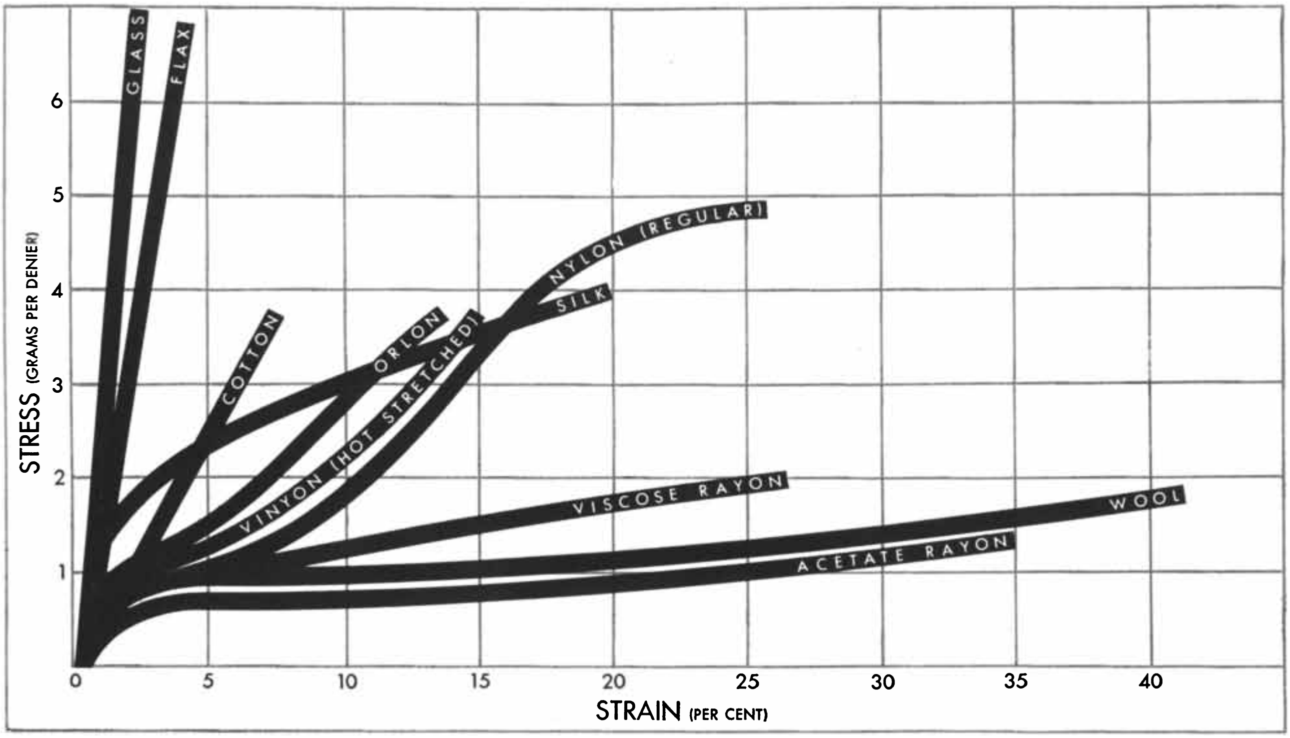
One widely used method of controlling shrinkage is to combine a fiber that is susceptible to shrinking in water with one that is not. Thus when rayon, wool or cotton is mixed with nylon, acetate, Dynel, Dacron or Orlon, the result is a fabric that is relatively stable to wetting. The fibers may be blended in staple form and spun together in a yarn, or yarns of different pure fibers may be mixed during weaving.

Wrinkling

Resistance to creasing is another aspect of dimensional stability. But this phenomenon is not yet well understood; in fact, about some phases of it we can do little more than say, with Richard Armour:

The crease and the wrinkle, there isn't much doubt,
Are alike in a number of ways,
But the crease is the one that so quickly comes out,
While the wrinkle's the one that stays.

Certainly resistance to creasing is affected by such factors as twist in the yarn, the number and size of the yarns, the weave and other construction details. For example, fabrics of crepe construction, which employs highly twisted yarns of fairly small diameter, are excellent in crease-resistance, whether made of rayon



TEN FIBERS are plotted against stress and strain. Actually the curves change with such factors as moisture content and filament and yarn denier. The curves are still a fair picture of relative characteristics.

or wool. Rayon is much more wrinkleproof in this form than, let us say, in a gabardine woven of normal-twist yarns. Presumably a springlike action due to the extra twisting of the yarn in the crepe is responsible for the fabric's resistance to wrinkling. This method of imparting unusual springiness to fibers has been applied to cotton, notoriously easy to wrinkle. The product is a corkscrew type of yarn which is highly elastic, performing like a rubber band over a limited range of stretch. Elastic bandage, made of cotton, embodies this principle. Into the fabric are woven filling yarns of very high twist which act like springs when the fabric is extended.

It is generally agreed that when a fabric is creased, the forces applied to any one fiber are very small, approximately 1 to 10 per cent of the total strain on the fiber. This would indicate that the elastic properties of the fiber at low loads, which markedly influence the rate of recovery, play a significant part in controlling wrinkle-resistance. This conclusion is borne out in part by the fact that wool, silk and mohair, which when dry exhibit the highest percentage of immediate elastic recovery at low loads, are also the fibers that resist wrinkling best. Nylon and Dacron recover more slowly when dry. When wet, nylon, Orlon, acetate and particularly Dacron are much superior to wool or silk in wrinkle-resistance. The new blends of wool with Dacron, Orlon or nylon are said to hold their shape over a wide range of moisture-absorption conditions.

For some years rayon has been impregnated with resins of the urea-formaldehyde, methylol-urea and melamine types to enhance its crease-resistance. More recently, similar treatments have been applied to wool and cotton, with more limited success than in the case of rayon. The mechanism whereby these polymers develop the additional resilience is still obscure.

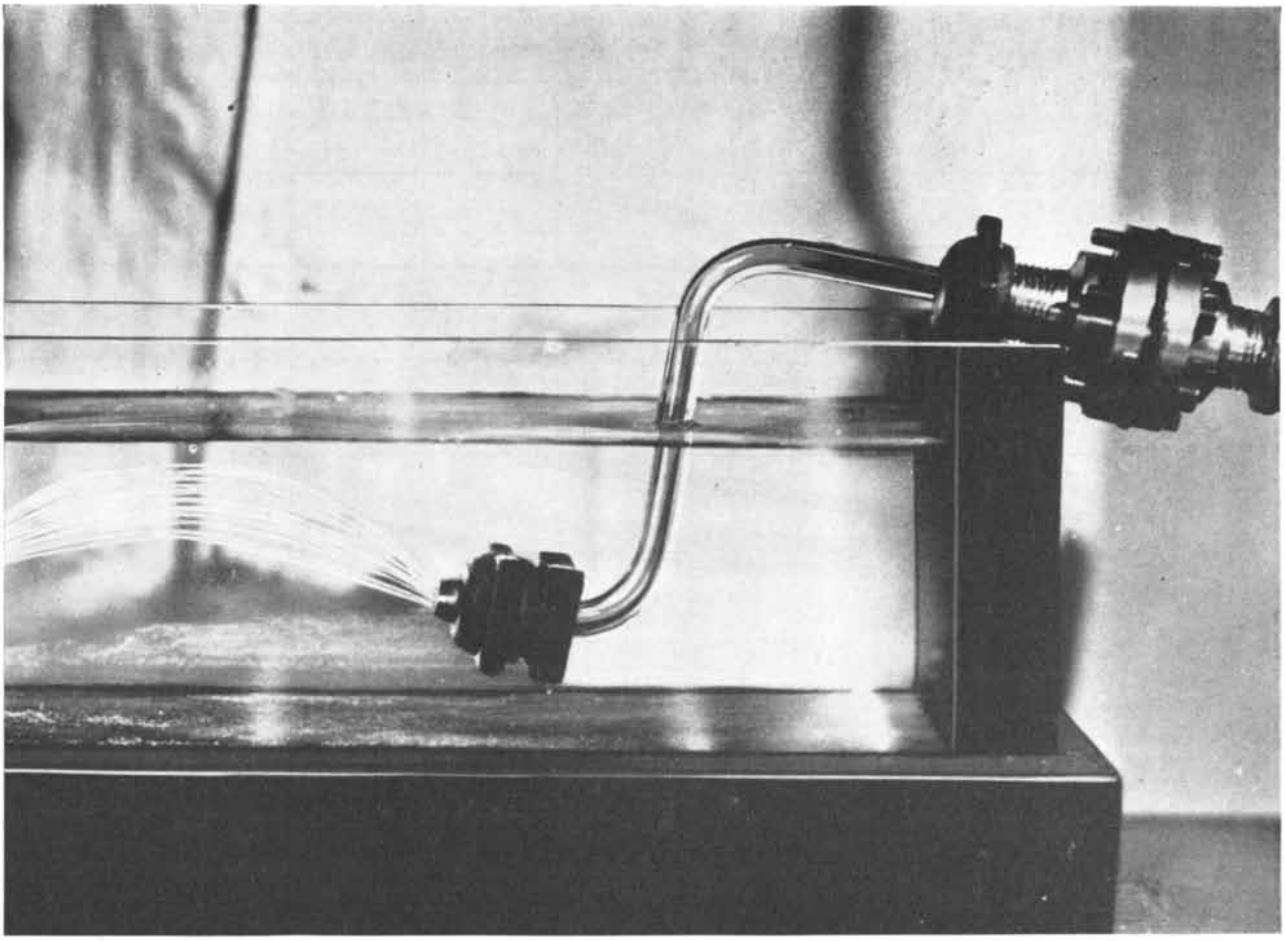
Comfort

A third major test of a clothing textile is its ability to keep the body warm or cool, as the case may be. This is one of the most complex problems in the textile field. It is complicated by physiological and psychological factors as well as by physical ones. Yet clothing is the most important outlet for textile fibers, and in order to judge the potential worth of artificial fibers to man we must evaluate their relative contributions to bodily comfort. No absolute ratings can be made, but we can at least list the relative advantages and disadvantages of various fibers under given sets of conditions.

The insulation quality of a fabric depends primarily upon its ability to trap air in spaces between the fibers and to continue to hold this air during use. There are many types of fibers that can form fabrics with good initial insulation quality. But as the fabric is used, some types of fibers pack down and lose air space and insulating value more quickly than others. From what has already been said about the elastic properties of the several fibers, it can be understood why wool, silk and nylon, with their ability to absorb and return large amounts of energy without permanent deformation, are superior to rayon, acetate, the azlons, cotton and glass. Dynel also has excellent insulating qualities in blankets and similar fabrics.

But other factors complicate this picture. The most significant are the fabric's capacity to absorb moisture and its porosity. As everyone is aware, perspiration is vital to the control of skin temperature. For this mechanism to function efficiently, perspiration and evaporation of the water must be in balance. Clothing can help evaporation in two ways: 1) by giving water vapor at the skin surface an outlet through the pores in the fabric, or 2) by absorbing the water in the solid substance of its fibers and evaporating it to the air at the outer surface of the fabric.

Fabrics made of fibers with a strong affinity for water, such as cotton, rayon and wool, apparently remove water by both mechanisms. In these cases tight weaving of the yarn does not greatly increase the resistance to evaporation. On the other hand, in fabrics such as nylon, Vinyon and glass the main pathway of evaporation is through the pores of the cloth; here increasing the thickness and density of the fabric rapidly increases the resistance to the passage of water. Hence in the case of these fabrics a thin cloth, with relatively few yarns per square inch, is best for evaporation. At first glance this might seem desirable, for it means a minimum weight of fabric on a man's back. But



VISCOSE RAYON emerges from the tiny holes of a spinneret. Liquid viscose is pumped to the spinneret through the tube at the right. When the viscose enters the solution in the small glass tank, it solidifies.

body temperature is also affected by the temperature differential between the body and the air, by air currents and by exposure to the sun's rays. When a wind is blowing or the sun is bright, the body, if covered with too porous a fabric, may cool too rapidly or be too exposed. A compromise must be struck between porosity and protection from moving air and radiant energy. The fibers that are capable of mediating the evaporative process by means of absorption—namely, cotton, rayon and wool—are definitely superior in effecting this compromise.

An absorbent material, however, may heat the body as well as cool it. While the fabric is being wet by perspiration, before it has become wet enough to evaporate water from its outer surface, it may release heat. This heat of wetting may be considerable. In a debate on the merits of natural *versus* man-made fibers the English physicist A. B. D. Cassie once pointed out that wool clothing absorbs a considerable amount of water from the atmosphere when a person goes outdoors on a day of high relative humidity: under certain condition an overcoat weighing five pounds may absorb as much as three quarters of a pound of water. The heat evolved during this wetting, he said, "is as much as the average man's body loses in three to four hours when he is awake."

During the first moments of perspiring from hard physical exercise a fabric such as nylon, Vinyon or acetate, which absorbs little water, may feel cooler than rayon, cotton or wool. But as perspiration accumulates, the nonabsorbent material begins to make the wearer feel uncomfortable, whereas an absorbent fabric like cotton sponges up excess perspiration and gives its wearer the benefit of evaporative cooling. This cumulative effect of the hydrophobic materials is responsible for many complaints men have registered about nylon, Orlon and acetate shirts, particularly on warm, humid days, and for the fact that, despite the porosity of hosiery, many women find nylon stockings less comfortable than silk.

On the whole, except for rayon and the synthetics based on protein the man-made fibers are not as comfortable over as wide a range of environmental conditions as the natural fibers when in contact with the skin. But for outer garments worn outdoors the water-repellent, abrasion-resistant, wind-resistant and lightweight fabrics, such as nylon, offer definite advantages. Nylon has also swept the field in women's underwear and hosiery, evidently because beauty and durability are more important to women than maximum comfort. The whims of the consumer are variables beyond the control of the textile scientist.

Fiber Immunity

The synthetic fibers have made many other contributions. In the chemical industry Vinyon and nylon, because of their chemical inertness, have been put to use as filters. Glass has brought about radical changes in electrical insulation and motor design, thanks to its ability to withstand extremely high temperatures, its low moisture-absorption and its excellent electrical resistance. The use of glass tape and yarn for wire insulation has eliminated many fire hazards. As the only completely incombustible textile, glass also is an excellent material for draperies where fire safety is important, as in public restaurants and dance halls. In general, the artificial fibers produced from synthetic high polymers do not support a flame, although some of them may burn. This does not necessarily mean, however, that the synthetic textiles in their finished form are fire-resistant. It should be emphasized that fabrics rarely reach the consumer without some impurities, such as oils, gums, dyes and resins, which are applied during the finishing operations. These substances may make the base fabric inflammable. They may also make the material susceptible to attack by fungi, bacteria and other degrading action, although the pure fiber itself may be impervious to such attack. It is these finishes, not the fabric itself, that are responsible for the allergic reactions of some consumers to some of the synthetic textiles; this has been demonstrated to be the case in nylon hosiery.

All the synthetic fibers except those made from cellulose or protein show good resistance against mildew or other biological attack. Even when they are treated with finishing compounds that encourage fungal and bacterial growth, the damage from such growth is usually superficial, more serious esthetically than in its effect on the basic physical structure of the fabric.

The synthetic fibers of course have some disadvantages along with their advantages. For example, because of their resistance to water absorption most of them are difficult to dye, and therefore they are available only in a limited range of colors. The rayons and azlons are exceptions, but the printing of fabrics such as nylon, Orlon and acetate is still an unsolved commercial problem. The property of water-repellency also causes such fabrics to accumulate static electricity on dry days, and this may make clothing stick to the skin or to other layers of fabric.

A fabric's resistance to abrasion may be a disadvantage under some circumstances. For example, nylon seat covers may cause excessive wear on fur coats and wool suits as the wearer rubs back and forth during driving and getting in and out of a car. The low strength of rayon and azlon when they are wet, and the sensitivity of acetate to heat and solvents have created problems in cleaning these fabrics. In short, the newness of the man-made fibers has presented many problems for the textile manufacturer.

Forecast

What about the future of the synthetic fibers? We began by noting that the artificial-fiber industry has grown with startling speed; its impact during the past few decades amounts to an industrial explosion. But there are many reasons for believing that the rate of increase in the size of the industry will be much slower in the coming decade than in the one just past. The research ingenuity responsible for the development of the synthetics has forced the natural-fiber industry to finance equally vigorous and productive research, and remarkable improvements have been wrought in the natural-fiber products during the past five years. Under the spur of competition the natural fibers now occupy a much healthier and more vigorous position than they had for some time. Moreover, one must remember that the magnitude and long history of man's occupation with the business of growing and processing natural fibers has created a strong cultural inertia. Thirty billion pounds of natural fiber are produced each year and flow into the main channels of international trade from almost every nation in the world. The enterprise of natural-fiber production is deeply ingrained; it involves the traditions of generations of farmers and herdsmen representing the full cultural spread of East and West. These are patterns of human organization that respond slowly to change, even in the 20th century. Further, the synthetic-fiber industry has problems of material shortages; it needs special steels for reaction chambers, platinum for spinnerets, organic solvents, sulfur—all of which can become very scarce in moments of political crisis. More than two thirds of the nations producing rayon must import chemically pure, dissolving grades of pulp from countries like Canada and Sweden. Every pound of rayon produced requires 2,000 gallons of water for processing, and the battle for good industrial water is already a factor to reckon with.

As far as the development of new synthetics is concerned, the greatest research need at the moment is to find more effective ways to use the ones we already have. It appears that, unless new fibers are developed that are cheaper to produce than those now available, the rate of introduction of new materials will be sharply reduced in the next few years.

All this is not to imply that the synthetic-fiber industry will stop growing. As we have seen, many factors, technical and political, favor the continued expansion of this new field of activity. The growth of world populations and rising standards of living are steadily expanding the markets for textiles. Industrialization and technical knowledge are spreading rapidly over the world, as is witnessed, for example, by the fact that more than 30 nations are producing rayon. It can safely be concluded that the synthetic fibers will continue to enjoy a healthy growth, but from now on the growth will be less spectacular and more typical of a mature business enterprise.

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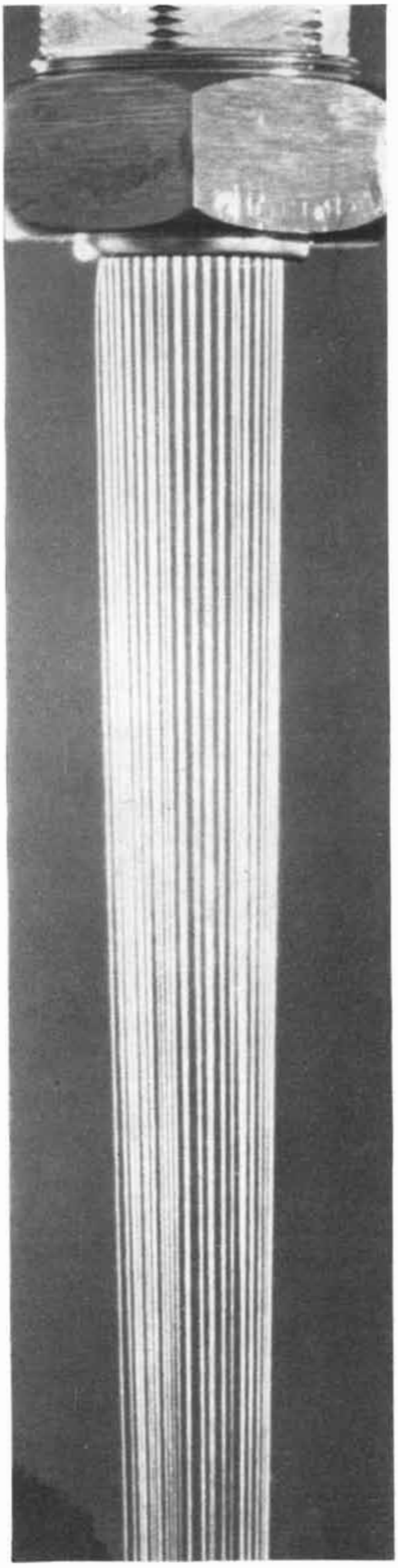

ACETATE is formed in air. A solution of acetate is forced through the holes of the spinneret; when solvent evaporates, solid acetate remains.

PIT DUG FOR A HOUSE is excavated in Pine Lawn Valley. In the large hole at the left side of the pit is a skeleton. The house was a beehive-shaped structure resting on posts that were sunk into the floor of the pit.

THE PEOPLES OF PINE LAWN VALLEY

For eight summers archaeologists have pieced together the cultural history of the Indians who lived in a small region of New Mexico while Greece and Rome rose and fell and northern Europe flowered

by Paul S. Martin

PEOPLE haven't changed much in the past two, five or 10 thousand years: witness the fact that in a prehistoric cave in New Mexico we found ropes tied in granny knots, square knots and slip knots; cradles, dice and mummies of ancient Indians with G.I. haircuts. We have devoted the past decade to reading the unwritten history of these Indians. Here is that history as we read it, layer by layer.

About 12,000 or 15,000 years ago the last great glaciers of the Ice Age had retreated into northern Canada, and wandering bands of Indians began to cross the Bering Strait from Asia into America. Some of these migrants settled in the southwestern part of the U. S.—Arizona, Colorado, New Mexico, Utah and Texas. In time, three important native "civilizations" developed: 1) Pueblo or Anasazi, 2) Hohokam, and 3) Cochise-Mogollon (pronounced Mog-ee-yoan). The first of these occupied mainly northern Arizona and New Mexico and southern Colorado and Utah. The second flourished mainly in southern Arizona. The third, the subject of our story, existed in a mountainous area in eastern Arizona and western New Mexico. I use the term "existed" because in many ways the Cochise-Mogollon Indians eked out a precarious life, and their culture was comparatively undeveloped, marginal and poor in material things.

We decided to investigate the Mogollon culture because it was much less well known than the Pueblo or Hohokam; indeed its existence had come to light only in 1934, when Emil W. Haury published the results of some excavations near Glenwood, N. M. We selected Pine Lawn Valley, near the town of Reserve in the west central part of New Mexico, as a promising theater of operations and laid out a comprehensive program of research. The Southwest Archaeological Expeditions of the Chicago Natural History Museum were organized and we began our work in 1939.

Now an archaeological expedition sounds romantic and exciting, and it is exciting; but I should like to point out that it also involves hard work, dust, heat and possibly illness—to mention only a few of our difficulties. Digging, of course, takes most of our time and money, but there are other matters that must be attended to so that digging may proceed smoothly. We must prepare carefully planned stocks of tools and other supplies, must order a three-months' supply of food and devise a way to store it, must arrange for a safe supply of milk and water (all of our water is hauled in a tank truck) and must make provision for laundry, delivery of mail, garbage disposal, and so on. We make friends with the people of the community and are prepared to render neighborly acts, to lend tools and supplies, to haul materials in case of truck breakdowns, to lecture to local clubs and schools, to stand by in case of sickness or death. All this is in addition to the main business of digging, washing, sorting and cataloguing the excavated objects, and shooting and developing movies and still pictures.

WE HAVE now worked eight summer seasons in the Pine Lawn Valley. During this time we have excavated the aforementioned cave and 76 rooms of houses at 10 different sites. They were probably inhabited over a time span of roughly 3,800 years—from about 2500 B.C. to A.D.1300. Pieced together, the small bits of information uncovered form a mosaic that reveals a fairly clear picture of what the American Indians were doing in Pine Lawn Valley during the rise and fall of Grecian and Roman civilizations and the rise of cultures in northern Europe.

We now know that this Mogollon culture grew directly out of an older subculture called the Cochise, so named for an Apache chief. Hence we shall start our story with the Cochise Indians.

The Cochise Indians settled in southeastern Arizona 10,000 years ago or somewhat later. Their history has been reconstructed by archaeologists and geologists from studies of old camp sites with hearthstones, charcoal, crude stone tools and the bones of extinct animals—all apparently lying exactly where the Indians had left them in the deposits of the Last Pluvial Age some 10,000 to 8,000 years ago. The climate of southern Arizona was then cool and moist. Hickory and other trees that like relatively moist places grew there, and the region abounded in lakes and streams that were frequented by beaver. In this place the Cochise Indians hunted several animals now extinct, such as the dire wolf, the American camel, the mammoth and the American horse. The people camped along the streams and lake shores, living on nuts, seeds, berries, roots and some animal food. We call such an economy a food-gathering one. Agriculture, architecture and pottery-making were unknown to them.

For about 8,000 years the Cochise Indians jogged along in the same old manner. There were changes and improvements in their tools, but food-gathering, plus some hunting, remained the subsistence pattern. In the meantime, however, the climate and environment had changed. The continental glaciers had receded, the very wet Pluvial Period was drawing to a close and the lakes and streams were drying up. Much of the lush country was fast becoming a desert. It became plain to the Cochise that their existence was threatened. It was a time of peril, unrest, insecurity. Life and conditions as they knew them were about to perish. The anguish of the Cochise people, three or four thousand years ago, must have been like our feelings in this age of uncertainty.

One thing was certain: some of the Cochise people had to move—and soon. Probably those in small, isolated camps farthest from water went first. Thus about 4,500 years ago, at the time when the Egyptian pyramids were being built, some Cochise migrants wandered into Pine Lawn Valley. Here, in this pleasant pine-covered valley, they found a

WOODEN HOUSE was built later than the pit house on page 46. Postholes and human bones have been dug out.

STONE HOUSE came still later. It was built on the surface of the ground and possessed several small rooms.

new homeland with sufficient food and water. Along the banks of a streamlet that issued from the mountain springs (and still does), they settled down and camped for centuries. They resumed their accustomed way of life—gathering seeds, nuts and roots, which they ground up on crude milling stones; cleaning skins with roughly formed scrapers; chopping poles and brush with heavy, ill-fashioned stone choppers; living in small tents. But in their new land they began to develop some worth-while new ideas.

By the year 1, the Cochise had progressed to the pit house, pottery-making and the practice of agriculture. The pit house, a shallow pit from 8 to 15 feet in diameter with a roof of poles and brush, may have been their own invention; more likely the Cochise borrowed the idea from a nearby people. Well before 1000 B.C. the Cochise people had begun to cultivate pod corn—a primitive type of maize.

ARCHAEOLOGISTS find it convenient to classify and name cultures, and we can say that roughly about the year 1, when pottery and houses were added to what the Cochise Indians had previously known and made, the primitive Cochise culture ended and the Mogollon culture (named after the Mogollon Mountains) began. There is no actual break in the story, only a transition from one stage of civilization to the next. When we speak of the Cochise "culture" or way of life we mean a food-gathering stage in which the people had certain types of stone tools but no pottery or agriculture. The term Mogollon means a continuation of the use of the Cochise stone tool types plus pottery, agriculture and houses.

Now the Cochise-Mogollon occupation of Pine Lawn Valley can be subdivided into seven periods, or phases, that mark changes in the evolution of this people's way of life. The first phase lasted from about 2500 B.C. to A.D. 1.

From this period we have recovered more than 70 stone tools of various kinds—milling stones, choppers, scrapers—that had been dropped or lost along the banks of the Wet Leggett arroyo. These artifacts were uncovered by a recent erosion cycle—a lucky accident for us, for they would otherwise have remained buried from three to 12 feet below the surface and no one would have dreamed of their existence. In addition, we have located several hearths and the floor of a shelter that was probably the site of a small skin tent.

During this period the people of Pine Lawn Valley began to accumulate possessions and found that they had to protect their homes and harvested crops from the rapacity of neighbors or enemies. In the second phase, lasting from about A.D. 1 to 500, they built villages containing from four to a dozen pit houses on high narrow mesas, one end of which was usually unscalable. Across this end was a wall behind which the people could retire in case of attack.

Each pit house was occupied by one or two families, related by blood or by marriage. The house was more or less round, with an average diameter of about 17 feet and an average depth in the ground of about three feet. It had a beehive-shaped roof of poles, branches and adobe, supported by one or more sturdy posts set in deep postholes. The occupants crawled into their house through a doorway consisting of a horizontal roofed-over tunnel or passage six feet long. A skin curtain or stone slab may have been used to shut out inclement weather. Food, skins and tools were stored in floor pits, some of which are six feet deep and four feet wide. Since each house was usually provided with several such "storerooms," they were probably covered by poles or planks; without such covers it would have been dangerous to walk about the house. We do not know what these people used for heat and light, for we have found neither fire pits nor hearths. Probably they did only a limited amount of cooking and carried it on outside the house. They ground corn meal and mashed nuts on milling stones or in stone mortars and pestles. Chairs and tables of course were unknown at this time. Rush or yucca mats and fur robes may have been used for bedding.

ALL THIS is reconstructed from the plain evidence of the remains. Where a pit house stood there is usually a shallow, saucer-shaped depression, with a collection of pottery fragments and broken stone tools. Excavation of such a depression discloses an outlining wall of earth that is harder than the deposited fill; postholes which sometimes still retain the stumps of posts that supported the roof; the lower part of the tunnel entrance, containing smaller postholes for the posts that held up the tunnel roof; pieces of adobe bearing the impressions of poles, branches, pine needles and the fingerprints of the builders; floor pits containing stone tools used for grinding, cutting and scraping; bone awls and needles, and fragments (in a burned house) of mats and baskets. The pottery of this period is all brown or red and lacks any decoration; we call such pottery "plain-ware." The stone tools, mainly made by grinding and pecking, include rubbing stones, milling stones, hammer stones, mauls and bowls. There are also some chipped implements: arrowheads, knives, scrapers, choppers and drills. For the most part, the types of stone tools found in this period are directly descended from the Cochise types.

The dead were frequently buried in a pit below the smoothed adobe floor, with the surviving members of the family continuing to occupy the house. Offerings to the dead are meager—a shell bracelet or two, perhaps a tubular tobacco pipe of stone, possibly a chopper or an arrowhead. Although burying the dead in the house may seem strange to us, perhaps the Mogollon Indians felt the same as the cowboy, who still pleads:

Oh, bury me not on the lone prairie,
Where the wild coyotes will howl o'er me . . .

We may assume that the Mogollon Indians, like all peoples, had religious convictions and dogmas. This assumption is strengthened by the fact that we have uncovered several "super" pit houses, perhaps temples of some kind, which measure some 33 feet in diameter and lack floor pits and other evidences of domestic usage.

The Mogollon culture of A.D. 100-500, in short, was undeveloped and unsophisticated, with no striking or dramatic features. Its people had few requirements and probably seldom sought contacts with other cultures. Yet it had made important advances over the more primitive Cochise culture and had started an upward trend.

IN the next three periods, extending from A.D. 500 to 1000, life slowly changed. Apparently unfriendly groups were conquered or dispersed, for we find that during this era pit houses were built in choice spots without necessarily being bunched together. They were made rectangular in shape instead of round and became markedly smaller—about 12 feet across. They also acquired fire pits or hearths and eliminated the floor storage pits; we do not know where food and tools were stored or where the dead were buried during this period. Corn was still ground indoors, but mortars and pestles were going out of fashion. Further internal evidence leads us to believe

FOOD-GRINDING SLAB that was used by the inhabitants of Pine Lawn Valley some 4,500 years ago was laid bare by erosion in Wet Leggett arroyo.

that agriculture (maize, beans, squash) and hunting had become the means of subsistence and that food-gathering was a thing of the past, although medicinal herbs may have been collected.

Perhaps the most striking changes took place in the pottery. Sometime between A.D. 500 and 650 the idea of painting designs on their pottery occurred to the Mogollon Indians. The earliest designs we have found were done in red on a brown background. They were geometric in layout and were applied with a steady hand. By the year A.D. 900 the designs and layouts had been so skillfully reworked, interwoven and varied that it takes an expert to perceive a relationship between this and the earlier work. By the time the Crusades were under way in the Old World the Mogollon potters had developed a painted ware that evokes the admiration of all who see it.

We assume that the density of the population had increased, for we find more rooms, or pit houses, at A. D. 900 than at A.D. 500. The individual pit houses of each village are smaller, from which we infer that only one family occupied a room and that perhaps an extended family (all members related by marriage or blood) occupied an entire village.

By the time William the Conqueror was invading England (A.D. 1066), a new period had been ushered in and profound changes had occurred in the Mogollon way of life in Pine Lawn Valley. Now we find that the Indians have suddenly changed their architecture; instead of pit houses they have multiroomed houses built entirely above the ground, with walls of stone masonry. As far as we can tell from our digging evidence, this change in type of dwelling did not develop out of any Mogollon tradition. It represents a borrowed idea, and was probably the result of Pueblo influence, perhaps an actual invasion of Pine Lawn Valley by Pueblo people. The Mogollon pottery also shows a sudden change; now it is white with black designs instead of red-on-brown—another indication of a fusion of Pueblo and Mogollon culture.

The Mogollon social structure, however, probably remained unchanged. We conjecture that the Mogollon Indians continued to reckon descent and inheritance through the female line, with several related families occupying a hamlet and the groom taking up residence at the home of the bride's mother.

Although our excavations have not proceeded beyond roughly A.D. 1150, we know from our reconnaissance of early village sites and of the ground in certain areas that the Mogollon culture continued to flourish for another hundred years or so. But about A.D. 1300 the Mogollon people suddenly abandoned this area. What was the reason? Disease, drought, displacement by Apaches? We do not know. Not until more than 400 years later was this region occupied again. This time it was settled by white men from Europe.

SOME SEASON soon we shall explore the villages of that last period of the Mogollon people in Pine Lawn Valley. But meanwhile a more pressing problem has arisen. All our digging up to the season of 1950 was in open sites in which only the durable and imperishable materials—bones, stone tools, pottery—remain. We had found no signs of the Mogollon Indians' clothing, objects of wood or leather or other perishable products of their culture. But by good luck—and a great deal of archaeology is luck—in the summer of 1949 we found several dry caves.

We decided to dig one of them, known as the Tularosa Cave, in 1950. In this work we have had unprecedented good fortune. Dry, well-preserved specimens have been turning up with such rapidity that we have scarcely had time to clean and catalogue them. Excavating in this cave is very arduous, because the dust has lain undisturbed for centuries. The slightest disturbance causes it to rise, and it remains in suspension for hours. We have therefore had to wear dust respirators and goggles in the cave.

We can only mention some of the more spectacular finds, because most of the materials still await careful analysis. The terrain near Tularosa Cave is covered with sharp volcanic rocks, thorns and a great deal of gravel. Consequently protection of the feet was of paramount importance to the Mogollon people who lived there, and they met this problem by making sandals. We have found about 200 sandals in various stages of wear. They were made of wild fibers—mostly of yucca—because skins and hence leather were scarce in this region.

The cave excavations also reveal that the Mogollon people resorted to ingenious methods to hunt meat. Of course they used spears and, in later times, bows and arrows, but they captured much of their game by means of snares. In one cache we found 11 large snares made of braided rope, each about six feet long. At one end of the snare was a tie for fastening it to a stake or a tree; at the other end, a large noose made with a slip knot. A noose such as this would easily snare a wild pig, a mountain sheep or a deer. We also learned that these early people knew all the knots we know, including the square knot, the granny, the slip, the half hitch and the sheet bend.

The ancient cave yielded a great treasure of other Mogollon artifacts: digging sticks for planting corn, rush mats, cradles, whistles or flutes, beads, fragments of cloth (some in colored designs), fur and feather blankets, string aprons, ornaments, bags, tobacco pipes, cigarettes, "Martini" sticks with juniper berries impaled like olives, wooden spoons (just like those sold in the 10-cent stores today), hair nets, cloth bags, religious fetishes or objects, a doctor's bag containing herbs and tools, baskets, and so on. But no hats of any kind.

Evidently the number one item in the Mogollon diet was corn. We have found in this cave the very early, primitive type of corn called pod corn. The interesting point about this is that whereas corn is supposed to have originated in South America, here in the North American Southwest we found a type of corn which may rank among the earliest and most primitive. The Mogollon Indians also grew popcorn, and popped it on the ear! Our corn may not settle the question as to the place in which corn originated, but it may greatly help botanists trace the history and development of this important cereal ("The Mystery of Corn," by Paul C. Mangelsdorf; SCIENTIFIC AMERICAN, July, 1950).

Besides corn these Indians raised beans, squash, pumpkins and gourds, and they ate walnuts, piñon nuts, grass seeds, sago-lily bulbs, yucca and cactus fruits.

The greatest of our finds in the Tularosa Cave last season were two mummies—the first to be surely identified with the Mogollon culture. They may date at about A.D. 700 or earlier. The mummies were those of two male Indians with hair trimmed in the G.I. style. One mummy wore a string apron and was wrapped in a fur robe. Each body had been laid on a soft bed of grass and had been carried to the grave on a large rush mat. A deerskin robe was placed over the body, then more soft grass and then dirt.

WE have traced here the story of a race of man from about 2500 B.C. to A.D. 1300—from a time before he had acquired the knowledge of agriculture, pottery and house-building to a time when he had become semicivilized. Why do we feel that this research is important? As far as we can tell, man has always suffered from economic and social ills, for which there has been no panacea. If we wish to seek alleviation for man's troubles, we must know as much as possible about the history of mankind, for only by studying the rise and fall of cultures can we hope to understand human societies and the way they function. By recovering all we can of the ancient Mogollon culture and by fitting it into its place in human history, we hope to contribute a mite to the knowledge and understanding of the causes of social disintegration.

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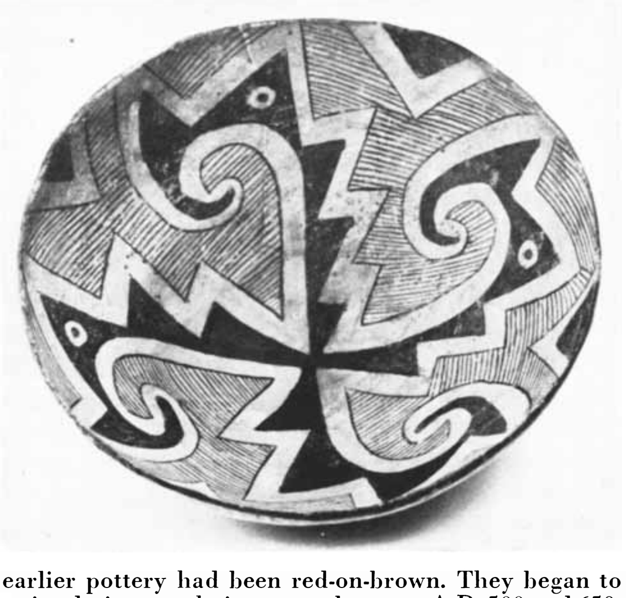
TULAROSA CAVE (*center*) contains evidence of human habitation for 2,000 years. In the open sites elsewhere only durable objects have survived; the cave has preserved clothes, household articles and two mummies.



BLACK-ON-WHITE POTTERY was made by the inhabitants of Pine Lawn Valley 900 years ago. Their earlier pottery had been red-on-brown. They began to paint designs on their pottery between A.D. 500 and 650.

The Theory of Numbers

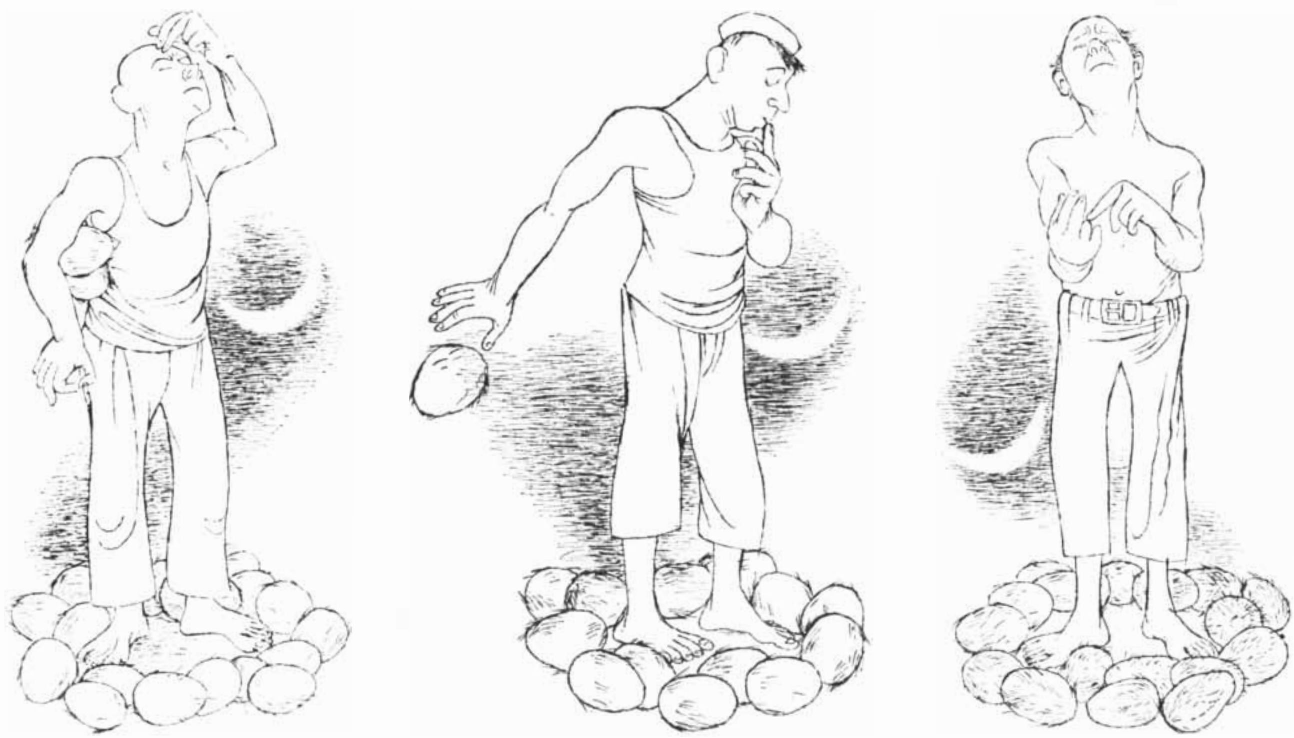
Concerning shipwrecked sailors, the curious habit of Pierre de Fermat, calculating machines, wine jugs, magic squares and other aspects of the fascinating properties of integers

by Paul S. Herwitz

THREE shipwrecked sailors found themselves on an island where the only food was coconuts. They gathered a large number of coconuts and decided to get some needed sleep before they divided the pile into three equal shares. During the night one of the sailors awakened and, not trusting his companions, decided to take his share of the collection without waiting until morning. He found that after throwing away one of the coconuts he could divide those remaining into three equal shares. He buried his share, left the rest in a pile and went back to sleep. Later one of the other sailors awakened and proceeded to go through the same routine: he threw away one coconut, took one third of the remainder and buried them, then went back to sleep. Still later the third sailor, no less suspicious than his mates, went through exactly the same procedure. What is the least number of coconuts the sailors must have collected originally so that there would be a whole number of coconuts left after all this? (We leave to the psychologists the problem of deciding how the sailors reacted to the shrinkage of the pile in the morning.)

Let x represent the number of coconuts collected by the sailors. The first sailor, after burying his share of them, left $2/3(x-1)$, the second left $2/3[2/3(x-1)-1]$; the final equation is $2/3\{2/3[2/3(x-1)-1]-1\}=y$, the number of coconuts left in the morning. This simplifies to $8x-27y=38$. As a general equation this has an infinite number of possible solutions for varying values of x, but we know from the terms of our particular problem that x and y must be positive whole numbers and that x must be the smallest positive integer that will permit y to be a positive integer. The last condition gives us one, and only one, answer, namely, the least number of coconuts the sailors originally collected was 25, and the next morning there would have been six left in the pile.

Had four sailors landed on the island and suffered the same mutual mistrust, our problem would have reduced to the equation $81x-256y=525$. If we generalize the problem to apply to any number of sailors, n (where n is more than 1), the final equation is $(n-1)^n x-n^n y=(n-1)^n+n(n-1)^{n-1}+n^2(n-1)^{n-2}+\ldots+n^{n-1}(n-1)$. (The series of dots indicates that there may be more terms, or fewer terms, than we have written.) This equation is itself a specific instance of the general equation $ax+by=c$, where all the numbers are integers and c is a constant. Many problems lead to



SUSPICIOUS SAILORS awoke one by one to divide a pile of coconuts into three equal shares. What is the smallest number of coconuts that could have been in the original pile? The drawings do not show all the coconuts.

FERMAT wrote a baffling theorem about numbers on the margin of a book. Generations of mathematicians have sought the proof, without success.

equations which are special cases of this general equation. Such an equation is called Diophantine, after the Greek mathematician Diophantus, who first discussed it around A.D. 250.

THE Diophantine equation is one of the cornerstones of the Theory of Numbers. This branch of study has as its aim the discovery of properties of the integers. The fact that these principles are frequently illustrated by application to the solution of puzzles and brain-teasers, such as that of the sailors and the coconuts, should not mislead anyone into thinking that the Theory of Numbers is nothing but a scientific curiosity. Simple as many properties of the integers may appear, their proofs have often entailed many years of study by numerous fine mathematicians, and number theory has long been an important branch of mathematics.

Pierre de Fermat, the celebrated 17th-century French mathematician, is considered to be the father of the modern theory of numbers. Fermat uncovered many interesting properties which are by no means obvious or superficial. Probably as famous as the ancient problem of trisecting an angle is what is known as Fermat's Last Theorem. Fermat was accustomed to write remarks and theorems, without their proofs, in the margins of his books. In his copy of Diophantus' *Arithmetica* he stated the following "theorem": *The equation* $x^n + y^n = z^n$ *has no nontrivial solution in integers for n greater than 2.* By a trivial solution is meant a solution such as x, y and z all equal to zero. Fermat claimed to have a proof of this "theorem," but to this day no general proof of it has been found for all values of n, although many proofs are known for particular values of n. The best known special case of Fermat's equation is the Pythagorean theorem, in which n=2. Pythagoras' principle can be stated as follows: If x and y represent the lengths of the sides of a right triangle and z the length of the hypotenuse, then $x^2+y^2=z^2$. This is a Diophantine equation, since there are more unknowns than equations, and integral solutions are desired.

OF first importance in the study of the Theory of Numbers is the concept of prime and composite numbers. A prime number of course is one that is evenly divisible only by plus or minus itself and by +1 and −1. All other integral numbers are composite, which means that they can be divided by some number other than themselves or 1 and yield a whole number as the quotient. A composite number can always be written as a product of two or more primes. The first few primes are 2, 3, 5, 7, 11, 13, 17, 19, 23. The composite number 12 can be written as the product of three primes: 2 × 2 × 3. Many unsuccessful attempts have been made to find a simple algebraic formula that will yield only prime numbers. One of the best known was suggested by Fermat: he believed that $2^{2^n}+1$ was a prime for all positive integral values of n. For n=1, 2, 3 and 4 we have respectively the primes 5, 17, 257 and 65,537. But the 18th-century Swiss mathematician Leonhard Euler showed that when n=5, the result is not a prime number; $2^{2^5}+1=4,294,967,297$, which is a composite number that can be factored into $641 \times 6,700,417$. In fact, it has not been proved that $2^{2^n}+1$ is a prime for any value of n greater than 4. The formula is laborious and difficult to investigate, because even relatively small values of n produce very large numbers: for instance, if n=7, Fermat's number is greater than 34×10^{37}, that is, 34 followed by 37 zeros. There are other formulas that yield primes up to a certain point, such as n^2-n+41, which is prime for integral values of n less than 41, and $n^2-79n+1,601$, prime for integral values of n less than 80. But no one has found a formula that produces primes for all values of n.

The distribution of the primes among the integers is highly irregular. The 19th-century German mathematician Peter Gustav Lejeune Dirichlet proved that in every arithmetic progression there are an infinite number of primes. An arithmetic progression is a sequence of numbers each of which is obtained from the preceding one by addition of a certain number; for example, 1, 3, 5, 7 is a progression formed by adding 2 in each case. Dirichlet's proof falls into the branch of mathematics known as analytic number theory—as contrasted to algebraic number theory. The analytic theory applies the calculus and the theory of functions to properties of the integers. The truth of Dirichlet's theorem is readily demonstrable by relatively simple considerations in certain particular cases, but for the general arithmetic progression a, a+d, a+2d and so on it has been necessary until recently to apply highly technical methods to prove the theorem. In 1949 the young mathematician Atle Selberg, of the Institute for Advanced Study, published a proof which has placed Dirichlet's problem in a new light. Selberg's work has revived interest in this problem and, along with several related proofs, has brought him international recognition.

An unsolved problem concerning the distribution of the primes is the problem of prime pairs. All primes larger than 2 are odd numbers, since any even number is divisible by 2. In the sequence of all odd numbers (1, 3, 5, 7, 9, 11 and so on) it has been noted that certain pairs of consecutive numbers are pairs of primes, as 3 and 5, 5 and 7, 11 and 13, 17 and 19, 29 and 31. Although it is thought that the number of such prime pairs is infinite, no one has yet succeeded in proving this to be so.

Another type of problem concerning the primes was posed in a letter that Christian Goldbach, a German teacher of mathematics, wrote to Euler in 1742. Goldbach said he believed that every even integer could be written as the sum of two primes and asked Euler whether he could prove this or could find an example to disprove it. Though Goldbach's only importance in the history of mathematics lies in this conjecture, his name will be remembered, for the problem has never been solved.

NO DISCUSSION of the Theory of Numbers could be considered complete without mention of the great German mathematician Carl Friedrich Gauss (1777-1855). In his *Disquisitiones arithmeticae* Gauss made monumental contributions to the theory. We shall consider here only one of the many subjects he discussed in this work. This is the notion of congruence of numbers, which Gauss defined somewhat as follows: If the difference of two integers, $a-b$, is divisible by a third integer c, then we say a is congruent to b with respect to the modulus c, or simply a is congruent to b modulo c. For example, 19 is congruent to 7 modulo 3, since $19-7=12$ and 12 is divisible by 3. The meanings of the words "congruence" and "modulus" give a hint as to the significance of this concept. The former word comes from the Latin *congruere,* meaning to coincide or agree, and the latter from the Latin *modulus,* a small measure. The number c acts as a measure of the "sameness" of the numbers a and b, in a certain sense.

Now when one number is divisible by another, the first of course is a multiple of the second; thus the number 6, divisible by 3, is a multiple of 3 obtained by multiplying 3 by 2. The notion of congruence, therefore, may be expressed by the equation $a-b=kc$, in which k represents the multiplier. This in turn can be written $a=b+kc$. So far we have nothing essentially new. The importance of Gauss' work springs from an implication inherent in a slight modification of notation which he introduced. Gauss wrote the second of the above equations as $a \equiv b \pmod{c}$, which reads: a is congruent to b modulo c. From this we may infer that the importance in the relationship between a and b is that they differ by a multiple of c, and the value of that multiplier (k in the original equation) is relatively unimportant.

From a slightly different standpoint, if in the equation $a=b+kc$ the integer b is less than c, but greater than or equal to zero, then b represents the remainder upon division of a by c. For example, 19 is congruent to 1 modulo 3 may be written $19/3=6+1/3$, or $19=1+6\times3$. Here $a=19$, $b=1$, $c=3$, $k=6$, and the division of 19 by 3 leaves the remainder 1. Again, 18 is congruent to zero modulo 3 may be written $18/3=6$, or $18=0+6\times3$. In this case $a=18$, $b=0$, $c=3$, $k=6$, and the remainder of the division of 18 by 6 is 0. In the same way 20 is congruent to 2, 21 is congruent to zero, 22 is congruent to 1, all taken modulo 3. In other words, with respect to the modulus 3, all numbers are congruent to one of the numbers 0, 1 or 2. If the modulus is represented by the general term c, then with respect to c every number is congruent to some number from 0 up to $c-2$ and $c-1$. In effect this manner of considering the integers places every integer in one of c *classes,* each class represented by one of the numbers 0, 1, and so on, up to $c-1$. For example, modulo 3 the numbers 18, 21, 24, etc., would be placed in the class represented by the number 0, since zero is the remainder left when each of these numbers is divided by 3; the numbers 17, 20, 23, 26, etc., would be placed in the class represented by the number 2, since 2 is their remainder after division by 3, and so on. The gain from this treatment is that we need not consider an infinite number of integers but only a finite number of classes. In a sense all members of a particular class are essentially the same, since they leave the same remainder upon division by their modulus.

11	18	25	2	9
10	12	19	21	3
4	6	13	20	22
23	5	7	14	16
17	24	1	8	15

MAGIC SQUARE adds up to 65 in each row, column and two diagonals.

Although this way of dealing with numbers may seem somewhat involved, actually we make use of it every day without examining the process. Suppose, for example, we had been telling the time of day from the year zero by giving each hour a new number. At the time of writing of this article it would be some time after 17,093,328 o'clock. That would be a pretty cumbersome way of telling time. But modulo 24, it is shortly after midnight. What we do is to consider the hours of the day as members of 24 classes modulo 24, represented by the names one o'clock, two o'clock and so on up to 24 o'clock. (In practice we break the day into two halves and use a 12-hour clock, distinguishing one half from the other by a.m. and p.m.) Thus there are 24 "hour-classes" in a day, or two sets of 12 "hour-classes" each. Similarly, there are seven "day-classes" in a week and 12 "month-classes" in a year. Consideration of the day and month classes and certain astronomical data permitted Gauss to state congruences and rules for their use which enable us to determine easily the dates of Easter and other holidays, depending upon both the lunar and solar calendars. Similar congruences assist us in finding the day of the week on which any given date falls in any year, so that we can tell in what years January 13 will fall on a Friday, when the 4th of July will next give us a long week-end, and so on.

There is a well-known rule of arithmetic that a number is divisible by 9 only if the sum of its digits is divisible by 9. This rule, and similar rules, may be proved easily by means of the concept of congruence. Let us take the number 234, the sum of whose digits is $2+3+4=9$. The number 234 may be written $2\times10^2+3\times10+4$. We represent this expression by N, and the expression $2+3+4$ by n. Then $N-n$ is $(2\times10^2+3\times10+4)-(2+3+4)$. This may be written $(2\times10^2-2)+(3\times10-3)+(4-4)$, and this simplifies to $2\times99+3\times9$. Since 9 and 99 are both divisible by 9, the difference $N-n$ is divisible by 9; in other words, N is congruent to n modulo 9. When the sum of the digits of a number is 9, as in our example, the remainder after dividing the number by 9 is zero. When the sum is a number greater than zero but less than 9, this sum represents the remainder that will be left after division by 9. When the sum of digits is greater than 9, we may apply the process to determine whether or not this new number is divisible by 9. For example, the number 73,506,816 is congruent to 36 (the sum of its digits), which is congruent to 9 modulo 9. Therefore, this number is divisible by 9. On the other hand, the number 73,506,818 is congruent to 38; 38 is congruent to 11; 11 is congruent to 2 modulo 9. Thus 73,506,818 leaves the remainder 2 when divided by 9.

Any number divisible by 9 is also divisible by 3, since 3 divides 9. We may state, then, a new rule: a number is divisible by 3 only if the sum of its digits is divisible by 3. Similar considerations allow us to state other rules: a number is divisible by 2 if its last digit on the right is divisible by 2; a number is divisible by 4 or 25, respectively, if the number formed by its last two digits is divisible by 4 or 25, respectively; a number is divisible by 5 if its last digit is zero or 5.

A check on multiplication called "Casting Out Nines" has as its basis the rule for division by 9. The check proceeds in this way: to find out whether the product c is correct in the multiplication $a\times b=c$, we find the remainder after dividing a by 9 and the remainder after dividing b by 9 and multiply the two remainders together. This product must equal the remainder after dividing c by 9. If it does not, the value of c obtained in the original multiplication was in error. What makes the check easy is that to obtain the remainders we need only add up the digits of the respective numbers. As an example let us check the multiplication $6{,}743\times826=5{,}569{,}718$. The sum of the first number's digits is $6+7+4+3=20$. Dividing 20 by 9 gives a remainder of 2, as can be shown by adding its digits: $2+0=2$. Similarly the second number yields $8+2+6=16$, which divided by 9 gives a remainder of

7. Multiplying the remainders, 2 × 7= 14. The sum of these digits is 1+4=5. The sum of the digits in the product, 5,569,718, is 41, and its digits also add up to 5, so the answer is probably correct. As a practical method the device of casting out nines was probably known in India before A.D. 800; it came into use in Europe in the Middle Ages. But the mathematical theory behind the method could not be explained easily until the arrival of modern number theory; imagine the difficulty of explaining the theoretical basis of these manipulations without using the ideas of congruence.

A VERY interesting modern application of the Theory of Numbers is made in the field of electronic computing machinery. Some of these machines use the binary instead of the decimal system of numbers. We have noted that 234 can be written $2 \times 10^2+3 \times 10+4$; this is a sum of multiples of powers of 10 (4 may be written as 4×10^0). The number 234 can also be written as a sum of multiples of powers of 2, thus: 1×2^7 (128) $+1 \times 2^6$ (64) $+1 \times 2^5$ (32) $+ 0 \times 2^4$ (0) $+1 \times 2^3$ (8) $+0 \times 2^2$ (0) $+ 1 \times 2$ (2) $+0 \times 2^0$ (0). Here we use the "base" 2 instead of 10 as in the decimal system. Instead of writing down a long string of powers of 2 we can "suppress the base" and write only the multipliers of the powers of 2, which in order from left to right are 11101010. (The reader should notice that he has been doing exactly the same thing in the decimal system whenever he has written a number larger than 10; he has suppressed the base 10.) Then decimal 234 is the same as binary 11101010; similarly, decimal 15 is binary 1111 and decimal 2 is binary 10. In an electronic computing machine the binary system has this great advantage: the only digits used are 0 and 1. In the "language" of the machine each 1 can be represented by an electrical impulse and each 0 by the absence of an impulse. In this way an electronic computing machine can handle operations with numbers very rapidly.

To return to the realm of games and puzzles, we might mention two typical problems that have been investigated by number theorists. The first is the familiar wine-jug problem, one version of which goes: A man has a five-gallon jug and a three-gallon jug. He wishes to purchase four gallons of wine from an innkeeper who has only a full eight-gallon jug. How does the man measure exactly four gallons without spilling a drop? With some thought you may figure out that he measures out three gallons in the three-gallon jug and pours this into the five-gallon jug, pours three more into the three-gallon jug and fills the five-gallon jug from this, leaving one gallon in the three-gallon jug, then empties the five-gallon jug into the eight-gallon jug and pours into the five-gallon jug the one gallon plus three more measured in the three-gallon jug. This problem has been solved by number theory in general terms for jugs holding A, B and C gallons, with D gallons to be measured out. That is, it is known for what values of A, B, C and D the problem has a solution, and a systematic way of measuring can be stated.

The second problem is the so-called magic square. A magic square is an array of n^2 integers arranged in n rows and n columns in such a way that the sum of the numbers in each row, column or principal diagonal (upper left to lower right and upper right to lower left) is magic; that is, each of these sums is equal to $n/2(n^2+1)$. Magic squares have fascinated man for ages, and many mathematicians have studied them. One method of constructing magic squares is based on notions of congruence. A simple method of constructing such squares, applicable to any square of odd n, is illustrated on the opposite page. In one of the squares shown, for example, n=5 and the magic sum is 65. Each box in the square (known as a cell) contains a number from 1 up to n^2, in this case $n^2=25$. The numbers are placed in the cells in their consecutive order according to the following rules:

Begin by placing the number 1 in the middle cell of the bottom row; after filling a cell in the bottom row, place the next number in the cell at the top of the next column on the right; as far as possible fill the cells in a downward diagonal line from left to right; upon filling a cell in the last right-hand column of the square, place the next number in the cell at the extreme left of the next lower row; if the next cell on the left-to-right downward diagonal is occupied, place the next number in the cell immediately above the one last filled; after filling the cell in the lower right-hand corner, place the next number in the cell immediately above.

MAGIC squares and wine jugs, calculating machines, prime numbers and congruences, Diophantine equations and shipwrecked sailors—all these furnish reasons that help to explain why the Theory of Numbers has interested so many people. Professionals and amateurs alike have been attracted by the subtle fascination of these problems, and the mark of their work has been felt in nearly every branch of mathematics. Problems in the Theory of Numbers are among the most challenging in mathematics, possibly because some of them are so difficult. Fortunately in mathematics as in all other scientific endeavors the difficulty experienced in solving a problem drives man to a continuing search for its solution. For he believes that the science of mathematics is a logical discipline, and as such is subject to complete understanding.

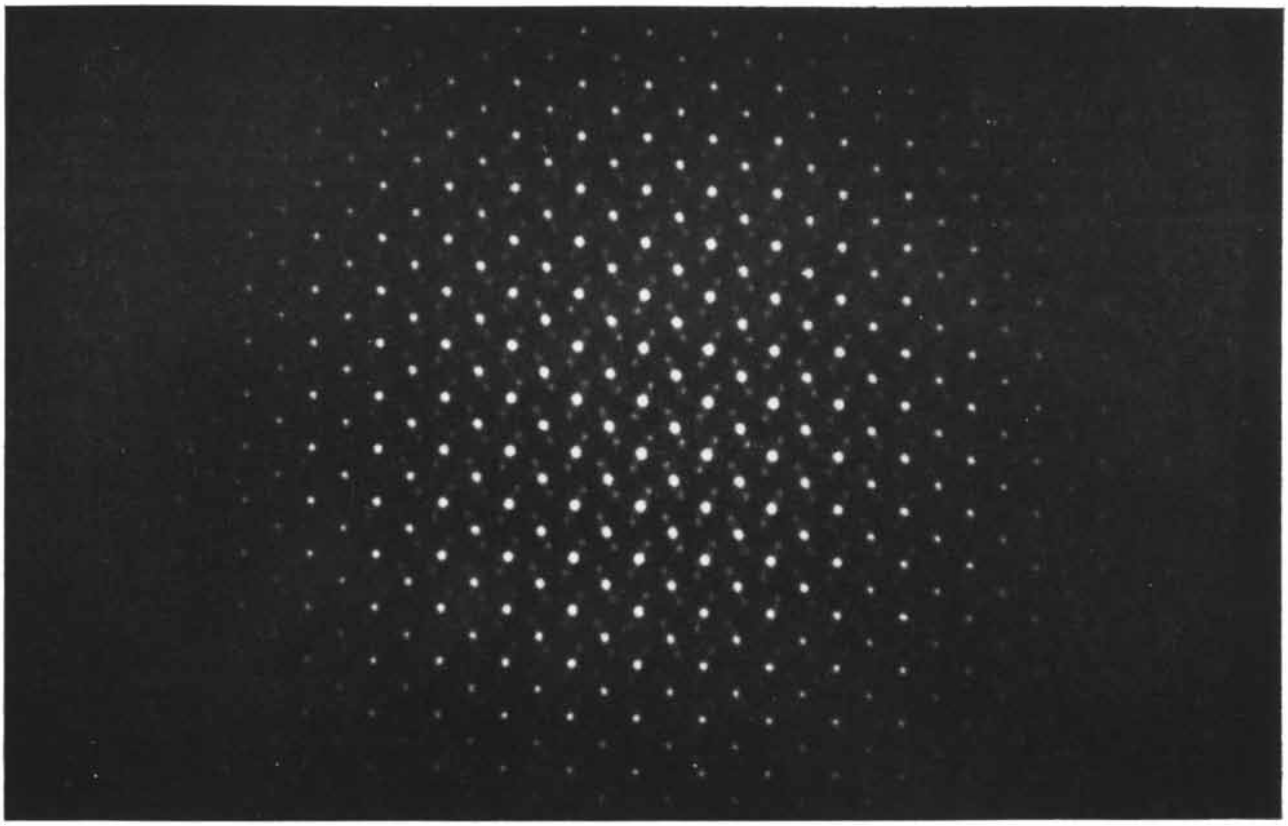
Paul S. Herwitz is associate professor of mathematics at the University of Cincinnati.

2	11	12	13	77	78	79	81	16
6	18	27	26	61	62	65	28	76
7	59	30	35	51	53	36	23	75
8	58	32	38	45	40	50	24	74
73	57	49	43	41	39	33	25	9
72	22	48	42	37	44	34	60	10
68	19	46	47	31	29	52	63	14
67	54	55	56	21	20	17	64	15
66	71	70	69	5	4	3	1	80

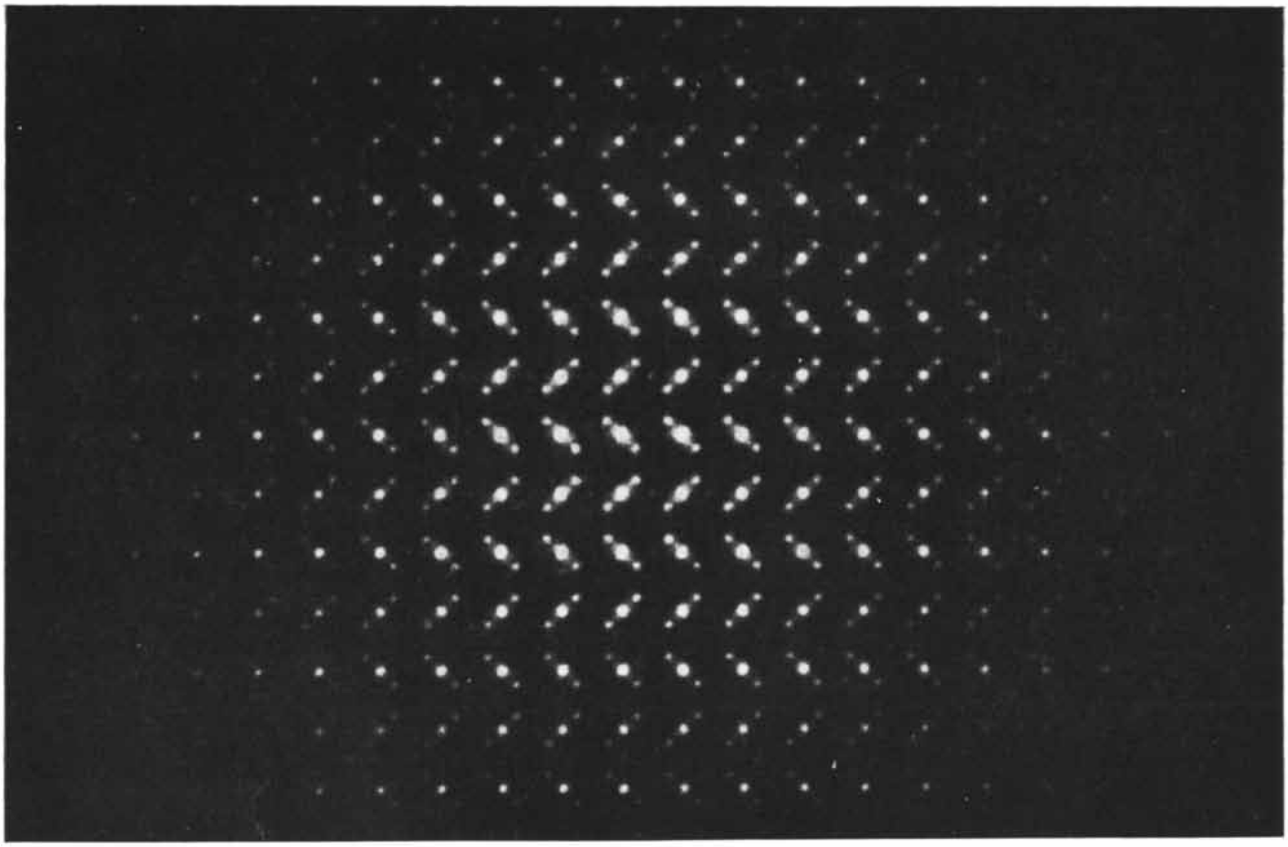
BORDERED SQUARE is magic overall, and each square formed by throwing away a border is also magic.

11	18	13	74	81	76	29	36	31
16	14	12	79	77	75	34	32	30
15	10	17	78	73	80	33	28	35
56	63	58	38	45	40	20	27	22
61	59	57	43	41	39	25	23	21
60	55	62	42	37	44	24	19	26
47	54	49	2	9	4	65	72	67
52	50	48	7	5	3	70	68	66
51	46	53	6	1	8	69	64	71

COMPOSITE SQUARE is similarly magic overall and at the same time magic for each of its smaller squares.



THE ATOMS OF MARCASITE, a crystal containing iron and sulfur, are magnified more than two million times by the two-stage microscope. The larger fuzzy spots are the atoms of iron; the smaller, those of sulfur.



THE ATOMS OF PYRITE, which also contains iron and sulfur, are magnified even more. The size of the images is a reflection of the fact that there are 26 electrons in each iron atom and 16 in each sulfur atom.

ATOMIC MICROSCOPE

A new instrument reveals the atoms of crystals in two steps: the first involving the diffraction of X-rays, the second the diffraction of light

THE MAGNIFICATION of a microscope is fundamentally limited by the length of the waves it uses; when an object is smaller than the individual waves, the microscope cannot resolve it. Thus objects smaller than a wavelength of light cannot be perceived through the light microscope. But the waves of X-rays are 100 to 10,000 times shorter than those of light: Why not an X-ray microscope? Although X-rays are virtually impossible to focus with lenses, there are other ways of manipulating them ("The X-Ray Microscope," by Paul Kirkpatrick; SCIENTIFIC AMERICAN, March, 1949). One of the methods even makes atoms visible.

Martin J. Buerger of the Massachusetts Institute of Technology has developed an ingenious new technique for utilizing the microscopic power of X-rays. Although X-rays are difficult to focus, they can easily be diffracted, *i.e.*, deflected at various angles by a tiny, regular grating such as that formed by the atoms of a crystal. The pattern made on a photographic plate by the diffraction of X-rays from each crystal is characteristic. By laborious mathematical procedures the pattern may be converted into a map of the atoms in the crystal.

In 1938 a German physicist named H. Boersch suggested an easier way to convert the X-ray diffraction patterns of crystals into pictures. His method involved two separate stages. The first consisted of making the usual diffraction pattern. The second required a grating much larger than that formed by the atoms of the crystal. This larger grating, capable of diffracting not X-rays but light, was designed in a certain way on the basis of the X-ray diffraction pattern. The light diffracted by it, Boersch reasoned, would make an actual picture of the atoms in the original crystal.

Shortly after Boersch published his paper, the English physicist W. L. Bragg succeeded in using this method to make a fine picture of the atoms in the mineral diopside. But Bragg's X-ray microscope could make pictures of crystals only in one very small class—that in which the waves of the X-rays, diffracted in various directions, were all in step.

Buerger's X-ray microscope can theoretically make a picture of any crystal. First he obtains an X-ray diffraction pattern of the crystal by means of an instrument called the precession camera. An enlargement of the diffraction pattern is the design of the larger grating, which is actually a metal plate through which small holes have been drilled. If light of one wavelength were shined through the holes, and if the pattern of the holes were derived from a crystal whose X-rays were all in step, it would form an image of the atoms in the crystal that was as much as 300,000 times larger than the atoms themselves. This is sufficiently large to be seen or photographed through a conventional microscope.

If the pattern of holes were derived from a crystal whose X-rays were out of step, no image would result. This is where Buerger has made his principal contribution. Behind each hole in the plate he placed a small piece of mica. By setting each piece at the proper angle, he was able to control the phase of the light diffracted through the holes so that it duplicated the phase of the original X-rays. Then he made the first photographs of the sulfur and iron atoms in the minerals marcasite and pyrite (*see opposite page*).

What GENERAL ELECTRIC People Are Saying

A. H. ADAMS
F. L. TEUSCHER
Apparatus Department

CONNECTION DIAGRAMS: A new type of connection diagram has been developed [for industrial control panels] which overcomes the undesirable features of the older type by providing an accurate and completely detailed scale representation of the panel. A photographic reproduction process is employed to produce the scale diagram in less time. Mechanical as well as electrical details are shown, materially increasing the usefulness of the diagram. . . .

The major advantage of the new diagram is that the panel and its components are to scale; the arrangement and size of symbols agree exactly with the layout of devices on the panel as manufactured. Relative heights, length of wire runs, and location of studs and terminals can be scaled directly from the diagram. Positive identification and location of devices make the scale diagram particularly useful during manufacturing, installation, and maintenance.

General Electric Review
February, 1951

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A. W. WHITE
E. O. HENRICKSON
F. W. FERNALD
Apparatus Department

TURBOSUPERCHARGERS: At 25,000 feet altitude a commercial transport engine which can develop only 1300 horsepower will produce, with a turbosupercharger, 2700 horsepower. . . .

The advantages of high-altitude flying, proven by turbosupercharged military bombers and transports, led the Boeing Airplane Company to use turbos on the world's largest luxury liner, the double-deck Stratocruiser. This four-engine plane can carry 75 passengers and is designed for intercontinental service.

With an operating altitude as high as 25,000 feet, four General Electric model BH-4 turbosuperchargers accelerate the large plane to a maximum cruising speed of over 300 miles per hour. The maximum range is over 4000 miles. . . .

Started in transport service early in 1949, the Stratocruiser has several times lowered the time of the trans-Atlantic record for commercial airliners. The extra power provided for each engine by the turbosupercharger is further illustrated by the fact that the large ship is capable of climbing to 15,000 feet with only two engines operating. . . .

Strange as it may seem, the conditions under which the BH-4 turbos operate in the Stratocruiser have proved to be actually more severe than are normally experienced with military airplanes. The temperature of the engine exhaust is higher in the commercial planes because military aircraft normally operate at higher engine powers and richer fuel mixtures. The lower exhaust temperature on the military planes is apparently due to the cooling effect of a small amount of raw fuel.

Society of Automotive Engineers
New York City
April 16, 1951

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A. J. NERAD
Research Laboratory

ROCKET FUELS: We might define a rocket as a device which is largely fuel, or, preferably, propellant. . . . Some people have referred to modern military airplanes as flying fuel tanks. The rockets are flying fuel. . .

The effect of improving the performance of the propellants is magnified often in the improvement in the usefulness of the rocket. Thus an improvement of ten per cent in the performance of the propellants of the V-2 will permit loading one ton less of fuel and adding nearly one ton of useful cargo without altering the maximum range of its flight. This means a doubling of its load-carrying capacity. This improved performance could be used, on the other hand, in obtaining greater range. Since the range of the rocket is approximately as the square of the propellant performance, it is obvious that a valuable magnification is obtained. It is this value of even small improvements in propellant performance which makes this a most energetic field of rocket investigation. . . .

If in some way hydrogen can be heated and pressurized, and it alone be the rocket propellant, we would realize a large gain in the velocity of the propellant and would enhance our margin of rocket performance. With hydrogen at practical pressures and temperatures, an exit velocity of 10,000 meters per second, approximately, could be realized.

One suggestion toward this accomplishment is that of fixing atomic hydrogen in some way. There is evidence that gases in metals sometimes reach extraordinarily high pressures. Hydrogen is, in a sense, stored in metal hydrides. There may be other means which, if used together or in various combinations, might yield the answer.

The physical state in which such hydrogen and the necessary energy are stored might well be the solid state. In this case we would have the solid propellant as being our hope for the pre-atomic rocket fuel of the future.

Since the pressure and/or temperature in a rocket motor must be higher the greater the molecular weight of the gases ejected for a given exhaust velocity, it is obvious that of the elements hydrogen would be the most advantageous in this respect.

American Chemical Society
New York City
May 11, 1951

You can put your confidence in—

GENERAL ELECTRIC

The Blood Relationships of Animals

Because the serum proteins of a species are as characteristic as its bones, the reactions between proteins from different species may be used to locate them in the evolutionary scheme of things

by Alan A. Boyden

Blood is a very special juice.
—Goethe

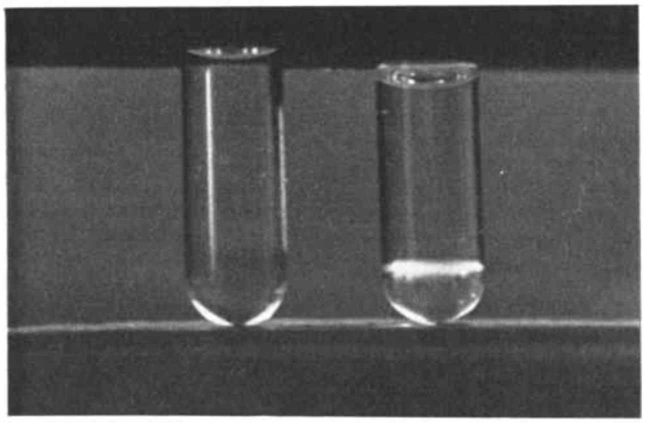
THE force of this statement has long been manifest to every physiologist and serologist, and the depth of its meaning increases with every passing year. For not only is blood necessary for life (in many animals), but it is also very special in the sense that each kind of animal is distinguished by its own particular kind of blood, and at the same time the properties of this juice reveal the kinships among various animals. This article will describe one of the newest uses of the study of blood: the classification, literally the "blood relationship," of animals in the evolutionary scheme.

No one needs to labor the importance to science of classification, which means simply the grouping of things in accordance with their natures. Without a practical means of grouping objects according to their similarities and differences, we would be overwhelmed by the complexity and diversity of nature and unable to think effectively about it. In the field of biology, classification has a special significance because it tells us much that we would not otherwise know about ourselves; for example, most of our present understanding of the physiology of the human body in health and disease has been gained not primarily from the human organism but from lower animals. Their similarities to human beings in certain characteristics make it possible to reach tentative conclusions that may safely be applied to man.

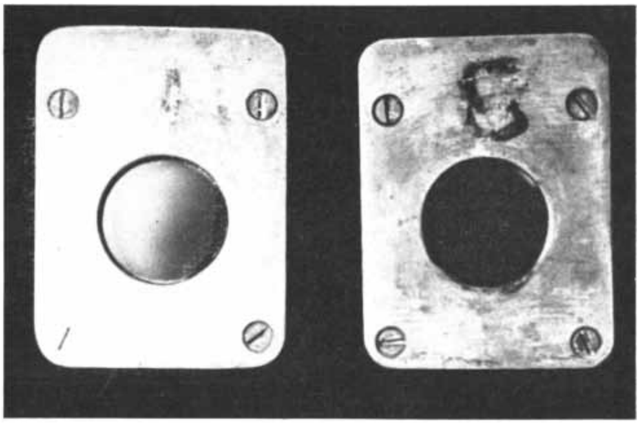
Obviously it is all-important that the classifications be accurate, for if they are unsound, conclusions and generalizations based on them may lead to serious errors. For two centuries and more the classification of organisms into species, genera, families, orders, classes and phyla have been based mainly on body structure, especially of the hard parts or skeleton. But this method has been difficult and not very satisfactory; during these two centuries there have been many shifts of opinion as to the criteria to be used and many changes in the actual classification of animals. Changes are still going on. We are as yet far from the goal of a generally accepted system.

What is needed is some quantitative, objective means, independent of structural features, for testing the essential natures of organisms. Such a means is now available. It is the study of certain reactions in the blood which indicate the degree of relationship among animals. This technique has nothing to do with the comparison of blood types—an entirely different method which also can be used, in a limited way, to establish genetic relationships. We are concerned here with interactions between antigens and antibodies in the serum of the blood.

AN ANTIGEN is a substance that induces an organism to form counteracting antibodies. Usually it is a substance foreign to the organism on which it produces its effects. Most antigens are proteins; indeed, under suitable conditions nearly all proteins are more or less antigenic. The antibody formed in reply to an antigen reacts with it, and the reaction produces a distinctive, observable effect. The interaction can be highly specific; in such instances a given antibody reacts only with the antigen that evoked it. But antibodies may also react to some degree with substances chemically similar to their specific antigen. This is the basis of the method for detecting relationships between animals. It is assumed that if proteins of one spe-



RING TEST for reaction between antigen and antibody is illustrated by two test tubes. In tube at left saline solution rests atop layer of antiserum. In tube at right antigen reacts with the antiserum to form a ring.



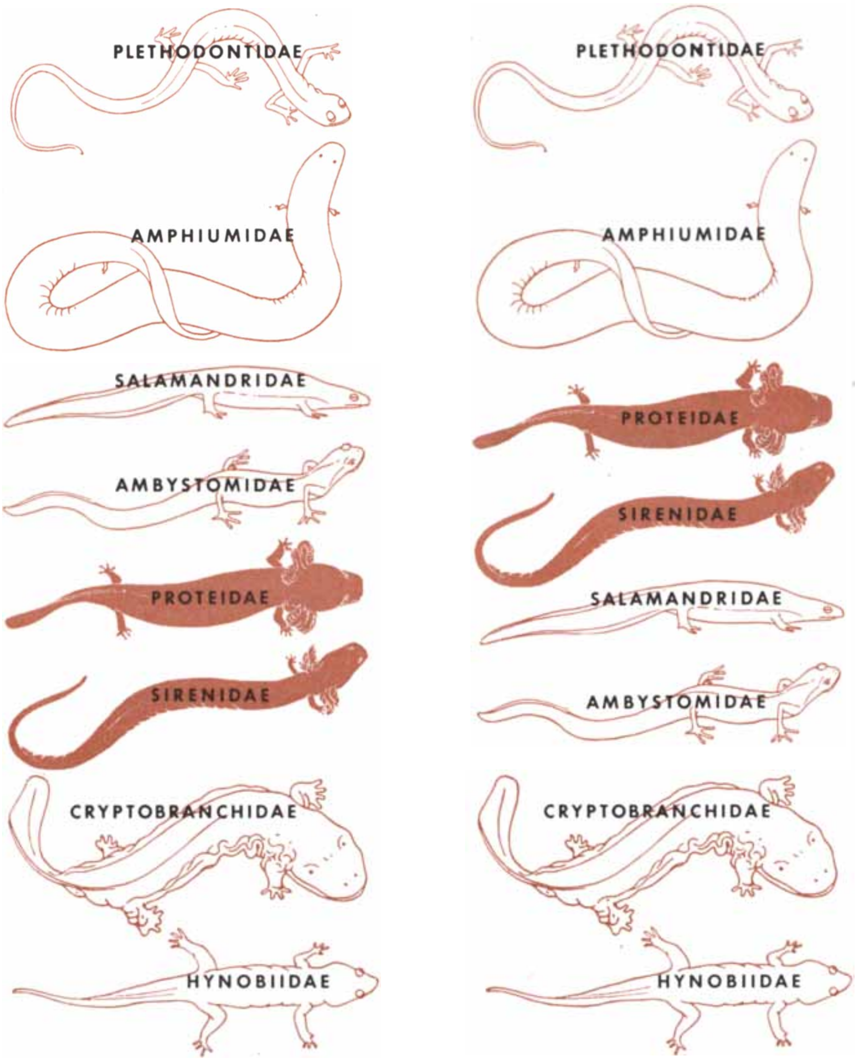
PHOTRONREFLECTOMETER TEST utilizes the turbidity of a solution in which the reaction has taken place. The cell at left contains the turbid solution of a strong reaction; the cell at right, the clear solution of a control.

cies of animal are very similar to those of another, the two species (or genera, as the case may be) are closely related. The method of determining this is to compare the effect of a given antibody on blood proteins of the two species. There are many types of antibodies; the particular kind used in this work are known as precipitins, from the fact that their reaction with antibody produces a precipitate in a solution.

Antibodies are found in the serum—the fluid part of the blood. A serum containing antibodies is called an antiserum. The chief materials employed in this work in comparative serology are antigens and antisera. For the production of suitable antisera containing precipitins the general procedure we now use is as follows: Healthy rabbits are injected with a certain kind of serum, for example, beef serum. This is the antigen. They first receive a small intravenous injection of one cubic centimeter or less, and after three or four weeks they get a series of four subcutaneous injections of one c.c. each, given every other day. Then there is a rest period of 7 to 10 days to allow adequate production of antibodies. To find out whether there is a sufficient concentration of antibody in the rabbits at the end of that time we test the effect of their antiserum, obtained from samples of their blood, on the antigen, *i.e.*, beef serum. If the reaction shows that the antiserum is sufficiently powerful, we proceed to use the rabbits' supply of antiserum for the main tests.

The first step is to react the antiserum with the generating antigen, beef serum, to establish a standard for measuring the reaction of this antiserum with antigens from other animals. Having reached this stage, with the cooperation of the rabbits and other participants, we are ready to explore the blood kinship of various species. In each case we test the serum (antigen) of the particular animal—bison, sheep, goat, giraffe, deer, camel, pig or whatever—by its reaction with our antiserum. If the sera of two species produce nearly the same amount of reaction, their proteins must be very similar; if not, they must be different, and we can determine the degree of difference.

The details of the reaction tests used are outside the scope of this article; all that need be said here is that the traditional "ring test" for antigen-antibody reactions, first described by the Italian investigator M. Ascoli in 1902, has been found less reliable in our work than a newer method developed by Raymond Libby at Rutgers University in 1938. This test, which we have adopted, uses an instrument called the Photronreflectometer to measure the amount of reaction by photoelectric means. The measure of the strength of the reaction is the amount of turbidity produced in a solution when the antibody and antigen interact. The turbidities produced by vari-



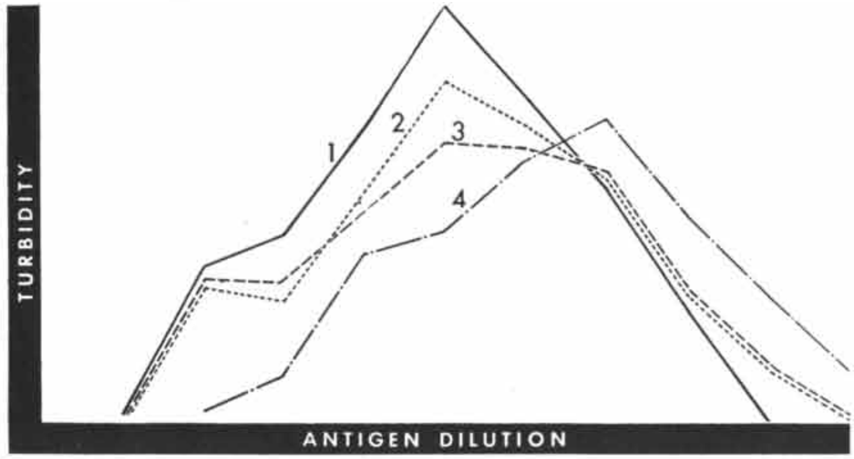
RELATIONSHIP OF THE SALAMANDERS was clarified by blood tests. Proteidae and Sirenidae were believed to occupy the place on the evolutionary scale shown at left. Tests indicated that they should be moved up (*right*).

ous sera under comparable conditions are plotted as curves and the total area under each curve represents the relative strength of that particular reaction.

THIS, then, is the general technique. What results has it produced when applied to the classification of animals? First, it can be said that the results of our serological tests agree very well with the facts in certain cases where the pedigrees and genetic relationships of the animals involved are thoroughly known. Let us look at the particular case of the horse and the donkey, two related species of the horse family, and their hybrid offspring. The offspring of a mare and a male donkey is a mule. The serological test was given to these three kinds of animal. It turned out that an antiserum against horse reacted most strongly with horse, next with mule and least with donkey. This confirms the validity of the serological test, because the mule, having received genes from both the horse and the donkey, should possess proteins intermediate in properties between those of its parents and therefore should show an intermediate strength of reaction in the test. The comparison has recently been extended to the hinny, a hybrid result of the mating of a stallion and a female donkey. Again the result was the same: the serum of the hinny was intermediate between those of the horse and the donkey.

Moreover, the blood-test results also agree with classifications made on the basis of body structure in cases involving small groups where there is little doubt that the traditional classifications are correct. In view of these agreements and the genetic ones, the blood-test method can be applied with confidence to the study of relationships among animals whose classification is in doubt.

ONE case in doubt is that of the whales, which comprise an order of animals known to taxonomists as the cetaceans. The whale is a mammal, but evolutionists have long been uncertain



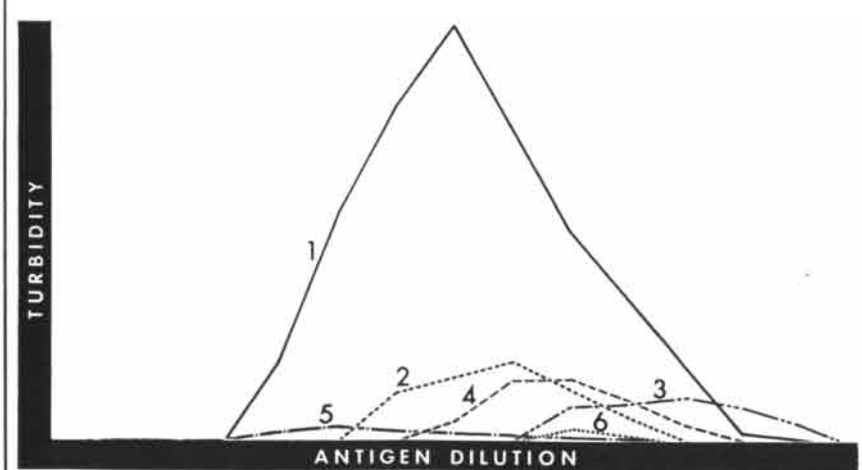
CLOSE RELATIONSHIP is shown by the similarity of curves on a blood-test diagram. The curves are (1) horse, (2) hinny, (3) mule and (4) donkey.

about just where to place it among the 18 present orders of mammals. George Gaylord Simpson, the brilliant naturalist of the American Museum of Natural History, recently stated the problem as follows:

"The cetaceans are on the whole the most peculiar and aberrant of mammals. . . . There is no proper place for them in a *scala naturae* or in the necessarily one-dimensional sequence of a written classification. Because of their strong specialization, they might be placed at the end, but this would remove them far from any possible ancestral or related forms and might be taken to imply that they are the culmination of the Mammalia or the highest mammals instead of merely being the most atypical. A position at the beginning of the eutherian series would be even more misleading. They are, therefore, inserted into this series in a more or less parenthetical sense."

Prompted by this uncertainty, and particularly by Simpson's statement, my Rutgers University associate Douglas Gemeroy and I undertook a study of whales' blood. We had on hand some whale sera which the English whale inspector Paul Crimp had obtained for us in the Antarctic. After preparing some anti-whale sera with this material, we tested the antisera's interaction with beef serum. The reaction was surprisingly strong! Then followed two years of careful and extensive testing in a many-sided survey during which we used antisera made with sera from animals representing 14 orders of mammals and tested the sera of representatives of all 18 of the existing mammalian orders listed by Simpson. The result of all this was a convincing body of evidence that the order to which whales are most closely related is the even-toed ungulates, that is, the group of animals which includes the cow, sheep, deer, camel and pig.

Very recently we have studied three peculiar animals: the giant pangolin (an anteater), the aardvark and the armadillo. These animals were once all placed in the same order, the Edentata, but they are now assigned by some taxonomists to separate orders. Our preliminary results indicate that the armadillo does belong to a separate order from the other two, but the aardvark and giant pangolin show a closer relationship to each other



LESS CLOSE RELATIONSHIP is shown by dissimilar curves. The curves are (1) fin whale, (2 and 3) beef, (4) kudu, (5) hedgehog and (6) giant pangolin.

in blood-serum proteins than separate orders usually do.

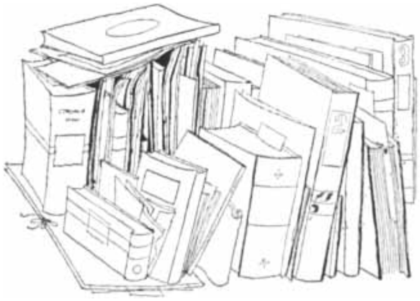
Fifty years ago the English parasitologist George H. F. Nuttall expressed a strong belief that the bloods of animals would yield important clues to their relationship. The past half-century of progress in serology bears out his belief. The serological method of determining animal relationships has many advantages, the most important of which is that it involves no subjective element of interpretation, such as always enters the picture when we try to determine the structural criteria by which animals should be classified. The blood test is particularly helpful for establishing the less intimate relationships, as between families, orders, classes and phyla.

By now this work, carried on at the Serological Museum at Rutgers, has become a large enterprise. The Museum was established only three years ago, yet already 50 cooperating institutions of many nations in all parts of the world have joined in assisting its work. These institutions and many individual collectors have sent in blood samples of animals from widely separated corners of the earth.

The Museum works on other problems besides those of taxonomy. For example, one of its investigations led to the identification of the principal host of certain malaria-carrying mosquitoes and to the discovery of what may prove to be a new kind of malaria. Seeking help on this problem, I. H. Vincke of the Public Health Service in the Belgian Congo sent to the Museum samples of the blood sucked by these mosquitoes; he obtained the samples by pressing the blood-engorged stomachs of captured mosquitoes upon filter paper. He also sent blood sera from certain animals of the Belgian Congo forests which might possibly be the malarial hosts upon which these mosquitoes fed. By antiserum tests Ralph DeFalco and Ellen Clark of the Serological Museum were able to prove that all the blood samples furnished by one of the species of mosquito came from a common antelope known as the oribi, an animal which had not previously been suspected of being a malaria carrier. Examination of its blood disclosed that the antelope apparently was infected with a kind of malaria that had not been known before.

It is the plan of the Serological Museum to promote a broad program of work in comparative and general serology through the collection and exchange of proteins, the development of new procedures for their study, the comparison of the proteins of animals in health and in disease, and the publication of a bulletin and scientific reports describing the results obtained.

Alan A. Boyden is director of the Rutgers University Serological Museum.



BOOKS

An imposing work on the whole sweep of the evolution of backboned animals

by Alfred S. Romer

EVOLUTION EMERGING, by William King Gregory. The Macmillan Company ($20.00).

HISTORY, in a broad and proper sense, should not be restricted to the narrow confines accepted by the professional historian; human history is only the last short chapter in the story of the evolution of the world and its countless and varied animal and plant inhabitants. Of the many chronicles that might be written of the past, none is potentially more interesting than the history of the animals with backbones. The vertebrates are but one of many major animal or plant types whose stories could be told; nor are they, so far as our knowledge goes, as old as many other groups. But the vertebrates have the great merit of possessing in almost every instance hard parts capable of fossilization so that (in contrast with the situation in many groups of lower animals and plants) the possibility exists of finding relatively complete evolutionary series in the geologic record. And this evolutionary story is of especial human interest; we are vertebrates, and their history is our own.

No other person is as competent to deal with the broad sweep of vertebrate evolution as William King Gregory. As a student at Columbia University half a century ago he became associated with the late Henry Fairfield Osborn, a distinguished figure in the development of vertebrate paleontology. When Osborn became president of the American Museum of Natural History, Gregory took over his teaching duties. For four decades he has exerted a major influence on the study of vertebrate history both through his training of advanced students and through his numerous anatomical and paleontological studies on problems ranging from those of fish classification to those of physical anthropology. He has long planned a book like *Evolution Emerging*. But it was not until his retirement a few years ago from teaching and museum duties that time became available to him to digest the enormous mass of data accumulated through his researches and those of many others, and to produce this splendid summary of the discipline to which his life had been devoted.

It seems to this reviewer that Gregory is a man of dual personality: he is both scientist and artist. The artist in him is rigidly disciplined to conform to the working methods of the scientist, but lends to his work a unique breadth of concept. For the most part scientific workers have but a restricted range of mental vision beyond the narrow fields in which they labor. Dr. Gregory has the ability to see a major area of science as a whole; to see the history of the vertebrates as a vast panorama, a total composition into which each discrete element may be fitted in appropriate position and proper perspective.

Evolution Emerging presents the vertebrate story in two stout volumes. One, somewhat the smaller, carries the text of the work; the other, more than 1,000 pages of illustrations. This cleavage between text and figure material is unusual, but on the whole it works out well. It is perhaps to be regretted that the text does not run to greater length, for there are many points of interest but lightly touched upon where a more thorough discussion would have been stimulating. On the other hand the volume of illustrations, with its many comparative series of skulls and skeletons and diagrams, is a complete narrative in itself.

In order to discuss the origin of the backboned animals, Gregory gives a brief account of the invertebrates. Quite surely the ancestors of the vertebrates were soft-bodied creatures of which it is unlikely that any fossil record will ever be discovered. They were presumably rather inactive forms, living on food particles sifted out by their gills or other organs.

The oldest traces of vertebrates consist of fragments of bony armor found in sediments of the Ordovician Period, laid down some 350 million years ago. These scraps tell us almost nothing, however, of the nature of the creatures from which they came. It is not until almost a full period of geologic time had elapsed that, in the latter part of the Silurian Period, well-preserved remains first come into view. These oldest backboned animals were, as one would expect, fishes; but fishes of a sort quite unlike anything we have today. Called ostracoderms because of the shell of bony armor in which they were encased, they lacked jaws and the paired fins of normal fishes. These ancient stream-dwellers lived of necessity as their ancestors did, by straining food particles through a highly developed series of gill pouches which made up a large proportion of their bodies. The ostracoderms soon became extinct; their descendants survive today in the form of the degenerate lampreys and hagfishes.

Succeeding chapters of the geologic record show the rapid evolution of more advanced types; by the end of the Devonian Period, which followed the Silurian, every major group of fishes had come into being. In the early part of the Devonian "Age of Fishes" the dominant forms were the placoderms. Now entirely extinct, these early fishes are as grotesque to our eyes as their ostracoderm forebears. Like them, they were armored types; but unlike them they possessed jaws and paired appendages. These structures, however, were so to speak still in an experimental stage and differed widely in many cases from the patterns familiar to us.

Following the placoderms there appear in the Devonian rocks early representatives of the two higher groups of fishes which still populate the earth's seas and streams. Lesser in importance of the two and somewhat degenerate in the loss of bony skeletal structures is that including the sharks and their relatives: the skates, rays and chimeras, which form a modest percentage of the inhabitants of modern oceans. Even older in date of appearance and more numerous throughout their history are the fishes of that dominant class known as the Osteichthyes. In them the bony skeletal structure has been retained and developed to advantage. This group is mainly represented today by the teleosts, whose representatives, perhaps 30,000 strong in number of species, dominate every body of water in the world. The classification and phylogeny of this vast host presents difficulties even to the specialist; not the least valuable of Gregory's contributions in the present work is a thorough discussion of the phylogeny of teleosts, to which a hundred pages of text and numerous figures and diagrams are devoted.

But the teleosts are a terminal if highly successful group. To follow the progress of vertebrates from water to dry land, through the amphibians to the reptiles, Gregory turns back to quite another group of bony fishes, the crossopterygians, almost extinct today but common in the Devonian. As Gregory himself has shown, these fish foreshadowed the amphibians in numerous features of skull and skeleton. From them, before the Devonian came to an end, evolved the first amphibians, differing most notably in their development of tiny legs from fins. The earliest members of this new transitional class still retained many piscine features and seem to be little more than a special type of fish modified to survive seasonal droughts, which appear to have then been widespread. By the time of the deposition of the great coal swamps of Carboniferous times, numerous more evolved and varied amphibians had made their appearance. Transitional stages from these older forms to the surviving amphibians—frogs and toads, newts and salamanders and a group of rare worm-like tropical forms—are none too well known. On the other hand, as Gregory's text and figures show, we have a considerable series of types showing the transition to the reptiles. In some instances we are none too certain to which of the two classes a given fossil belongs. This is not surprising, for the keynote of reptilian evolution lies not in adult structure but in the mode of development—the perfecting of a shelled type of egg which frees a reptile from the necessity of returning to the water for reproduction.

The reptilian pattern of skeletal organization, found in early Permian forms, is described by Gregory. Following this he sketches the great story of the radiation of the class during the Mesozoic "Age of Reptiles"—a radiation which gave rise to such diverse groups as the turtles, the lizards and their modified limbless cousins the snakes and the curious marine groups of the ichthyosaurs and plesiosaurs. Most spectacular of the ancient reptiles were the members of the subclass Archosauria, which included the vast array of dinosaurs. Except for the crocodiles and alligators these ruling reptiles have long since vanished. But they survive in transfigured form for, as Gregory demonstrates, the skeletal organization of the birds clearly indicates their origin from archosaurian reptile ancestors.

To pursue the "main line" of evolution leading to our own kin, the warm-blooded members of the class Mammalia, Gregory turns back to the earliest days of reptilian history. At this time there appeared a group known as the pelycosaurs, reptiles still archaic in most respects but showing features faintly suggestive of mammalian relationships. From them arose in turn the therapsids, a group which dominated the terrestrial scene before the rise of the dinosaurs. These were the typical mammal-like reptiles, some of which approached the mammals closely in many features of skull and skeleton—so closely, in fact, that in certain cases it has been difficult to be sure of their proper classification.

With the rise of the dinosaurs early in the Mesozoic the therapsids disappeared from the scene, but not without leaving small surviving types which persisted into the time of dinosaur domination to give rise to the first mammals. Our knowledge of these tiny ancestors of ours is meager. The evidence indicates, however, that during their long period of subordination progressive forms made notable improvements in bodily organization, abandoned the ancestral egg-laying habit for one in which the young were born alive and early in their history developed the nursing habit to which the class Mammalia owes its name.

Some 70 million years ago the Age of Reptiles came to an end, and a new age—the Cenozoic or Age of Mammals—dawned. With the earth cleared of enemies, the mammals flowered in a wide variety of types which swarmed over every continent. Australia became a center where there evolved a great variety of pouched mammals. On other continents the dominant mammals were of the sort commonly termed placentals, in which a highly efficient method of nourishing the young within the mother's body had been attained. Gregory sketches the evolution of the many phyletic lines which diverged from the basal placental stock, most notably the carnivores and the hoofed mammals upon which they preyed. His main attention, however, is devoted to the group to which man himself belongs—the order Primates. Our record of this series is far from complete, although the discovery in recent years of new fossil great apes and man-apes in Africa has constituted a valuable advance. Nevertheless a consideration both of the living members of this mainly arboreal order and their fossil relatives shows clearly the main steps in human progress. These lead upward from shrew-like ancestors through relatives of the lemurs still surviving in Madagascar and of little *Tarsius* of the East Indies to a primitive monkey stage, to ancestral apes and finally, at a late period in the world's history, to forms which had left the arboreal home of the primates to become terrestrial and at last definitely human.

It is impossible to avoid an anthropocentric point of view in a story which involves man himself. Freely conceding this, Gregory devotes much of the concluding portion of his text to a resumé of the evolutionary sequence as seen from the human viewpoint. Many of the basic features of human structure were already laid down in our lower ancestors. Other structural patterns which persist in us today were established in the piscine stages, and further features still present can be recognized as appearing successively in reptilian, primitive mammalian, pro-simian and simian stages of our ancestry. Man bears within his body unmistakable evidence of the evolutionary processes from which he has emerged.

This, in broad outline, is the story of

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the vertebrates as told by Gregory—an epitome of his research and teachings. Is this a "definitive" work, not subject to criticism or change? Not at all; Gregory, most open-minded of scientists, would be the last to make such a claim. There are as yet many great gaps in our knowledge of the fossil record and alternative explanations are possible for many of the interpretations reached by our author; specialists on one group or another may reasonably dispute certain of Gregory's conclusions. We have here a vast panorama painted by a master hand. Details are obscure in many places; the future will, we may be sure, show the need of correction or addition in various areas. But the work as a whole is one of great and enduring value.

Alfred S. Romer is director of the Harvard College Museum of Comparative Zoology.

THE LONELY CROWD: A STUDY OF THE CHANGING AMERICAN CHARACTER, by David Riesman in collaboration with Reuel Denney and Nathan Glazer. Yale University Press ($4.00). In this controversial but interesting and stimulating volume, the proposition is advanced that the character structure typical of a society is related to the position it occupies on a curve of population growth and distribution. Certain societies possess high growth potential (high birth and death rates), and their people are said to be tradition-directed; others are in a transitional period of population growth, and their people are inner-directed; a third group shows incipient trends to population decline (such societies are also characterized by leisure and abundant consumer goods), and their people are other-directed. The U. S. is emerging from the second of these phases into the third, and its people, education, politics, work habits and leisure-time activities are beginning to show characteristics of "other-direction." The inner-directed man has a sort of internal gyroscope, which guides him and keeps him on an even keel, whatever his circumstances. The other-directed man, however, possesses a highly sensitive psychological radar, by means of which he detects the reactions of others so that he may modify his behavior to ensure their approval of him. Real feelings give way to reserve, apathy and loneliness in the other-directed person, and he is apt to pursue knowledge so that he may exhibit it. Dr. Riesman believes that a fourth type, the autonomous man, shows the most desirable features, but the wide development of autonomy is difficult in an other-directed society. Of some interest as an instance of the meaning of the shift from inner- to other-directedness is the following: "The old *Scientific American* used to be read by inner-directed hobbyists of science; now it has become a slick-paper periodical, catering with brilliance and sophistication to the consumer of science. . . ."

PARACELSUS: SELECTED WRITINGS, edited by Jolande Jacobi. Pantheon Books ($4.50). The opinions of Theophrastus Bombastus von Hohenheim, commonly called Paracelsus, famous 16th-century practitioner of magic, alchemy, astrology, physic and surgery; reformer of medicine, mystic, and founder of the sect of Iatrochemists who sought to apply chemistry "to the preparation of medicines and to the explanation of processes in the living body." It was said by his factotum that Paracelsus "dictated his works when drunk"—which is not difficult to believe on the basis of many of his writings. This volume is ornamented by more than 150 wonderful woodcuts conveying the flavor of the period even better than the selections themselves.

TIME AND ITS MYSTERIES, by Henry Norris Russell, Adolph Knopf, James T. Shotwell, George P. Luckey. New York University Press ($3.00). The third volume in the series of James Arthur Foundation lectures on the historic and philosophic implications, as well as on the practical aspects, of time and its measurement. Mr. Russell deals with the time scale of the universe; Mr. Knopf with geologic records of time; Mr. Shotwell with the topic "Time and Historical Perspective"; Mr. Luckey with developments in portable timepieces. A thoroughly readable book on an intriguing subject; the earlier volumes, which contain lectures by Robert A. Millikan, Harlow Shapley, James Henry Breasted, John Dewey, Arthur H. Compton and others, are also recommended.

UTTERMOST PART OF THE EARTH, by E. Lucas Bridges. E. P. Dutton & Co. ($7.50). A fascinating memoir by a missionary's son who was born on Tierra del Fuego in 1874 and lived among the Indians there for many years. Don Lucas, who died in 1949, writes of the land, of the habits, legends and culture of the Yahgan, Ona, Aush and Alacaloof tribesmen. Less than 200 of them survive, measles having wiped out most of about 8,000 who inhabited the country when the story begins. He also tells of a visit by the dubious Dr. Cook; of flowers, fish, birds, hunting, sheep tending, tribal wars, religion, tattooing, witches, wrestling and murder; of the strangeness and the beauty of this uttermost populated part of the Southern Hemisphere. Lucas was a sympathetic and remarkably skilled observer and his book deserves a place among the classics, not only of adventure but of ethnography. Numerous illustrations and maps.

THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

THE amateur builds telescopes not only as an approach to astronomy but also for the pleasure of the precise optical work itself, which he enjoys triply because the precision attained is the product of his own hands. The TN, or "telescope nut," makes mirror after mirror and lens after lens largely for the satisfaction of knowing that he is a precision workman. Most amateur telescope makers are in love with high precision in any field; many of them are "gun cranks," a self-applied term for riflemen whose main pleasure is high accuracy in shooting a paper target.

An additional satisfaction in all the precision hobbies is the smug knowledge that these "snobby hobbies" exclude the imprecise and thus have a limited following. One such hobby is horology, the science of measuring time and the art of building and regulating timekeepers. There is little practical need today to build clocks, since accurate electric clocks are everywhere. Like the maker of sun dials, the amateur horologist or "clock maniac" builds from a love of mechanism and the other motives already named. There is a fraternity of horologists with their own periodicals, and a large technical literature on fine clocks.

The elder J. Pierpont Morgan used to observe that for most of our actions there are two reasons: the reason given and the real reason. The ostensible reason for including in the book *Amateur Telescope Making—Advanced* a chapter of instructions for building a Synchronome clock was to enable the amateur astronomer to use it in his observatory. Yet the amateur has little need for a clock precise to one second a week. The real reason was the one already described: the amateur telescope maker is potentially an amateur precision clockmaker and horologist. No one knows how many Synchronome clocks have been built by amateurs, but this department knows of several and the total must be fairly respectable.

The Synchronome clock, invented by F. Hope-Jones of England, bears little resemblance to conventional mechanical clocks and none to the familiar electric clock. It has no gear wheels and pinions. It consists essentially of a seconds pendulum approximately 39 inches long, with bob attached, and about a score of simple, open parts. This unit is usually housed in a tall, narrow, glass-faced mahogany wall cabinet. Though electrically driven, it is entirely independent of electric power lines. It is run by two ordinary dry batteries which last for months or years because they work only 1/300 of the time.

The clock mechanism does not operate the hands on the dial by direct mechanical connection. Instead it closes an electrical circuit, energizing a magnet which moves the hands. This system permits the dial to be placed inside or outside the clock cabinet, in another room or even another building. In a series circuit one clock will operate a dozen or more dial movements; for example, one in each room of a residence, with, incidentally, a considerable cumulative saving in power cost. Since the Synchronome is accurate within a second a week, it will give even more precise time to all these dials in most localities than ordinary electric motor clocks, which are regulated by the frequency of power-line alternating current.

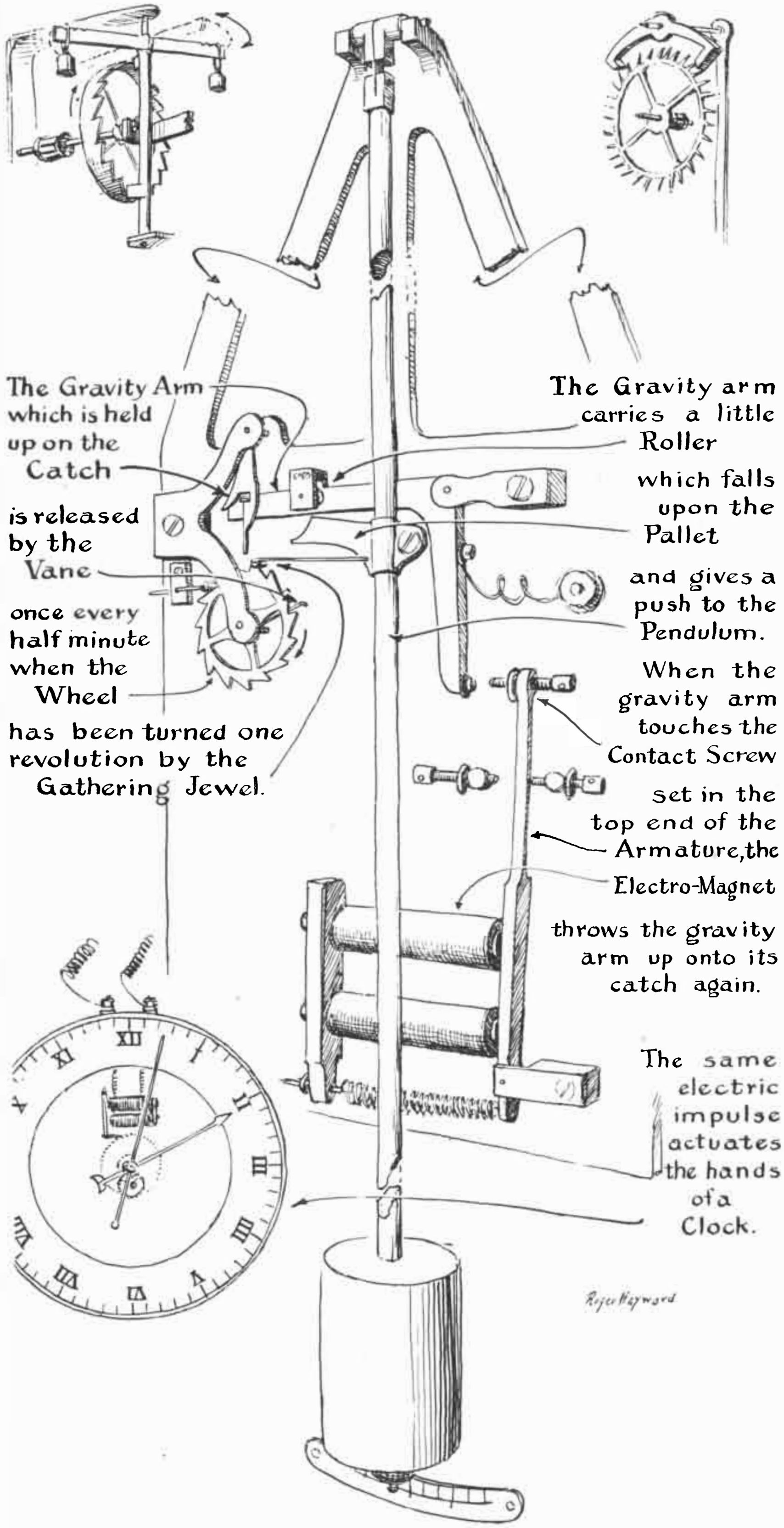
This frequency is controlled by the power companies as accurately as practicable, yet it is often temporarily slow or fast. This is not the fault of the power companies or of the clocks. It is no one's fault. Each time a motor is started or a light is turned on, there is a momentary drop in frequency until the automatic speed governors on the turbines in the generating stations make the necessary adjustment for the change in system load. Thus, for example, in two interconnected Eastern states the nominal frequency of 60 cycles per second varies more or less constantly between 59.85 and 60.15, causing clocks to drift back and forth one or two seconds slow or fast. They are rarely more than three or four seconds wrong except during serious disturbances, and the error is usually corrected at the rate of one second in 20 minutes. The standard used is the National Bureau of Standards' time signals over Station WWV.

The Synchronome may be set by the same signals, which are sent out continuously night and day from Beltsville, Md., and Maui, T. H., on 5, 10, 15 megacycles and other radio frequencies, and almost hourly over U. S. Naval Radio Station NSS, Annapolis, Md., 4.39 megacycles; Station NPG, Mare Island, Calif., .115 megacycles, and others. These signals are determined by the world's most precise type of clock, the quartz crystal oscillator invented by W. A. Marrison of the Bell Telephone Laboratories, which is accurate to about one third of a second per *year*.

The action of the Synchronome is so simple that when the illustration on the opposite page has been carefully traced through a single cycle its working principle is clearly understood. (The drawings in the upper corners are not related to this clock.) The little gathering jewel on the end of the short stem that protrudes to the left from the pallet on the pendulum reaches out every two seconds and almost silently pulls the unresisting "count wheel" toward it. This is not an escapement wheel, and the Synchronome has no escapement. Every 30 seconds the count wheel completes one revolution, carrying the tiny vane behind it around to trip the catch above it. Down comes the gravity arm, pushing the pallet and pendulum with a soft thud that blends instantly into a sharp click as it is thrown back upward onto its catch by the lively slap of the armature. The same electrical impulse moves the hands of the clock ahead half a minute.

There is a fascination in watching this action and listening for the widely spaced clicks, which in no way resemble the ticks of a conventional clock. Some persons in the families of amateur clock maniacs have loudly asserted their annoyance at these sharp clicks coming between long silences. No doubt they are relatives of those who tensely wait for the dropping of the other shoe. There are city people who when in the country actively *listen* for unfamiliar noises and thus are kept awake by katydids and crickets, though they easily fall asleep in the subway. Anyone who is distracted by the widely separated clicks of the Synchronome may be cheered to learn that a subsidiary seconds switch can be attached to the pendulum to make it click once a second like a conventional clock. This switch will also move the hands on the dial once a second, to please those who think a clock cannot be accurate if its hands move only once every 30 seconds. However, since this appliance is actuated by the pendulum, the clock will actually lose precision because of it. Physicists have long known what many clock inventors have ignored: that every interference with the freedom of the pendulum, whether from tangible or magnetic contacts or from escapements, steals energy from the pendulum and wars with good timekeeping.

As the astronomer Sir George Airy stated in a famous theorem, interference with the pendulum is least disruptive at the center of the swing, and most harmful at the ends—just where escapements do their interfering. In the Synchronome, where the mechanism monkeys with the pendulum only once in 30 swings, the



The Synchronome electrical impulse clock addition of a seconds beat is a backward step except when required for some practical reason. The Synchronome has survived a host of forgotten clock inventions just because it does its monkeying scientifically; the interference is kept at arm's length from the sacred pendulum. The pendulum tells the gravity arm when to fall, and the gravity arm gives the needed impulse to the pendulum.

While it is fun to build a Synchronome, the best fun follows its completion. Unless the builder is not only a genius but a lucky one, the clock will not start out keeping within one second a week of the right time. Bringing the error down to that limit may involve weeks or months of sleuthing, adjusting and timing subsequent runs by the signals from WWV. Hope-Jones, the inventor of the Synchronome, has defined the ultimate target in terms of the barometer: "All other sources of error having been eliminated or sufficiently mitigated excepting only variations of air pressure, see that it gains with the fall and loses with the rise. One inch rise or fall of mercury will make a difference of about one third second per day." The density of the atmosphere keeps changing, offering greater or lesser resistance to the pendulum, and the clock cannot be made more precise than the limitation from this source.

The cost of building a Synchronome is comparable to that of a telescope. The castings and some of the parts are supplied by the Synchronome Company, Ltd., Alperton, Wembley, Middlesex, England. Import duty on small purchases is payable to the local letter carrier with no more red tape than a C.O.D. purchase.

Court G. Helmstetter, a tool designer of Detroit, Mich., made one of these clocks in his spare time between the months of January and August and housed it in a mahogany and glass cabinet in his living room. "The best it performed," he states, "was one-second error in 11 days. It is almost unbelievable that a home-made clock can be so accurate, especially since it is not installed in a special vault or vacuum chamber but simply hangs on a wall."

A. P. Fletcher, a Detroit design engineer, built a Synchronome that once ran five weeks with an error of only half a second, though he attributes this partly to luck. "This clock hobby," he writes, "has afforded me much pleasure and some very valuable information. A small adjustment of the parts accomplishes a large result, if it is of the right kind and in the right place. I have found about 10 of these places that affect the action of the clock."

Henry F. Millon of Brownsville, Tex., made a Synchronome of stainless steel that performed, he reports, "with phenomenal accuracy, two-seconds' error in 10 days. Ultimately the clock gained 15 seconds and for several days hung at that point, varying plus or minus only half a second. Frankly, I can't figure it out, since the clock is not supposed to perform with such accuracy. I still get a kick every time the gong that I added to the dial movement rings on the hour." Later he wrote, "A run of less than one second variation has at last ended after 28 days, when the variation increased very sharply, no doubt because of spring fever."

William Buchele, a professional precision optician of Toledo, Ohio, is another who once made a Synchronome clock.

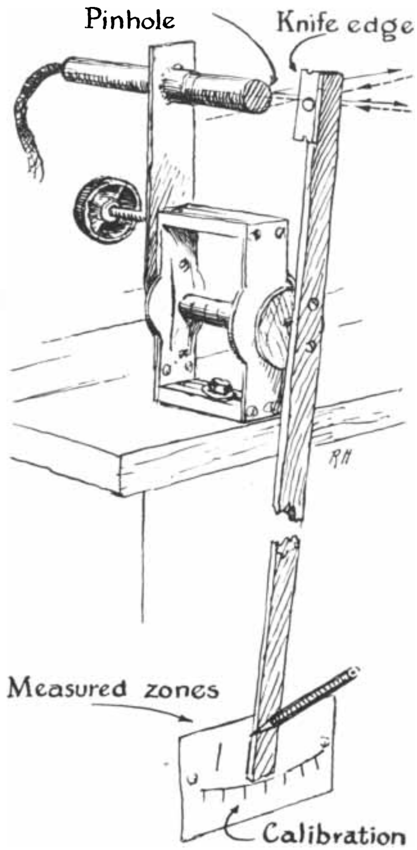
H. L. Rogers of Toronto, Ont., made his Synchronome's pendulum of wood instead of the specified Invar with a temperature-compensated bob. Nevertheless, he says, "it keeps better time than any other timepiece in my house. When I was regulating the clock I thought my watch was pretty accurate, but now that I have the clock regulated to within a few seconds of the time signals, my watch and all other clocks are set by the Synchronome. Certainly anyone with enough mental fertility to make a good telescope would not find this clock too difficult."

Some years ago L. C. Eichner of Bloomfield, N. J., built a Jaggar earthshock recorder or local seismograph (SCIENTIFIC AMERICAN, November, 1929), and made a Synchronome clock to mark time signals on its records in the basement of his home. "For a time," he writes, "it was fun to follow the passage of trains by means of the shock recorder, to be able to tell whether a Ford or a GM truck was passing my home, and to determine the exact moment when a bootleg-still in nearby Silver Lake blew up. But I found that the earth bottom beneath my community afforded too poor a base for a seismograph, and gave the Synchronome to the Custer Institute." The Custer Institute is a kind of amateur scientists' "Stellafane" at Southold, N. Y., near the eastern tip of Long Island, of which Eichner, a professional scientific instrument maker who remains an amateur scientist, is a member. Later Eichner built 10 seismographs for Columbia University and an extra one to give to the Custer Institute, where the Synchronome serves as a time standard.

During World War II Harris Rush of Westfield, N. J., built a Synchronome clock which has proved highly satisfactory, and which he proudly calls beautiful and distinguished. The conductor of this department has often watched this clock in action.

In 1940 Hope-Jones published the book *Electrical Time Keeping*, in which he described the history of the earliest mechanical clocks, the first electric clocks (1840) and their successors, and his own invention of the Synchronome in 1895, with its principles and the subsequent improvements. The book was soon out of print, but is again available in a second edition from the N.A.G. Press, Ltd., 226 Latymer Court, Hammersmith, London W. 6, England. It contains facts that supplement the instructions in *Amateur Telescope Making—Advanced* for building the Synchronome, and provide a clearer understanding of its principles.

The earliest clocks, built at the end of the 14th century, worked on the principle of the verge and foliot balance, shown in the upper left-hand drawing on page 69. The unhurried medieval world put up with this crude mechanism, with its error of an hour a day, for three centuries until in 1583 Galileo Galilei discovered the isochronism of



Foucault test apparatus

the pendulum—the independence of its period from the amplitude of its oscillation. In 1657 the Dutch physicist Christian Huygens, he of the famous wave theory of light, invented the pendulum clock. Huygens set forth its mathematics in 1673 in his *Horologium Oscillatorium*. Three years later the English physicist Robert Hooke, author of the classic *Micrographia*, invented the anchor escapement shown in the upper right-hand drawing. This was an immense improvement over the foliot balance, yet, as Hope-Jones states, "it involved almost continuous interference with the pendulum and prevented it from swinging undisturbed in its own natural period of vibration. The subtleties of the escapement," he adds, "provided a lifetime's job for the scientists of two centuries, and the science of horology may be said to have existed for the amelioration of escapement evils. When it failed the only thing to do was to dispense with the escapement altogether." It failed, Hope-Jones means, because it could not meet modern demands for clock precision.

Hope-Jones describes a vast amount of invented clock mechanism that fascinates the mechanically minded, the reason given for describing it being to show why most of it was bad. Clock-design inventors ignore physical laws and the failures that have preceded them, make the same mistakes over and over and never seem to learn. By a wide variety of electrical means they attempted to escape from the escapement, and Hope-Jones was the first to succeed.

He sought and found a way to relieve the pendulum of *any* share of the necessary contact. As shown in the drawing, all of the energy that lifts the gravity arm and thus indirectly keeps the pendulum swinging is transmitted through the electrical contact itself. Thus it simultaneously serves two ends: the first electrical, the second mechanical; the armature, moving forcibly against the gravity arm, provides an excellent contact during a full .06 second; then the contact is swiftly and cleanly broken by the momentum of the arm after the armature has reached its stop. A brute-force operation is thus accomplished without interfering with the pendulum, yet deftly timed by it.

Many other features of the clock are likely to be overlooked unless the builder reads the Hope-Jones book. It contains a chapter on synchronous motor clocks, *e.g.*, the Warren Telechron, and one explaining the Marrison quartz crystal clock. The quartz crystal oscillator clock may not be beyond the skill of amateurs.

"He is a happy man," Hope-Jones concludes about the Synchronome and himself, "who can turn a hobby into a business. There are few more pleasant companions than a simple pendulum of one's own construction whose 'remontoire' compares itself with the wireless time signals, and remains 'within the six dots' for months at a time. And it is a pleasure which I have been able to share by giving facilities to many a keen amateur mechanic . . . with permission and assistance to make one for their own use, not for sale. Thousands have done so and, though the policy would never square with a businessman's ethics, it was never regretted. It brought enthusiastic friends and champions, and advanced horological education."

F. Hope-Jones is dead, but the Synchronome Company has continued his policy of supplying amateur builders with sets of the necessary rough castings for the Synchronome—a very small detail of their business of supplying factories, schools and municipal institutions with master Synchronome clocks that operate hundreds of dials. They require only that the amateur builder "give undertaking that such instrument when completed would not be used for any commercial purpose whatsoever." Since no one can make, even for his own use, a patented article without the authorization of the patentee, this reservation is a legal right. The same free policy does not extend to the Shortt-Synchronome clock.

The Hope-Jones book is almost wholly about electric clocks; the beginner in horology may prefer a general treatise on horology to fill in his background. The most nearly up-to-date book in print is *Time and Timekeepers,* by the astronomer Willis I. Milham. To improve his knowledge of clocks and watches, Milham spent many hours with watch and clock repairmen. A less elementary treatment of clocks and timekeeping appears in a 30-page article by Ralph Allen Sampson in Volume 3 of Sir Richard Glazebrook's famous *Dictionary of Applied Physics.* Actually the dictionary is an encyclopedia. The article about clocks in the *Encyclopaedia Britannica* contains good data. *Clocks, Watches and Bells* by Edmund Beckett, published half a century ago, today out of print but available in some libraries, may also interest the amateur horologist. The quartz crystal clock is described in *Evolution of the Quartz Crystal Clock,* by W. A. Marrison.

If 10,000 of the knife-edge testing devices used by amateur telescope mirror makers could be assembled it is certain that no two of them would be alike, a fact that is not viewed with alarm by this department. The illustration on the opposite page shows one more of these dingbats devised by Garland S. Whitney of Seattle, Wash., whose telescope was described in this department last month. Its central part is an old radio-tuning condenser. While the knife-edge remains on the right and the pinhole on the left, as is conventional, lateral adjustment is obtained by moving the pinhole instead of the knife-edge. For longitudinal adjustment the knife-edge is moved by means of the lever on which it is mounted at a leverage of 8 to 1.

"The position of the indicating point, out of view at the lower end of the lever, tends," says Whitney, "to promote honesty in the ancient game of self-deception by 'fudging' the readings to agree with previous readings. Computed zonal positions may, if desired, be added on the card at the bottom where they are also beyond temptation. This tester," he continues, "permits no backlash. The Big Boys will probably find some reason to doubt the accuracy of the shadows, due to changing tilt of the knife-edge. If there is an error it is small. Anyway, my Gregorian telescope with a mirror made with this tester has proved up well on the stars, and separates doubles close to the Dawes limit."

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